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Final Regulatory Impact Analysis

Corporate Average Fuel Economy for MY 2017-MY 2025 Passenger Cars and Light Trucks

Office of Regulatory Analysis and Evaluation
National Center for Statistics and Analysis

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Contents

EXECUTIVE SUMMARY

This Final Regulatory Impact Analysis (FRIA) has been prepared by the National Highway Traffic Safety Administration (NHTSA) to examine the costs and benefits of increasing the Corporate Average Fuel Economy standards for passenger cars and light trucks for model years (MY) 2017 through MY 2025. NHTSA is required to set CAFE standards by the Energy Policy and Conservation Act of 1975 (EPCA), as amended by the Energy Independence and Security Act of 2007 (EISA). NHTSA does not have the discretion to not set CAFE standards each model year for passenger cars and light trucks. CAFE standards must be set at least 18 months prior to the beginning of the model year, must be "attribute-based and defined by a mathematical function," and must be set at the maximum feasible level that NHTSA determines manufacturers can reach for that fleet in that model year, among other requirements. *See* 49 U.S.C. 32902 and Section IV.D of the preamble that this FRIA accompanies for more information.

This assessment examines the costs and benefits of improving the fuel economy of passenger cars and light trucks for the final MY 2017-2021 standards and the augural[1] MY 2022-2025 standards.[2] It also examines the costs and benefits of improving the fuel economy of those vehicles at alternative rates of increase (both higher and lower) during those model years. As part of that examination, it includes a discussion of the technologies that can improve fuel economy, analysis of the potential impact on retail prices, safety, lifetime fuel savings and their

[1] For the PRIA, NHTSA described the proposed standards for MYs 2022-2025 as "conditional." "Conditional" was understood and objected to by some readers as implying that the future proceeding would consist merely of a confirmation of the conclusions and analysis of the current rulemaking, which would be incorrect and inconsistent with the agency's obligations under both EPCA/EISA and the Administrative Procedure Act. The agency must conduct a *de novo* rulemaking for model years 2022-2025. To avoid creating an incorrect impression, the agency is changing the descriptor for the 2022-2025 standards that are presented and discussed in these documents. The descriptor must convey that the standards we are now presenting for MYs 2022-2025 reflect the agency's current estimate of what we would have set at this time had we the authority to do so, but also avoid suggesting that the future process for establishing final standards for 2022-2025 would be anything other than a rulemaking based on a totally white-sheet-of-paper evaluation looking at all of the freshly gathered and solicited information before the agency at that future time and reflecting a fresh balancing of all statutorily relevant factors, in light of the considerations existing at the time of the evaluation. The agency deliberated extensively, considering many alternative descriptors, and concluded that the best descriptor was "augural," from the verb "to augur," meaning to foretell future events based on current information (as in, "these standards may augur well for what the agency might establish in the future"). This is precisely what the MYs 2022-2025 standards presented in these documents are – our best estimate of what we would set, based on the information before us today, but knowing that future information and thus our future decision may just as well be different as not.

[2] Throughout the FRIA, cost and benefit analyses are presented for individual model years as well as the 9-year total; however, 9-year totals include costs and benefits of MYs 2022-2025, for which the CAFE standards are augural at present.

value to consumers, and other societal benefits such as improved energy security and reduced emissions of pollutants and greenhouse gases.[3]

As explained above, EISA requires NHTSA to set attribute-based CAFE standards that are based on a mathematical function. The CAFE standards for MY 2017-2025 passenger cars and light trucks are based on vehicle footprint, as were the standards for MYs 2012-2016.[4] The mathematical function or "curve" representing the footprint-based standards is a constrained linear function that provides a separate fuel economy target for each vehicle footprint, generally with more stringent targets for smaller vehicles and less stringent targets for larger vehicles. Different parameters for the continuous mathematical function are derived. Individual manufacturers will be required to comply with a single fuel economy level that is based on the distribution of its production for that year among the footprints of its vehicles. Although a manufacturer's compliance obligation is determined in the same way for both passenger cars and light trucks, the footprint target curves for the different fleets are established with different continuous mathematical functions that are intended to be specific to the vehicles' design capabilities, to reflect the statutory requirement that the standards are supposed to be "maximum feasible" for each fleet separately.

In order to evaluate the costs and benefits of the rule, a baseline prediction of the fuel economy and mix of vehicles that would be sold in MYs 2017 to 2025 in the absence of the new standards was constructed. As was done for the MY 2012-2016 final rule and in the Preliminary Regulatory Impact Analysis (PRIA) for the MY 2017-2025 rule, a baseline was developed using each manufacturer's MY 2008 fleet as represented in CAFE certification data available to EPA; however, in the final MY 2017-2025 rule, NHTSA included an additional baseline fleet that was developed using each manufacturer's MY 2010 fleet, also derived from CAFE certification data. Throughout this FRIA, the majority of tables present results calculated separately using the 2008 and 2010 baselines. In order to conduct these analyses, we assume that similar vehicles will be produced through MY 2025 and technologies are added to each of these baseline fleets to determine what mpg levels could be achieved by the manufacturers in the MYs 2017-2025 timeframe. The main analysis includes a "flat" baseline, for which we assume that manufacturers would have made no fuel economy improvements above the MY 2016 CAFE standards. In the sensitivity analysis section, we examine an alternative baseline, for which we assume that manufacturers would meet market demand for slightly higher fuel economy levels in light of higher real prices of fuel and given the recently promulgated fuel economy labeling rule,

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[3] This analysis does not contain NHTSA's assessment of the potential environmental impacts of the final rule for purposes of the National Environmental Policy Act (NEPA), 42 U.S.C. 4321-4347, which is contained in the agency's Environmental Impact Statement (EIS) accompanying the final rule.

[4] Vehicle Footprint is defined as the wheelbase (the distance from the center of the front axle to the center of the rear axle) times the average track width (the distance between the centerline of the tires) of the vehicle (in square feet).

and would supply technologies that have a consumer payback (defined by fuel savings exceeding retail price increases) in one year or less.

NHTSA examined nine alternatives, including six that are defined as annual percentage improvements over the baseline – 2%/year, 3%/year, 4%/year, 5%/year, 6%/year, and 7%/year. In addition to those six are what NHTSA has called the "Preferred Alternative," the "Maximum Net Benefits" alternative, which Executive Orders 12866 and 13563 encourage the agency to choose unless statutory considerations mandate otherwise; and the "Total Costs Equal Total Benefits" alternative. Looking at the "required" mpg levels in Tables 3a and 3b, the "Preferred Alternative" for passenger cars would require fuel economy levels that are generally between the 3 and 4 percent annual increase alternatives, although the percentage increase varies from year to year. The "Preferred Alternative" for light trucks starts at less than the 2% alternative in MY 2017 and increases to between the 3 and 4 percent alternative in MY 2025. The "Maximum Net Benefits" alternative is based upon the agency's assessment of the availability of technologies and a marginal cost/benefit analysis. In this case the agency continues to include additional technologies in its analysis until the marginal cost of adding the next technology exceeds the marginal benefit. The "Maximum Net Benefits" alternative maximizes net benefits within each of the nine years, but it does not attempt to maximize benefits over all 9 years together. The "Maximum Net Benefit" for passenger cars would require levels that are higher than the "Preferred Alternative" in all years. The "Maximum Net Benefit" required mpg level for light trucks is higher in every year than the levels in the "Preferred Alternative." The "Total Costs Equal Total Benefits" alternative represents an increase in the standard to a point where essentially total costs of the technologies added together over the baseline added equals total benefits over the baseline. In this analysis, for brevity, at times it is labeled "TC = TB." The "TC = TB" levels are higher than the "Preferred" alternative levels in all years.[5]

The agency performed a variety of sensitivity analyses to examine the variability of the CAFE model's results to certain economic assumptions. Sensitivity analyses were performed on the following:

1) The price of gasoline: The main analysis uses the Reference Case AEO 2012 Early Release estimate for the price of gasoline. As the AEO 2012 Early Release does not contain Low and High Price Cases, ranges derived from the Low and High Price Cases from the AEO 2011 were utilized in conjunction with the Reference Case AEO

[5]The agency notes that the "TC = TB" alternative would be expected to show costs and benefits that exactly offset each other, so that the resulting net benefits would be zero. However, the agency's analysis accounts for certain real-world manufacturer constraints, and because of those constraints the "TC=TB" alternative has net benefits that are greater than zero. Because economic and technology-related considerations impose certain limitations on manufacturers' abilities to add fuel-saving technologies during specific model years, technology is sometimes "exhausted" before total costs reach the level of total benefits. When this occurs in a given model year, this regulatory alternative is defined by the stringency leading to this exhaustion of available technology

2012 Early Release to study the effect of the Low and High Price Cases on the model results.

2) The rebound effect: The main analysis uses a rebound effect of 10 percent to project increased miles traveled as the cost per mile decreases. In the sensitivity analysis, we examine the effect of using a 5, 15, or 20 percent rebound effect.
3) The value of CO_2 benefits: The main analysis uses an initial value of $22 per ton to quantify the benefits of reducing CO_2 emissions. Sensitivity analysis surrounding this assumption considers the use of alternate base values of $5, $36, and $68.[6]
4) Global Warming Potential (non-CO_2 GHG benefits): The main analysis does not monetize benefits associated with the reduction of non-CO_2 GHGs (methane, nitrous oxide, HFC-134a). This sensitivity analysis uses a GWP approach to convert non-CO_2 gases to CO_2-equivalence to monetize these benefits using the same methods with which the benefits of CO_2 reductions are valued.
5) The military security component: The main analysis does not assign a value to the military security benefits of reducing fuel consumption. In the sensitivity analysis, we examine the impact of using a value of 12 cents per gallon instead.
6) Consumer benefit: The main analysis assumes there is no loss in value to consumers resulting from vehicles that have an increase in price and higher fuel economy. This sensitivity analysis assumes that there is a 25, or 50 percent loss in value to consumers – equivalent to the assumption that consumers will only value the calculated benefits they will achieve at 75, or 50 percent, respectively, of the main analysis estimates.
7) Post-warranty repair costs: The main analysis includes repair costs during the warranty period; post-warranty repair costs are addressed in a sensitivity analysis. The warranty period is assumed to be 5 years for the powertrain and 3 years for the rest of the vehicle. This sensitivity analysis scales the frequency of repair by vehicle survival rates, assumes that per-vehicle repair costs during the post-warranty repair period are the same as in the in-warranty period, and that repair costs are proportional to incremental direct costs (therefore vehicles with additional components will have increased repair costs).
8) ICM and RPE cost methods: The main analysis uses the ICM cost method with an overall markup factor from variable cost to equivalent retail price of 1.2 to 1.25. The retail price equivalent (RPE) cost method results in higher cost estimates for each of the technologies, as it uses a markup factor of 1.5. A sensitivity analysis involving the RPE method was conducted. The agency also performed a sensitivity analysis using the ICM method, but with NAS estimates of technology costs.
9) Technology costs with NAS cost estimates: The agency conducted a sensitivity analysis using values that were derived from the 2011 NAS report.[7] This analysis used a RPE markup factor of 1.5 for non-electrification technologies, which is consistent with the NAS estimation for technologies manufactured by suppliers, and a

[6] These values are rounded to the nearest dollar; the values used in the sensitivity analysis are unrounded. The unrounded values are presented in Chapter X.

[7] Committee on the Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy; National Research Council. "Assessment of Fuel Economy Technologies for Light-Duty Vehicles" (2011). *Available at* http://www.nap.edu/catalog.php?record_id=12924 (last accessed November 13, 2011)

RPE markup factor of 1.33 for electrification technologies (HEV, PHEV and EV); three types of learning which include no learning for mature technologies, 1.25 percent annual learning for evolutionary technologies, and 2.5 percent annual learning for revolutionary technologies; technology cost estimated for 52 percent (33 out of 63) technologies; and technology effectiveness estimates for 56 percent (35 out of 63) of technologies. Cost learning was applied to technology costs in a manner similar to how cost learning is applied in the central analysis for many technologies which have base costs which are applicable to recent or near-term future model years. As noted above, the cost learning factors used for the sensitivity case are different than the values used in the central analysis. For the other inputs in the sensitivity case, where the NAS study has inconsistent information or lacks projections, NHTSA used the same inputs NHTSA used in the central analysis.

10) Battery cost: The agency conducted a sensitivity analysis of battery costs in relation to HEV, PHEV, and EV batteries. For HEV batteries, a sensitivity analysis was performed with a +/- 10 percent variation in cost per kWh, while sensitivity analyses involving PHEV and EV batteries utilized alternate ranges contingent on the type of battery cathode (see chapter X for additional detail). PHEV and EV battery costs ranged between -20 percent and +35 percent in this sensitivity analysis.
11) Mass reduction cost: A sensitivity analysis was performed examining the impact of vehicle mass reduction that could feasibly be accomplished with a +/- 40 percent impact on vehicle cost.
12) Market-driven response: A sensitivity analysis was performed to simulate potential increases in fuel economy over the compliance level required if MY 2016 standards were to remain in place. The key assumption for this sensitivity analysis is that the market would drive manufacturers to put technologies into their vehicles that they believe consumers would value and be willing to pay for, applying a payback period of one year for purposes of calculating the value of future fuel savings when simulating whether manufacturers would apply additional technology to an already CAFE-compliant fleet.
13) Transmission shift optimization technology disabled: As part of the simulation work for the final rule, ANL attempted to replicate the shift optimizer technology but produced different results than those of Ricardo, particularly in the application of shift optimization to naturally aspirated engines. Because of this uncertainty in effectiveness values, NHTSA conducted a sensitivity case analysis with transmission shift optimizer technology disabled.

The agency also performed a probabilistic uncertainty analysis on the model results of the preferred alternative using the 2010 fleet baseline, as mandated by OMB Circular A-4. Over all nine MYs covered by the final (2017-2021) and augural (2022-2025) standards of this rule, the higher CAFE standards will produce an impact ranging from a net cost of $69.3 billion to a net benefit of $774.7 billion. Across all nine model years, each model year's passenger car fleet has, at minimum, an 88.9 percent certainty that higher CAFE standards will produce a net benefit.

For light truck fleets, this value is 97.2 percent. The uncertainty analysis is presented in detail in Chapter XII.

The final MY 2017-2021 and augural MY 2022-2025 CAFE standards, like the MYs 2012-2016 CAFE standards, are being issued jointly with the Environmental Protection Agency (EPA), which is concurrently establishing greenhouse gas (GHG) standards for the same vehicles for the same model years. The joint standards extend the National Program established for MYs 2012-2016 into the future. In working together to establish the final standard for MYs 2017-2021 and augural standards for MYs 2022-2025, NHTSA and EPA built on the success of the first phase of the National Program to regulate fuel economy and GHG emissions from U.S. light-duty vehicles, which established the strong and coordinated standards for model years 2012-2016. As for the MYs 2012-2016 rulemaking, collaboration with California Air Resources Board (CARB) and with industry and other stakeholders has been a key element in developing the agencies' rules. Continuing the National Program would ensure that all manufacturers can build a single fleet of U.S. vehicles that would satisfy all requirements under both programs as well as under California's program, helping to reduce costs and regulatory complexity while providing significant energy security and environmental benefits. The coordinated program would achieve important reductions of fuel consumption and GHG emissions from passenger cars and light trucks, based on technologies that either are commercially available or that the agencies project will be commercially available in the rulemaking timeframe and that can be incorporated at a reasonable cost. Consistent with Executive Order 13563, this rule was developed with early consultation with stakeholders, employs flexible regulatory approaches to reduce burdens, maintains freedom of choice for the public, and helps to harmonize federal and state regulations. Because the agencies are collaborating on the National Program, however, it is important to note throughout this analysis that there is significant overlap in costs and benefits for NHTSA's CAFE program and EPA's GHG program, and therefore combined program costs and benefits are not a sum of the two individual programs.

Table 1 presents the total costs (technology and social), benefits, and net benefits for NHTSA's 2017-2025 final and augural preferred alternative CAFE levels. The values in Table 1 display (in total and annualized forms) costs for all MY 2011-2025 vehicles and the benefits and net benefits represent the impacts of the standards over the full lifetimes of the vehicles projected to be sold during model years 2011-2025. Impacts to MYs 2011 - 2016 represent additional costs and benefits over and above those of the previously-issued light duty CAFE 2012 - 2016 standards that occur as a result of manufacturer preparation for the MY 2017 - 2025 standards. In the annualization of costs, benefits, and net benefits shown in Table 1, impacts to years prior to 2017 are considered to be MY 2017 impacts. In the following Executive Summary tables, tables that present total or net costs or benefits include a column documenting the estimated cumulative impact of this rule resulting from fuel economy improvements in MY 2011 - 2016 vehicles that manufacturers will make in preparation for the MY 2017 and beyond standards set forth in this rule.

This is the first CAFE rulemaking wherein the agency has included operating costs other than outlays for fuel purchases in its analysis of the costs and benefits of new standards. In past CAFE rulemakings, reported monetized costs of new standards included only the costs (on an MSRP basis) of technology estimated to be added in response to the new standards. All other monetized impacts occur as incremental changes to social costs between the baseline and regulatory alternatives, and were reported as benefits and, if negative, as negative benefits (*i.e.*, disbenefits).

In considering how to report monetized impacts on different costs to own and operate a new vehicle, the agency has more generally revisited its approach to categorizing different monetized effects as either costs or benefits. Noting that OMB guidance generally calls for agencies to treat positive monetized impacts as benefits, and negative monetized impacts as costs, NHTSA revised its reporting of costs and benefits to follow this approach. Thus, for example, while we have previously treated monetized damages related to additional congestion, accidents, and noise attributable to the rebound effect as negative benefits, we now report those impacts as social costs. This change in reporting in no way changes the agency's resultant calculations of net benefits which has always correctly accounted for the sign of monetized impacts.

However, NHTSA notes that, while straightforward in principle, the concept of categorizing negative monetized impacts as costs and positive negative monetized impacts as benefits is subject to considerable practical complications. For example, in NHTSA's current analysis, monetized impacts on highway fatalities change sign between model years and between passenger car and light truck fleets. Also, disaggregation of criteria pollutant emissions would lead increased tailpipe emissions to be treated as costs, and reduced upstream emissions to be treated as benefits. For future fuel economy rulemaking analysis, NHTSA plans to further consider how best to report monetized impacts as either costs or benefits.

Table 1
NHTSA's Estimated 2011-2025 Model Year Costs, Benefits, and Net Benefits under the Preferred Alternative CAFE Standards

(Billions of 2010 Dollars)

Cumulative Across MYs 2011 - 2021 (Final Standards Only)					
	Baseline Fleet	Totals		Annualized	
		3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Costs	2010 2008	($60.6) - ($56.5)	($57.9) - ($53.6)	($2.4) - ($2.2)	($3.6) - ($3.3)
Benefits	2010 2008	$243.1 - $240.2	$195.2 - $194.3	$9.2 - $9.0)	$11.3 - $11.0
Net Benefits	2010 2008	$182.5 - $183.8	$137.3 - $140.7	$6.8 - $6.8	$7.7 - $7.8
Cumulative Across MYs 2011 - 2025 (Includes Augural Standards)					
	Baseline Fleet	Totals		Annualized	
		3% Discount Rate	7% Discount Rate	3% Discount Rate	7% Discount Rate
Costs	2010 2008	($154.3) - ($155.7)	($146.8) - ($148.1)	($5.4) - ($5.4)	($7.6) - $7.5)
Benefits	2010 2008	$629.7 - $639.0	$502.7 - $510.0	$21.0 - $21.3	$24.2 - $24.4
Net Benefits	2010 2008	$475.5 - $483.2	$356.0 - $361.9	$15.7 - $15.9	$16.7 - $16.9

Table 2 shows the overall analysis summary of costs, benefits, and net benefits for the 15 model years (2011 through 2025) by alternative for the combined light duty fleet. Table 4 shows the agency's projection of the estimated actual harmonic average that would be achieved by the manufacturers, assuming that some manufacturers will pay fines rather than meet the required levels. Table 3 shows the estimated required levels. Tables 3 and 4 present values for model years 2017 through 2025 only, as this rule does not change the fuel economy standards previously established in the 2012 through 2016 rule. All of the tables in this analysis compare the flat MY 2016 baselines to the projected achieved harmonic average. Additionally all of the tables in the Executive Summary and in the analysis as a whole use the central value for the Social Cost of Carbon (SCC), which is the average SCC across models at the 3 percent discount rate. The SCC is discussed in more detail in Chapter VIII. For purposes of capturing the uncertainties involved in regulatory impact analysis, we emphasize the importance and value of considering the full range of SCC values.

Costs: Costs were estimated based on the specific technologies that were applied to improve each manufacturer's fuel economy up to their achieved level under each alternative or fines that would be assessed. Table 5 provides the cost and fine estimates on an average per-vehicle basis (for MYs 2017 through 2025 only), and Tables 6 and 9 provide those estimates (including social costs and excluding fines) on a fleet-wide basis in millions of dollars at 3 and 7 percent discount rates, respectively, for all model years. Note that for fleet-wide estimates, the determination of whether the value associated with an individual line item (e.g., value of reduced fatalities -- see Executive Summary Tables 13 and 14 for a complete list of line items) for each model year is performed independently; this approach was employed to address the potential for certain line items to be positive (a benefit) in some model years and negative (a cost) in others. Due to this approach, the sum of social costs computed separately for the passenger car fleet and the light truck fleet may not be identical to the total social costs shown in Tables 13 and 14 for the combined fleet. These differences are not due to error or rounding; rather, they are consequences of instances in which a given line item is negative (a cost) for either of the two fleets in a given year and positive (a benefit) for the other fleet in the same year. The resulting offset manifests as a very slight difference in total social costs as seen in Tables 13 and 14. Total net benefits, however, are unaffected.

Throughout this FRIA, the following conventions are applied to the presentation of costs:

- Tables that exclusively present costs display all costs as positive values (e.g., Table 5 in the Executive Summary).

- Tables that contain a mix of costs and benefits that are aggregated to a net or total value (e.g., Tables 13 and 14 in the Executive Summary) display costs as parenthesized values to aid the reader in following the summation logic.

Benefits: Benefits are determined mainly from fuel savings over the lifetime of the vehicle, but include any line item (see Executive Summary Tables 13 and 14 for a complete list of line items) in which the rule is projected to result in a societal benefit. As noted above in the discussion of costs, due to this approach, the sum of social benefits computed separately for the passenger car fleet and the light truck fleet may not be identical to the total social benefits shown in Tables 13 and 14 for the combined fleet. These differences are not due to error or rounding; rather, they are consequences of instances in which a given line item is positive (a benefit) for either of the two fleets in a given year and negative (a cost) for the other fleet in the same year. The resulting offset manifests as a very slight difference in total social benefits as seen in Tables 13 and 14. Total net benefits, however, are unaffected. The agency uses a 3 percent and 7 percent discount rate to value intra-generational future benefits and costs. Inter-generational[8] benefits from future carbon dioxide reductions are discounted at 3 percent in the main analysis, even when intra-generational benefits are discounted at 7 percent. Sensitivity analyses in Chapter X consider other inter-generational discount rates that accompany alternative estimates of the social cost of carbon. Table 7 provides those estimates on an industry-wide basis at a 3 percent discount rate

[8] Inter-generational benefits, which include reductions in the expected future economic damages caused by increased global temperatures, a rise in sea levels, and other projected impacts of climate change, are anticipated to extend over a period from approximately fifty to two hundred or more years in the future, and will thus be experienced primarily by generations that are not now living.

and Table 10 provides the estimates at a 7 percent discount rate; both Tables 7 and 10 present estimates for model years 2011 through 2025.

Net Benefits: Tables 8 and 11 compare total net benefits of each alternative at the 3 percent and 7 percent discount rates, respectively, for model years 2011 through 2025.

Liquid Fuel Savings: Tables 12a through 12c show the lifetime fuel savings in millions of gallons of liquid fuel, for model years 2011 through 2025.

Change in Electricity Consumption: Tables 12d through 12f show the lifetime net change in electrical consumption, in gigawatt-hours, for model years 2011 through 2025.

Table 2
Total Costs, Benefits, and Net Benefits
Passenger Cars and Light Trucks
MYs 2011-2025 Combined
(Millions of 2010 Dollars)

Passenger Cars & Light Trucks	Baseline Fleet	3% Discount Rate			7% Discount Rate		
		Costs	Benefits	Net Benefits	Costs	Benefits	Net Benefits
Preferred Alternative	2010 2008	($154,266) - ($155,745)	$629,730 - $638,957	$475,465 - $483,211	($146,786) - ($148,074)	$502,749 - $509,987	$355,963 - $361,913
2% Annual Increase	2010 2008	($102,455) - ($93,872)	$415,077 - $439,025	$312,622 - $345,152	($97,193) - ($88,357)	$330,940 - $350,058	$233,747 - $261,701
3% Annual Increase	2010 2008	($142,891) - ($134,011)	$615,110 - $629,811	$472,218 - $495,800	($135,603) - ($126,639)	$490,527 - $502,208	$354,924 - $375,569
4% Annual Increase	2010 2008	($192,520) - ($188,182)	$764,785 - $792,084	$572,264 - $603,903	($183,713) - ($179,271)	$610,071 - $631,640	$426,358 - $452,369
5% Annual Increase	2010 2008	($256,995) - ($256,852)	$861,224 - $902,008	$604,229 - $645,156	($246,447) - ($246,144)	$686,890 - $719,081	$440,443 - $472,937
6% Annual Increase	2010 2008	($323,141) - ($347,730)	$938,564 - $1,004,451	$615,422 - $656,720	($310,804) - ($333,810)	$748,347 - $800,259	$437,543 - $466,450
7% Annual Increase	2010 2008	($387,383) - ($417,165)	$993,836 - $1,066,051	$606,453 - $648,886	($373,215) - ($401,120)	$792,351 - $849,296	$419,136 - $448,176
Max Net Benefits	2010 2008	($287,685) - ($315,127)	$926,440 - $1,017,426	$638,755 - $702,299	($249,132) - ($266,152)	$712,807 - $767,897	$463,675 - $501,745
Total Cost = Total Benefit	2010 2008	($313,999) - ($365,437)	$955,125 - $1,077,946	$641,125 - $712,509	($302,120) - ($351,789)	$761,720 - $858,888	$459,600 - $507,100

Table 3a
Alternative CAFE Levels
Estimated Required Average for the Passenger Car Fleet, in mpg[9]

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Preferred Alternative	2010 2008	39.6 - 40.1	41.1 - 41.6	42.5 - 43.1	44.2 - 44.8	46.1 - 46.8	48.2 - 49.0	50.5 - 51.2	52.9 - 53.6	55.3 - 56.2
2% Annual Increase	2010 2008	39.0 - 39.5	39.8 - 40.3	40.6 - 41.2	41.4 - 42.0	42.3 - 42.9	43.2 - 43.9	44.1 - 44.7	45.0 - 45.7	46.0 - 46.7
3% Annual Increase	2010 2008	39.4 - 39.9	40.7 - 41.2	41.9 - 42.5	43.2 - 43.8	44.6 - 45.2	46.0 - 46.7	47.4 - 48.2	49.0 - 49.7	50.6 - 51.3
4% Annual Increase	2010 2008	39.9 - 40.4	41.5 - 42.1	43.2 - 43.9	45.1 - 45.7	47.0 - 47.7	49.1 - 49.8	51.1 - 51.9	53.4 - 54.1	55.6 - 56.5
5% Annual Increase	2010 2008	40.3 - 40.8	42.4 - 43.0	44.7 - 45.3	47.1 - 47.7	49.6 - 50.4	52.3 - 53.1	55.1 - 56.0	58.2 - 59.0	61.3 - 62.3
6% Annual Increase	2010 2008	40.7 - 41.2	43.4 - 44.0	46.1 - 46.8	49.2 - 49.9	52.4 - 53.2	55.8 - 56.7	59.5 - 60.4	63.5 - 64.5	67.7 - 68.7
7% Annual Increase	2010 2008	41.2 - 41.7	44.3 - 44.9	47.7 - 48.4	51.4 - 52.1	55.4 - 56.2	59.7 - 60.6	64.3 - 65.3	69.4 - 70.4	74.8 - 76.0
Max Net Benefits (3% Discount Rate)	2010 2008	44.6 - 45.4	46.9 - 47.5	49.1 - 49.8	50.6 - 51.4	51.9 - 52.5	52.8 - 53.6	53.8 - 54.6	56.1 - 55.8	58.2 - 57.0
Max Net Benefits (7% Discount Rate)	2010 2008	44.1 - 45.2	46.0 - 47.1	47.8 - 48.5	49.6 - 50.0	50.9 - 50.8	51.7 - 51.1	52.5 - 51.9	54.2 - 53.0	55.6 - 55.0
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	45.3 - 46.8	47.2 - 48.8	49.1 - 50.3	50.6 - 52.1	52.5 - 53.3	54.1 - 55.5	55.5 - 57.3	58.5 - 59.1	60.7 - 60.3
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	45.3 - 46.8	47.2 - 48.8	49.1 - 50.3	50.6 - 52.1	52.5 - 53.3	54.1 - 55.5	55.5 - 57.3	58.5 - 59.1	60.7 - 60.3

[9] The choice of a 3 or 7 percent discount rate can impact the results of the Max Net Benefits and Total Cost = Total Benefits scenarios. The results of all other scenarios are not impacted by choice of discount rate. Results for both 3 and 7 percent discount rates are therefore presented for both Max Net Benefits and Total Cost = Total Benefit scenarios.

Table 3b
Alternative CAFE Levels
Estimated Required Average for the Light Truck Fleet, in mpg

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Preferred Alternative	2010 2008	29.1 - 29.4	29.6 - 30.0	30.0 - 30.6	30.6 - 31.2	32.6 - 33.3	34.2 - 34.9	35.8 - 36.6	37.5 - 38.5	39.3 - 40.3
2% Annual Increase	2010 2008	29.7 - 30.1	30.3 - 30.8	30.9 - 31.5	31.5 - 32.1	32.2 - 32.8	32.8 - 33.5	33.5 - 34.2	34.3 - 35.1	35.0 - 35.8
3% Annual Increase	2010 2008	29.9 - 30.3	30.9 - 31.4	31.9 - 32.5	32.9 - 33.5	33.9 - 34.6	35.0 - 35.7	36.1 - 36.9	37.3 - 38.2	38.5 - 39.4
4% Annual Increase	2010 2008	30.2 - 30.6	31.6 - 32.1	32.9 - 33.6	34.3 - 34.9	35.8 - 36.5	37.3 - 38.1	38.9 - 39.8	40.6 - 41.6	42.3 - 43.4
5% Annual Increase	2010 2008	30.5 - 30.9	32.2 - 32.8	34.0 - 34.7	35.8 - 36.4	37.7 - 38.5	39.8 - 40.6	42.0 - 42.9	44.3 - 45.3	46.7 - 47.9
6% Annual Increase	2010 2008	30.8 - 31.2	32.9 - 33.4	35.1 - 35.8	37.4 - 38.1	39.8 - 40.6	42.5 - 43.4	45.3 - 46.3	48.3 - 49.5	51.5 - 52.8
7% Annual Increase	2010 2008	31.1 - 31.6	33.6 - 34.2	36.3 - 37.0	39.1 - 39.8	42.1 - 43.0	45.4 - 46.3	49.0 - 50.1	52.8 - 54.1	57.0 - 58.4
Max Net Benefits (3% Discount Rate)	2010 2008	32.0 - 35.7	32.9 - 37.5	35.3 - 39.3	37.5 - 40.9	40.9 - 42.2	41.6 - 43.3	42.5 - 43.9	43.4 - 44.9	44.5 - 46.6
Max Net Benefits (7% Discount Rate)	2010 2008	32.0 - 35.0	32.9 - 36.7	35.1 - 38.6	37.3 - 40.2	40.3 - 41.5	40.9 - 42.0	41.8 - 42.3	42.9 - 43.3	44.7 - 44.9
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	32.3 - 36.1	33.3 - 37.7	35.3 - 39.5	37.5 - 41.3	41.2 - 42.6	41.8 - 43.1	42.7 - 44.1	43.4 - 45.6	44.7 - 46.8
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	32.3 - 36.1	33.3 - 37.7	35.3 - 39.5	37.5 - 41.3	41.2 - 42.6	41.8 - 43.1	42.7 - 44.1	43.4 - 45.6	44.7 - 46.8

Table 3c
Alternative CAFE Levels
Estimated Required Average for the Combined Fleet, in mpg

Passenger Cars & Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Preferred Alternative	2010 2008	35.1 - 35.4	36.1 - 36.5	37.1 - 37.7	38.3 - 38.9	40.3 - 41.0	42.3 - 43.0	44.3 - 45.1	46.5 - 47.4	48.7 - 49.7
2% Annual Increase	2010 2008	35.1 - 35.5	35.8 - 36.3	36.6 - 37.2	37.4 - 37.9	38.2 - 38.8	39.0 - 39.6	39.8 - 40.5	40.8 - 41.5	41.6 - 42.5
3% Annual Increase	2010 2008	35.4 - 35.8	36.6 - 37.0	37.7 - 38.3	39.0 - 39.6	40.2 - 40.9	41.5 - 42.2	42.9 - 43.6	44.3 - 45.2	45.8 - 46.7
4% Annual Increase	2010 2008	35.8 - 36.2	37.4 - 37.8	38.9 - 39.6	40.7 - 41.3	42.4 - 43.1	44.3 - 45.0	46.2 - 47.0	48.3 - 49.2	50.4 - 51.4
5% Annual Increase	2010 2008	36.2 - 36.5	38.1 - 38.7	40.2 - 40.9	42.4 - 43.1	44.8 - 45.5	47.2 - 48.0	49.8 - 50.7	52.6 - 53.6	55.5 - 56.7
6% Annual Increase	2010 2008	36.5 - 36.9	39.0 - 39.5	41.5 - 42.2	44.3 - 45.0	47.3 - 48.0	50.4 - 51.3	53.8 - 54.8	57.4 - 58.6	61.3 - 62.5
7% Annual Increase	2010 2008	36.9 - 37.3	39.8 - 40.3	42.9 - 43.6	46.3 - 47.0	49.9 - 50.8	53.9 - 54.8	58.2 - 59.2	62.8 - 64.0	67.8 - 69.2
Max Net Benefits (3% Discount Rate)	2010 2008	39.1 - 41.3	40.8 - 43.4	43.1 - 45.5	45.1 - 47.1	47.5 - 48.4	48.3 - 49.5	49.4 - 50.4	51.1 - 51.6	52.8 - 53.1
Max Net Benefits (7% Discount Rate)	2010 2008	38.9 - 40.8	40.3 - 42.7	42.4 - 44.5	44.5 - 46.1	46.7 - 47.2	47.4 - 47.6	48.3 - 48.2	49.8 - 49.3	51.4 - 51.2
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	39.6 - 42.3	41.1 - 44.1	43.1 - 45.9	45.1 - 47.7	47.9 - 49.0	49.2 - 50.5	50.4 - 52.0	52.4 - 53.8	54.2 - 55.1
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	39.6 - 42.3	41.1 - 44.1	43.1 - 45.9	45.1 - 47.7	47.9 - 49.0	49.2 - 50.5	50.4 - 52.0	52.4 - 53.8	54.2 - 55.1

Table 3d
Estimated Required Preferred Alternative CAFE Levels
Projected Required Average for the Fleet, in gallons per 100 miles

	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Passenger Cars	2010 2008	2.5247 - 2.4936	2.4359 - 2.4043	2.3515 - 2.3190	2.2633 - 2.2313	2.1713 - 2.1385	2.0728 - 2.0424	1.9815 - 1.9517	1.8918 - 1.8640	1.8075 - 1.7800
Light Trucks	2010 2008	3.4391 - 3.3969	3.3818 - 3.3307	3.3304 - 3.2683	3.2627 - 3.2064	3.0636 - 3.0019	2.9219 - 2.8657	2.7918 - 2.7308	2.6642 - 2.6007	2.5416 - 2.4824
Combined	2010 2008	2.8485 - 2.8232	2.7703 - 2.7379	2.6966 - 2.6553	2.6109 - 2.5715	2.4788 - 2.4387	2.3631 - 2.3256	2.2555 - 2.2155	2.1502 - 2.1088	2.0517 - 2.0104

Table 4a
Alternative CAFE Levels
Projected Achieved Harmonic Average for the Passenger Car Fleet, in mpg[10]

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Preferred Alternative	2010 2008	39.4 - 39.5	41.1 - 41.5	43.3 - 43.8	45.1 - 46.3	47.1 - 47.9	48.1 - 49.3	49.6 - 50.0	51.3 - 51.5	52.1 - 52.9
2% Annual Increase	2010 2008	38.2 - 38.8	39.4 - 40.1	40.5 - 41.4	41.8 - 42.7	42.8 - 43.6	43.3 - 44.2	44.0 - 44.9	44.9 - 45.8	45.2 - 46.2
3% Annual Increase	2010 2008	38.9 - 39.2	40.3 - 41.1	42.1 - 42.9	43.9 - 45.1	44.9 - 46.1	45.8 - 47.2	47.0 - 47.7	48.7 - 48.4	49.5 - 49.1
4% Annual Increase	2010 2008	39.6 - 39.9	41.3 - 42.2	43.6 - 44.3	46.1 - 46.8	48.1 - 48.5	49.2 - 49.7	50.5 - 50.7	51.7 - 52.2	53.3 - 53.6
5% Annual Increase	2010 2008	40.2 - 40.5	42.3 - 42.9	45.3 - 45.3	48.0 - 48.6	50.0 - 50.9	51.4 - 52.3	53.2 - 53.5	55.4 - 55.8	58.3 - 57.8
6% Annual Increase	2010 2008	40.8 - 41.2	43.0 - 43.9	46.6 - 46.3	49.1 - 49.7	52.0 - 52.5	53.3 - 55.1	55.8 - 56.7	59.6 - 59.8	62.2 - 63.9
7% Annual Increase	2010 2008	41.7 - 42.0	44.1 - 44.9	47.7 - 47.6	50.3 - 51.1	52.6 - 54.3	55.6 - 57.8	58.0 - 59.2	61.3 - 62.8	64.8 - 64.7
Max Net Benefits (3% Discount Rate)	2010 2008	42.4 - 43.2	44.1 - 45.1	47.4 - 47.3	49.6 - 49.7	51.1 - 51.5	52.1 - 52.2	53.2 - 52.7	55.0 - 54.1	56.2 - 54.9
Max Net Benefits (7% Discount Rate)	2010 2008	42.1 - 43.1	43.7 - 44.6	46.4 - 46.4	48.7 - 48.4	50.2 - 49.9	50.8 - 50.6	51.6 - 51.2	53.2 - 52.3	54.0 - 53.4
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	42.6 - 44.8	44.2 - 46.4	47.7 - 48.2	49.9 - 50.8	51.7 - 52.6	52.9 - 53.8	54.9 - 54.8	56.9 - 56.3	58.0 - 57.6
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	42.6 - 44.8	44.2 - 46.4	47.7 - 48.2	49.9 - 50.8	51.7 - 52.6	52.9 - 53.8	54.9 - 54.8	56.9 - 56.3	58.0 - 57.6

[10] The choice of a 3 or 7 percent discount rate can impact the results of the Max Net Benefits and Total Cost = Total Benefits scenarios. The results of all other scenarios are not impacted by choice of discount rate. Results for both 3 and 7 percent discount rates are therefore presented for both Max Net Benefits and Total Cost = Total Benefit scenarios.

Table 4b
Alternative CAFE Levels
Projected Achieved Harmonic Average for the Light Truck Fleet, in mpg

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Preferred Alternative	2010 2008	28.8 - 29.3	29.3 - 30.3	31.3 - 31.9	32.8 - 33.3	34.9 - 35.2	35.5 - 36.1	36.5 - 36.8	37.4 - 37.9	37.6 - 39.0
2% Annual Increase	2010 2008	29.8 - 30.0	30.2 - 30.7	31.4 - 31.9	32.3 - 32.8	32.9 - 33.8	33.3 - 34.3	33.8 - 34.6	34.3 - 35.1	34.3 - 35.3
3% Annual Increase	2010 2008	30.2 - 30.5	30.7 - 31.4	32.3 - 33.3	33.9 - 34.7	35.3 - 36.1	36.0 - 36.8	36.9 - 37.4	37.5 - 38.2	37.9 - 38.6
4% Annual Increase	2010 2008	30.2 - 31.0	31.1 - 32.2	32.9 - 34.6	34.9 - 36.4	36.9 - 38.1	37.6 - 38.9	38.6 - 39.9	39.7 - 40.8	41.0 - 41.4
5% Annual Increase	2010 2008	30.5 - 31.3	31.3 - 32.9	33.7 - 35.8	36.2 - 38.4	38.7 - 40.3	39.6 - 41.4	41.4 - 42.5	42.8 - 43.9	43.9 - 44.9
6% Annual Increase	2010 2008	30.8 - 31.9	31.8 - 33.5	34.1 - 36.5	36.8 - 39.9	39.5 - 42.0	40.6 - 43.4	42.4 - 44.3	44.4 - 46.1	46.6 - 47.7
7% Annual Increase	2010 2008	31.1 - 32.2	32.2 - 34.1	34.7 - 37.2	37.8 - 40.2	40.5 - 42.8	41.4 - 44.2	43.1 - 45.6	44.7 - 46.8	46.1 - 48.6
Max Net Benefits (3% Discount Rate)	2010 2008	31.2 - 34.0	32.1 - 35.2	34.3 - 37.5	36.7 - 40.2	39.1 - 42.1	39.9 - 42.8	41.3 - 43.6	42.2 - 44.6	43.3 - 45.4
Max Net Benefits (7% Discount Rate)	2010 2008	31.3 - 33.8	32.1 - 35.0	34.3 - 37.4	36.6 - 39.3	38.9 - 41.0	39.6 - 41.7	41.1 - 42.2	42.0 - 43.0	43.8 - 43.8
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	31.4 - 34.2	32.2 - 35.4	34.2 - 37.8	36.9 - 40.4	39.4 - 42.3	39.9 - 43.0	41.3 - 43.9	42.3 - 44.8	43.6 - 45.7
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	31.4 - 34.2	32.2 - 35.4	34.2 - 37.8	36.9 - 40.4	39.4 - 42.3	39.9 - 43.0	41.3 - 43.9	42.3 - 44.8	43.6 - 45.7

Table 4c
Alternative CAFE Levels
Projected Achieved Harmonic Average for the Combined Fleet, in mpg

Passenger Cars & Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Preferred Alternative	2010 2008	34.8 - 35.0	36.0 - 36.6	38.2 - 38.7	39.9 - 40.8	42.0 - 42.6	42.9 - 43.8	44.2 - 44.6	45.6 - 46.0	46.2 - 47.4
2% Annual Increase	2010 2008	34.7 - 35.0	35.6 - 36.1	36.7 - 37.5	37.9 - 38.6	38.8 - 39.6	39.2 - 40.2	39.9 - 40.8	40.7 - 41.6	40.9 - 41.9
3% Annual Increase	2010 2008	35.3 - 35.5	36.3 - 37.0	38.0 - 38.9	39.8 - 40.8	41.1 - 42.1	41.9 - 43.0	43.0 - 43.7	44.3 - 44.5	44.9 - 45.1
4% Annual Increase	2010 2008	35.7 - 36.1	37.0 - 38.0	39.1 - 40.3	41.5 - 42.6	43.6 - 44.3	44.5 - 45.4	45.7 - 46.5	47.0 - 47.7	48.5 - 48.9
5% Annual Increase	2010 2008	36.1 - 36.6	37.6 - 38.7	40.4 - 41.4	43.1 - 44.5	45.4 - 46.6	46.7 - 48.0	48.5 - 49.2	50.4 - 51.2	52.6 - 52.8
6% Annual Increase	2010 2008	36.6 - 37.2	38.2 - 39.5	41.2 - 42.3	44.0 - 45.8	46.9 - 48.3	48.1 - 50.4	50.4 - 51.8	53.5 - 54.5	56.0 - 57.5
7% Annual Increase	2010 2008	37.2 - 37.8	39.0 - 40.3	42.1 - 43.4	45.1 - 46.7	47.7 - 49.7	49.7 - 52.3	51.9 - 53.8	54.5 - 56.4	57.1 - 58.4
Max Net Benefits (3% Discount Rate)	2010 2008	37.6 - 39.3	38.9 - 41.0	41.8 - 43.3	44.2 - 45.9	46.2 - 47.8	47.1 - 48.5	48.5 - 49.2	49.9 - 50.5	51.1 - 51.4
Max Net Benefits (7% Discount Rate)	2010 2008	37.5 - 39.2	38.7 - 40.6	41.2 - 42.8	43.7 - 44.8	45.6 - 46.4	46.3 - 47.1	47.5 - 47.8	48.9 - 48.8	50.1 - 49.8
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	37.8 - 40.2	39.1 - 41.7	41.9 - 43.9	44.5 - 46.6	46.7 - 48.5	47.6 - 49.5	49.4 - 50.6	51.0 - 51.9	52.2 - 53.1
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	37.8 - 40.2	39.1 - 41.7	41.9 - 43.9	44.5 - 46.6	46.7 - 48.5	47.6 - 49.5	49.4 - 50.6	51.0 - 51.9	52.2 - 53.1

Table 4d
Preferred Alternative CAFE Levels
Projected Achieved Harmonic Average for the Fleet, in gallons per 100 miles

	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Passenger Cars	2010 2008	2.5378 - 2.5332	2.4316 - 2.4083	2.3069 - 2.2815	2.2175 - 2.1579	2.1224 - 2.0870	2.0789 - 2.0301	2.0182 - 1.9985	1.9487 - 1.9425	1.9193 - 1.8913
Light Trucks	2010 2008	3.4751 - 3.4136	3.4105 - 3.3040	3.1968 - 3.1343	3.0481 - 3.0015	2.8684 - 2.8400	2.8167 - 2.7690	2.7405 - 2.7154	2.6731 - 2.6364	2.6604 - 2.5637
Combined	2010 2008	2.8697 - 2.8545	2.7776 - 2.7309	2.6207 - 2.5836	2.5064 - 2.4522	2.3794 - 2.3488	2.3311 - 2.2842	2.2624 - 2.2412	2.1911 - 2.1731	2.1658 - 2.1118

Table 5a
Average Incremental Technology Costs and Fines Per Vehicle[11]
Passenger Cars (2010 Dollars)

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Preferred Alternative	2010 2008	$284 - $208	$424 - $377	$603 - $571	$762 - $837	$934 - $1,034	$1,024 - $1,168	$1,129 - $1,255	$1,328 - $1,440	$1,361 - $1,577
2% Annual Increase	2010 2008	$130 - $125	$232 - $224	$333 - $322	$443 - $449	$546 - $529	$592 - $578	$638 - $631	$744 - $719	$741 - $708
3% Annual Increase	2010 2008	$209 - $172	$317 - $330	$476 - $455	$608 - $656	$673 - $764	$755 - $865	$833 - $885	$986 - $962	$1,029 - $1,018
4% Annual Increase	2010 2008	$346 - $255	$482 - $455	$693 - $623	$894 - $882	$1,062 - $1,064	$1,149 - $1,201	$1,246 - $1,332	$1,380 - $1,503	$1,525 - $1,594
5% Annual Increase	2010 2008	$414 - $315	$592 - $550	$944 - $747	$1,208 - $1,196	$1,418 - $1,541	$1,579 - $1,723	$1,832 - $1,927	$2,117 - $2,298	$2,407 - $2,401
6% Annual Increase	2010 2008	$453 - $453	$676 - $734	$1,108 - $933	$1,405 - $1,381	$1,866 - $1,887	$2,040 - $2,416	$2,700 - $2,761	$3,508 - $3,437	$3,450 - $3,675
7% Annual Increase	2010 2008	$664 - $584	$959 - $979	$1,461 - $1,251	$1,688 - $1,712	$2,136 - $2,424	$3,048 - $3,275	$3,705 - $3,606	$4,382 - $4,525	$4,333 - $4,168
Max Net Benefits (3% Discount Rate)	2010 2008	$774 - $830	$908 - $981	$1,373 - $1,287	$1,515 - $1,525	$1,634 - $1,680	$1,722 - $1,710	$1,831 - $1,756	$2,083 - $1,941	$2,037 - $1,866
Max Net Benefits (7% Discount Rate)	2010 2008	$696 - $797	$816 - $899	$1,048 - $1,090	$1,281 - $1,265	$1,427 - $1,384	$1,466 - $1,408	$1,522 - $1,462	$1,712 - $1,597	$1,674 - $1,625
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	$804 - $1,351	$929 - $1,422	$1,485 - $1,562	$1,626 - $1,775	$1,849 - $1,930	$1,965 - $2,069	$2,325 - $2,199	$2,607 - $2,396	$2,399 - $2,297
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	$804 - $1,351	$929 - $1,422	$1,485 - $1,562	$1,626 - $1,775	$1,849 - $1,930	$1,965 - $2,069	$2,325 - $2,199	$2,607 - $2,396	$2,399 - $2,297

[11] The choice of a 3 or 7 percent discount rate can impact the results of the Max Net Benefits and Total Cost = Total Benefits scenarios. The results of all other scenarios are not impacted by choice of discount rate. Results for both 3 and 7 percent discount rates are therefore presented for both Max Net Benefits and Total Cost = Total Benefit scenarios.

Table 5b
Average Incremental Technology Costs and Fines Per Vehicle
Light Trucks (2010 Dollars)

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Preferred Alternative	2010 2008	$158 - $87	$187 - $179	$416 - $331	$596 - $470	$863 - $648	$911 - $752	$1,000 - $808	$1,081 - $888	$1,047 - $1,040
2% Annual Increase	2010 2008	$376 - $133	$379 - $205	$457 - $280	$509 - $376	$555 - $449	$590 - $512	$626 - $524	$667 - $564	$649 - $562
3% Annual Increase	2010 2008	$435 - $172	$445 - $258	$570 - $409	$739 - $583	$876 - $706	$928 - $777	$996 - $820	$1,039 - $898	$1,065 - $935
4% Annual Increase	2010 2008	$468 - $280	$526 - $399	$679 - $635	$917 - $864	$1,071 - $1,083	$1,163 - $1,166	$1,247 - $1,255	$1,378 - $1,369	$1,534 - $1,426
5% Annual Increase	2010 2008	$489 - $363	$568 - $534	$870 - $851	$1,334 - $1,301	$1,667 - $1,567	$1,819 - $1,792	$2,004 - $1,906	$2,289 - $2,190	$2,358 - $2,216
6% Annual Increase	2010 2008	$542 - $506	$639 - $704	$1,012 - $1,057	$1,507 - $1,770	$1,960 - $2,046	$2,132 - $2,320	$2,371 - $2,462	$2,910 - $2,937	$3,179 - $3,108
7% Annual Increase	2010 2008	$670 - $535	$797 - $801	$1,191 - $1,240	$1,805 - $1,907	$2,178 - $2,339	$2,361 - $2,685	$2,641 - $3,144	$3,207 - $3,504	$3,419 - $3,878
Max Net Benefits (3% Discount Rate)	2010 2008	$756 - $1,070	$798 - $1,167	$1,130 - $1,370	$1,481 - $1,990	$1,780 - $2,175	$1,860 - $2,237	$2,011 - $2,315	$2,116 - $2,502	$2,151 - $2,375
Max Net Benefits (7% Discount Rate)	2010 2008	$755 - $1,019	$788 - $1,121	$1,106 - $1,320	$1,438 - $1,692	$1,726 - $1,873	$1,811 - $1,915	$1,939 - $1,927	$2,074 - $2,046	$2,227 - $1,994
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	$791 - $1,144	$827 - $1,221	$1,081 - $1,427	$1,574 - $2,076	$1,855 - $2,265	$1,907 - $2,338	$2,054 - $2,447	$2,159 - $2,617	$2,223 - $2,484
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	$791 - $1,144	$827 - $1,221	$1,081 - $1,427	$1,574 - $2,076	$1,855 - $2,265	$1,907 - $2,338	$2,054 - $2,447	$2,159 - $2,617	$2,223 - $2,484

Table 5c
Average Incremental Technology Costs and Fines Per Vehicle
Passenger Cars and Light Trucks Combined (2010 Dollars)

Passenger Cars & Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Preferred Alternative	2010 2008	$239 - $164	$340 - $306	$537 - $486	$704 - $709	$909 - $900	$985 - $1,025	$1,085 - $1,104	$1,245 - $1,256	$1,257 - $1,400
2% Annual Increase	2010 2008	$217 - $128	$284 - $217	$377 - $308	$466 - $423	$549 - $501	$591 - $555	$634 - $595	$718 - $668	$710 - $660
3% Annual Increase	2010 2008	$289 - $172	$362 - $304	$509 - $439	$653 - $630	$743 - $744	$814 - $834	$888 - $863	$1,004 - $941	$1,041 - $991
4% Annual Increase	2010 2008	$389 - $264	$497 - $435	$688 - $627	$902 - $875	$1,065 - $1,071	$1,154 - $1,189	$1,246 - $1,306	$1,379 - $1,459	$1,528 - $1,539
5% Annual Increase	2010 2008	$441 - $333	$583 - $545	$918 - $784	$1,252 - $1,233	$1,504 - $1,550	$1,661 - $1,747	$1,890 - $1,920	$2,174 - $2,262	$2,391 - $2,340
6% Annual Increase	2010 2008	$485 - $472	$663 - $723	$1,074 - $977	$1,440 - $1,516	$1,899 - $1,942	$2,071 - $2,383	$2,589 - $2,660	$3,308 - $3,271	$3,360 - $3,489
7% Annual Increase	2010 2008	$666 - $566	$902 - $915	$1,366 - $1,247	$1,729 - $1,780	$2,150 - $2,395	$2,813 - $3,072	$3,345 - $3,450	$3,989 - $4,186	$4,029 - $4,073
Max Net Benefits (3% Discount Rate)	2010 2008	$767 - $918	$869 - $1,048	$1,287 - $1,316	$1,503 - $1,687	$1,684 - $1,852	$1,769 - $1,891	$1,892 - $1,945	$2,094 - $2,127	$2,075 - $2,033
Max Net Benefits (7% Discount Rate)	2010 2008	$717 - $878	$806 - $979	$1,068 - $1,172	$1,336 - $1,414	$1,530 - $1,554	$1,584 - $1,582	$1,663 - $1,619	$1,833 - $1,747	$1,858 - $1,746
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	$799 - $1,276	$893 - $1,349	$1,343 - $1,514	$1,608 - $1,880	$1,851 - $2,046	$1,945 - $2,162	$2,234 - $2,283	$2,457 - $2,470	$2,341 - $2,358
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	$799 - $1,276	$893 - $1,349	$1,343 - $1,514	$1,608 - $1,880	$1,851 - $2,046	$1,945 - $2,162	$2,234 - $2,283	$2,457 - $2,470	$2,341 - $2,358

Table 6a
Incremental Total Costs by Societal Perspective[12], by Alternative
Passenger Cars, 3% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$5,736 - $4,252	$3,491 - $2,607	$5,168 - $4,683	$7,638 - $7,291	$9,601 - $10,810	$12,106 - $13,242	$13,430 - $15,277	$15,119 - $16,605	$18,042 - $19,378	$18,843 - $21,598	$109,173 - $115,742
2% Annual Increase	2010 2008	$2,345 - $2,777	$1,605 - $1,607	$2,803 - $2,859	$4,270 - $4,244	$5,803 - $6,007	$7,217 - $7,131	$8,036 - $8,071	$9,060 - $9,116	$10,821 - $10,705	$11,058 - $10,939	$63,017 - $63,455
3% Annual Increase	2010 2008	$6,762 - $5,823	$2,606 - $2,180	$3,894 - $4,167	$6,079 - $5,916	$7,922 - $8,674	$8,907 - $10,121	$10,167 - $11,685	$11,645 - $12,362	$14,084 - $13,701	$14,994 - $14,821	$87,059 - $89,451
4% Annual Increase	2010 2008	$10,997 - $8,332	$4,164 - $3,145	$5,761 - $5,595	$8,574 - $7,791	$11,189 - $11,269	$13,569 - $13,639	$14,852 - $15,612	$16,440 - $17,455	$18,526 - $20,047	$20,750 - $21,910	$124,822 - $124,795
5% Annual Increase	2010 2008	$7,785 - $6,809	$5,012 - $3,842	$7,065 - $6,644	$11,417 - $9,169	$14,716 - $14,620	$17,395 - $18,733	$19,669 - $21,332	$22,848 - $24,232	$26,790 - $29,385	$31,262 - $31,810	$163,959 - $166,576
6% Annual Increase	2010 2008	$8,399 - $9,895	$5,531 - $5,361	$8,018 - $8,602	$13,240 - $11,105	$16,863 - $16,597	$22,173 - $22,413	$24,372 - $29,313	$31,536 - $34,180	$42,338 - $43,766	$42,657 - $49,357	$215,127 - $230,588
7% Annual Increase	2010 2008	$13,565 - $13,078	$7,847 - $6,806	$10,987 - $11,131	$16,890 - $14,395	$19,740 - $20,165	$24,429 - $28,395	$34,527 - $39,071	$42,017 - $43,210	$50,372 - $56,007	$51,007 - $52,581	$271,381 - $284,839
Max Net Benefits	2010 2008	$16,908 - $17,814	$8,895 - $9,396	$10,319 - $11,118	$15,851 - $14,538	$17,866 - $17,970	$19,681 - $20,307	$21,194 - $21,259	$23,039 - $22,387	$26,684 - $25,420	$27,075 - $25,554	$187,511 - $185,763
Total Cost = Total Benefit	2010 2008	$17,641 - $23,750	$9,126 - $14,897	$10,572 - $15,664	$17,021 - $17,382	$19,073 - $20,695	$21,891 - $23,075	$23,719 - $25,237	$28,568 - $27,487	$32,717 - $30,802	$31,287 - $31,239	$211,616 - $230,228

[12] "Societal perspective" includes technology costs and societal costs, but does not include payment of civil penalties by manufacturers in lieu of compliance with the CAFE standards.

Table 6b
Incremental Total Costs by Societal Perspective, by Alternative
Light Trucks, 3% Discount Rate
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$1,862 - $493	$1,056 - $644	$1,255 - $1,385	$2,889 - $2,543	$3,977 - $3,608	$5,781 - $4,925	$6,227 - $5,717	$6,895 - $6,130	$7,640 - $6,749	$7,510 - $7,811	$45,092 - $40,004
2% Annual Increase	2010 2008	$5,809 - $1,743	$2,477 - $1,055	$2,495 - $1,624	$3,122 - $2,204	$3,430 - $2,992	$3,769 - $3,563	$4,112 - $4,051	$4,463 - $4,146	$4,901 - $4,485	$4,860 - $4,553	$39,438 - $30,417
3% Annual Increase	2010 2008	$6,651 - $1,956	$2,885 - $1,374	$2,957 - $2,050	$3,856 - $3,160	$4,975 - $4,432	$5,921 - $5,342	$6,347 - $5,941	$7,041 - $6,280	$7,468 - $6,852	$7,732 - $7,173	$55,832 - $44,560
4% Annual Increase	2010 2008	$7,007 - $2,600	$3,083 - $2,104	$3,465 - $3,008	$4,535 - $4,648	$6,070 - $6,273	$7,182 - $7,697	$7,751 - $8,330	$8,531 - $8,945	$9,458 - $9,681	$10,616 - $10,101	$67,698 - $63,387
5% Annual Increase	2010 2008	$6,880 - $3,555	$3,241 - $2,641	$3,736 - $3,869	$5,658 - $6,019	$8,474 - $8,965	$10,564 - $10,708	$11,527 - $12,190	$12,974 - $12,887	$14,691 - $14,575	$15,292 - $14,866	$93,037 - $90,275
6% Annual Increase	2010 2008	$7,734 - $6,351	$3,601 - $3,552	$4,187 - $4,906	$6,414 - $7,208	$9,364 - $11,731	$12,128 - $13,622	$13,139 - $15,423	$14,617 - $16,199	$17,561 - $18,815	$19,269 - $19,334	$108,015 - $117,142
7% Annual Increase	2010 2008	$8,676 - $6,717	$4,340 - $3,765	$5,092 - $5,544	$7,419 - $8,306	$11,036 - $12,508	$13,212 - $15,351	$14,138 - $17,401	$15,486 - $19,411	$17,941 - $20,984	$18,662 - $22,339	$116,003 - $132,326
Max Net Benefits	2010 2008	$10,852 - $16,621	$4,747 - $6,982	$5,094 - $7,671	$7,052 - $8,903	$9,232 - $12,788	$10,967 - $14,149	$11,609 - $14,686	$12,811 - $15,253	$13,603 - $16,435	$14,206 - $15,876	$100,174 - $129,364
Total Cost = Total Benefit	2010 2008	$11,022 - $17,325	$4,930 - $7,383	$5,269 - $7,996	$6,807 - $9,232	$9,707 - $13,367	$11,357 - $14,762	$11,809 - $15,378	$12,980 - $16,105	$13,890 - $17,092	$14,614 - $16,570	$102,383 - $135,209

Table 6c
Incremental Total Costs by Societal Perspective, by Alternative
Passenger Cars and Light Trucks Combined, 3% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$7,598 - $4,745	$4,547 - $3,251	$6,423 - $6,067	$10,528 - $9,834	$13,578 - $14,417	$17,887 - $18,167	$19,657 - $20,994	$22,013 - $22,735	$25,682 - $26,126	$26,353 - $29,409	$154,266 - $155,745
2% Annual Increase	2010 2008	$8,154 - $4,520	$4,082 - $2,662	$5,298 - $4,484	$7,392 - $6,449	$9,232 - $8,999	$10,987 - $10,694	$12,148 - $12,122	$13,523 - $13,262	$15,722 - $15,190	$15,917 - $15,492	$102,455 - $93,872
3% Annual Increase	2010 2008	$13,413 - $7,779	$5,490 - $3,554	$6,851 - $6,218	$9,935 - $9,076	$12,897 - $13,106	$14,828 - $15,463	$16,514 - $17,626	$18,686 - $18,642	$21,552 - $20,553	$22,726 - $21,994	$142,891 - $134,011
4% Annual Increase	2010 2008	$18,004 - $10,932	$7,247 - $5,249	$9,227 - $8,603	$13,109 - $12,439	$17,259 - $17,541	$20,751 - $21,336	$22,603 - $23,942	$24,971 - $26,400	$27,984 - $29,728	$31,365 - $32,011	$192,520 - $188,182
5% Annual Increase	2010 2008	$14,665 - $10,364	$8,253 - $6,483	$10,801 - $10,513	$17,075 - $15,188	$23,190 - $23,586	$27,959 - $29,440	$31,196 - $33,521	$35,822 - $37,119	$41,481 - $43,961	$46,554 - $46,676	$256,995 - $256,852
6% Annual Increase	2010 2008	$16,133 - $16,246	$9,132 - $8,913	$12,205 - $13,509	$19,654 - $18,313	$26,228 - $28,328	$34,301 - $36,035	$37,511 - $44,736	$46,152 - $50,379	$59,899 - $62,581	$61,927 - $68,691	$323,141 - $347,730
7% Annual Increase	2010 2008	$22,241 - $19,795	$12,187 - $10,571	$16,079 - $16,674	$24,309 - $22,701	$30,777 - $32,672	$37,641 - $43,746	$48,665 - $56,472	$57,503 - $62,621	$68,314 - $76,991	$69,669 - $74,920	$387,383 - $417,165
Max Net Benefits	2010 2008	$27,760 - $34,435	$13,641 - $16,379	$15,412 - $18,788	$22,904 - $23,441	$27,098 - $30,758	$30,647 - $34,455	$32,803 - $35,945	$35,850 - $37,640	$40,287 - $41,856	$41,281 - $41,430	$287,685 - $315,127
Total Cost = Total Benefit	2010 2008	$28,663 - $41,075	$14,056 - $22,281	$15,841 - $23,660	$23,828 - $26,614	$28,780 - $34,062	$33,248 - $37,837	$35,528 - $40,615	$41,548 - $43,592	$46,606 - $47,894	$45,901 - $47,808	$313,999 - $365,437

Table 7a
Present Value of Lifetime Societal Benefits[13], by Alternative
Passenger Cars, (3% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	\$21,819 - \$19,735	\$12,907 - \$10,806	\$18,736 - \$18,668	\$28,873 - \$27,786	\$35,979 - \$38,398	\$44,882 - \$45,214	\$49,850 - \$51,915	\$56,963 - \$56,756	\$65,450 - \$64,370	\$70,184 - \$71,111	\$405,643 - \$404,758
2% Annual Increase	2010 2008	\$9,462 - \$12,652	\$5,837 - \$6,938	\$9,334 - \$11,448	\$14,408 - \$15,901	\$20,483 - \$21,837	\$25,159 - \$25,879	\$28,024 - \$29,368	\$32,250 - \$33,833	\$37,921 - \$39,561	\$40,227 - \$42,743	\$223,104 - \$240,160
3% Annual Increase	2010 2008	\$26,039 - \$27,205	\$9,919 - \$9,455	\$14,567 - \$16,773	\$22,637 - \$23,710	\$30,754 - \$33,073	\$35,437 - \$37,947	\$39,941 - \$43,515	\$46,372 - \$47,564	\$55,237 - \$52,143	\$60,140 - \$56,463	\$341,043 - \$347,848
4% Annual Increase	2010 2008	\$37,891 - \$38,216	\$13,906 - \$13,355	\$19,540 - \$22,085	\$29,969 - \$29,907	\$39,996 - \$40,478	\$48,846 - \$47,604	\$53,826 - \$53,705	\$60,116 - \$59,242	\$66,687 - \$67,012	\$73,837 - \$74,047	\$444,612 - \$445,650
5% Annual Increase	2010 2008	\$28,921 - \$31,883	\$17,365 - \$16,047	\$24,279 - \$25,387	\$36,863 - \$34,222	\$47,250 - \$46,910	\$55,294 - \$55,843	\$60,933 - \$61,541	\$67,990 - \$67,320	\$77,140 - \$76,642	\$86,660 - \$84,612	\$502,696 - \$500,407
6% Annual Increase	2010 2008	\$32,559 - \$38,402	\$20,141 - \$19,577	\$27,546 - \$29,371	\$41,832 - \$37,952	\$50,211 - \$50,491	\$59,960 - \$59,418	\$65,225 - \$68,535	\$73,709 - \$75,196	\$85,385 - \$85,604	\$94,315 - \$97,714	\$550,884 - \$562,260
7% Annual Increase	2010 2008	\$41,692 - \$46,171	\$24,124 - \$23,157	\$32,035 - \$33,353	\$45,415 - \$42,565	\$53,534 - \$54,400	\$61,517 - \$63,139	\$70,425 - \$73,626	\$77,671 - \$79,531	\$88,055 - \$90,305	\$98,386 - \$98,130	\$592,853 - \$604,379
Max Net Benefits	2010 2008	\$51,991 - \$62,497	\$27,812 - \$28,457	\$32,030 - \$33,766	\$44,228 - \$40,246	\$51,352 - \$49,366	\$57,354 - \$56,328	\$61,814 - \$60,264	\$67,230 - \$64,227	\$74,694 - \$71,187	\$80,595 - \$76,360	\$549,100 - \$542,696
Total Cost = Total Benefit	2010 2008	\$54,272 - \$73,670	\$28,621 - \$34,195	\$32,625 - \$38,340	\$45,037 - \$43,337	\$52,566 - \$52,880	\$58,957 - \$59,629	\$64,273 - \$65,194	\$71,657 - \$70,606	\$80,198 - \$77,820	\$85,543 - \$84,341	\$573,750 - \$600,012

[13] These benefits are considered from a “societal perspective” because they include externalities. They are distinguished from a consumer perspective, because consumers generally would not think about the value of carbon dioxide, energy security, etc. Table 7 includes only social benefits; social costs are included in Table 6.

Table 7b
Present Value of Lifetime Societal Benefits, by Alternative
Light Trucks, (3% Discount Rate)
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$7,245 - $2,676	$4,388 - $3,430	$5,868 - $7,976	$14,954 - $14,829	$19,870 - $21,498	$27,579 - $29,219	$30,592 - $33,374	$34,742 - $36,035	$38,691 - $40,324	$40,159 - $44,838	$224,088 - $234,199
2% Annual Increase	2010 2008	$21,081 - $13,015	$9,939 - $7,528	$10,723 - $10,510	$15,393 - $14,918	$17,403 - $19,141	$19,356 - $22,746	$21,270 - $25,347	$23,726 - $26,818	$26,166 - $28,792	$26,916 - $30,049	$191,973 - $198,864
3% Annual Increase	2010 2008	$24,986 - $15,860	$11,983 - $10,205	$13,299 - $14,101	$19,689 - $21,375	$24,595 - $27,770	$29,699 - $33,034	$32,616 - $36,078	$36,653 - $38,540	$39,090 - $41,313	$41,457 - $43,688	$274,067 - $281,963
4% Annual Increase	2010 2008	$25,361 - $18,658	$12,424 - $13,062	$15,080 - $18,041	$22,708 - $27,140	$28,976 - $34,540	$35,597 - $40,576	$38,631 - $43,886	$42,757 - $47,289	$46,959 - $50,252	$51,680 - $52,990	$320,173 - $346,434
5% Annual Increase	2010 2008	$25,809 - $21,615	$13,587 - $14,886	$16,288 - $21,130	$25,710 - $31,711	$32,799 - $41,217	$40,027 - $47,024	$43,494 - $50,923	$49,223 - $54,129	$53,760 - $57,927	$57,830 - $61,039	$358,528 - $401,601
6% Annual Increase	2010 2008	$30,559 - $30,047	$15,518 - $17,355	$18,317 - $23,627	$27,050 - $34,101	$34,537 - $44,752	$42,482 - $50,979	$46,264 - $55,322	$51,805 - $57,468	$57,401 - $61,941	$63,747 - $66,600	$387,680 - $442,190
7% Annual Increase	2010 2008	$31,708 - $33,096	$16,678 - $18,772	$19,817 - $26,200	$29,088 - $36,181	$37,251 - $45,423	$44,825 - $52,959	$48,012 - $57,010	$53,251 - $60,351	$57,780 - $63,487	$62,575 - $68,192	$400,983 - $461,672
Max Net Benefits	2010 2008	$33,809 - $54,484	$16,794 - $26,116	$19,135 - $29,996	$27,735 - $36,862	$34,273 - $45,119	$41,705 - $51,142	$44,660 - $53,847	$49,478 - $56,135	$52,658 - $58,957	$57,092 - $62,072	$377,340 - $474,730
Total Cost = Total Benefit	2010 2008	$35,474 - $55,377	$17,491 - $26,847	$19,733 - $30,611	$27,100 - $37,631	$34,841 - $45,375	$42,388 - $51,005	$44,579 - $53,652	$49,320 - $56,245	$52,982 - $58,900	$57,465 - $62,293	$381,375 - $477,934

Table 7c
Present Value of Lifetime Societal Benefits, by Alternative
Passenger Cars and Light Trucks Combined, (3% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$29,064 - $22,410	$17,295 - $14,236	$24,604 - $26,644	$43,827 - $42,615	$55,849 - $59,896	$72,461 - $74,433	$80,442 - $85,289	$91,704 - $92,791	$104,140 - $104,694	$110,343 - $115,948	$629,730 - $638,957
2% Annual Increase	2010 2008	$30,543 - $25,666	$15,776 - $14,466	$20,057 - $21,959	$29,801 - $30,818	$37,885 - $40,978	$44,515 - $48,625	$49,295 - $54,715	$55,976 - $60,651	$64,087 - $68,352	$67,143 - $72,792	$415,077 - $439,025
3% Annual Increase	2010 2008	$51,025 - $43,064	$21,903 - $19,660	$27,865 - $30,874	$42,325 - $45,085	$55,349 - $60,842	$65,136 - $70,981	$72,558 - $79,593	$83,025 - $86,103	$94,326 - $93,456	$101,597 - $100,152	$615,110 - $629,811
4% Annual Increase	2010 2008	$63,253 - $56,874	$26,329 - $26,416	$34,620 - $40,126	$52,677 - $57,046	$68,972 - $75,018	$84,442 - $88,180	$92,457 - $97,592	$102,873 - $106,531	$113,646 - $117,264	$125,516 - $127,037	$764,785 - $792,084
5% Annual Increase	2010 2008	$54,730 - $53,498	$30,952 - $30,933	$40,567 - $46,517	$62,573 - $65,934	$80,049 - $88,128	$95,321 - $102,867	$104,428 - $112,464	$117,213 - $121,449	$130,900 - $134,569	$144,490 - $145,651	$861,224 - $902,008
6% Annual Increase	2010 2008	$63,119 - $68,449	$35,659 - $36,932	$45,863 - $52,998	$68,882 - $72,053	$84,748 - $95,243	$102,443 - $110,396	$111,490 - $123,857	$125,514 - $132,664	$142,786 - $147,544	$158,062 - $164,314	$938,564 - $1,004,451
7% Annual Increase	2010 2008	$73,400 - $79,267	$40,802 - $41,930	$51,851 - $59,554	$74,502 - $78,747	$90,785 - $99,823	$106,342 - $116,098	$118,436 - $130,637	$130,922 - $139,882	$145,834 - $153,792	$160,961 - $166,322	$993,836 - $1,066,051
Max Net Benefits	2010 2008	$85,800 - $116,981	$44,606 - $54,573	$51,165 - $63,762	$71,963 - $77,108	$85,625 - $94,485	$99,059 - $107,470	$106,475 - $114,111	$116,708 - $120,362	$127,352 - $130,144	$137,687 - $138,432	$926,440 - $1,017,426
Total Cost = Total Benefit	2010 2008	$89,747 - $129,048	$46,113 - $61,043	$52,359 - $68,950	$72,137 - $80,968	$87,407 - $98,254	$101,345 - $110,633	$108,852 - $118,846	$120,977 - $126,851	$133,179 - $136,719	$143,009 - $146,634	$955,125 - $1,077,946

Table 8a
Present Value of Net Total Benefits[14] by Alternative
Passenger Cars, (3% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$16,084 - $15,483	$9,416 - $8,199	$13,568 - $13,985	$21,234 - $20,495	$26,378 - $27,589	$32,776 - $31,972	$36,420 - $36,638	$41,844 - $40,151	$47,407 - $44,992	$51,342 - $49,513	$296,469 - $289,016
2% Annual Increase	2010 2008	$7,117 - $9,874	$4,232 - $5,331	$6,531 - $8,589	$10,138 - $11,656	$14,680 - $15,830	$17,942 - $18,749	$19,989 - $21,298	$23,190 - $24,718	$27,100 - $28,856	$29,169 - $31,804	$160,087 - $176,705
3% Annual Increase	2010 2008	$19,277 - $21,381	$7,314 - $7,275	$10,673 - $12,606	$16,558 - $17,794	$22,832 - $24,399	$26,530 - $27,826	$29,774 - $31,830	$34,727 - $35,202	$41,153 - $38,442	$45,146 - $41,642	$253,984 - $258,397
4% Annual Increase	2010 2008	$26,894 - $29,883	$9,742 - $10,209	$13,778 - $16,490	$21,395 - $22,116	$28,807 - $29,209	$35,276 - $33,965	$38,974 - $38,093	$43,676 - $41,787	$48,160 - $46,966	$53,087 - $52,136	$319,790 - $320,855
5% Annual Increase	2010 2008	$21,136 - $25,074	$12,354 - $12,205	$17,214 - $18,744	$25,446 - $25,053	$32,535 - $32,290	$37,898 - $37,110	$41,265 - $40,209	$45,142 - $43,088	$50,350 - $47,257	$55,398 - $52,801	$338,737 - $333,831
6% Annual Increase	2010 2008	$24,160 - $28,507	$14,610 - $14,216	$19,528 - $20,769	$28,592 - $26,847	$33,347 - $33,894	$37,787 - $37,005	$40,853 - $39,222	$42,173 - $41,017	$43,047 - $41,837	$51,658 - $48,357	$335,757 - $331,672
7% Annual Increase	2010 2008	$28,128 - $33,093	$16,277 - $16,351	$21,048 - $22,223	$28,525 - $28,170	$33,794 - $34,235	$37,088 - $34,744	$35,898 - $34,555	$35,654 - $36,321	$37,682 - $34,298	$47,379 - $45,549	$321,473 - $319,540
Max Net Benefits	2010 2008	$35,083 - $44,682	$18,917 - $19,061	$21,712 - $22,648	$28,376 - $25,708	$33,486 - $31,396	$37,674 - $36,022	$40,620 - $39,004	$44,191 - $41,840	$48,010 - $45,767	$53,520 - $50,806	$361,589 - $356,934
Total Cost = Total Benefit	2010 2008	$36,631 - $49,921	$19,495 - $19,298	$22,054 - $22,676	$28,016 - $25,954	$33,493 - $32,184	$37,066 - $36,553	$40,554 - $39,957	$43,089 - $43,119	$47,481 - $47,018	$54,256 - $53,103	$362,134 - $369,783

[14] This table is from a societal perspective, thus, civil penalties are deleted from the costs because they are a transfer payment (from manufacturers to the U.S. Treasury).

Table 8b
Present Value of Net Total Benefits by Alternative
Light Trucks, (3% Discount Rate)
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$5,383 - $2,183	$3,332 - $2,786	$4,613 - $6,591	$12,064 - $12,286	$15,893 - $17,890	$21,798 - $24,294	$24,365 - $27,657	$27,847 - $29,905	$31,051 - $33,576	$32,648 - $37,026	$178,996 - $194,195
2% Annual Increase	2010 2008	$15,272 - $11,272	$7,462 - $6,473	$8,228 - $8,886	$12,270 - $12,713	$13,973 - $16,150	$15,587 - $19,183	$17,158 - $21,296	$19,264 - $22,671	$21,265 - $24,307	$22,056 - $25,497	$152,535 - $168,447
3% Annual Increase	2010 2008	$18,335 - $13,904	$9,099 - $8,830	$10,342 - $12,051	$15,833 - $18,215	$19,619 - $23,337	$23,778 - $27,692	$26,270 - $30,138	$29,612 - $32,260	$31,622 - $34,460	$33,725 - $36,516	$218,234 - $237,403
4% Annual Increase	2010 2008	$18,355 - $16,058	$9,340 - $10,957	$11,614 - $15,033	$18,173 - $22,492	$22,906 - $28,268	$28,415 - $32,879	$30,879 - $35,556	$34,226 - $38,344	$37,502 - $40,571	$41,064 - $42,889	$252,475 - $283,048
5% Annual Increase	2010 2008	$18,929 - $18,060	$10,346 - $12,245	$12,552 - $17,261	$20,052 - $25,692	$24,325 - $32,252	$29,464 - $36,316	$31,968 - $38,733	$36,249 - $41,242	$39,070 - $43,351	$42,538 - $46,173	$265,492 - $311,326
6% Annual Increase	2010 2008	$22,825 - $23,696	$11,917 - $13,803	$14,130 - $18,720	$20,636 - $26,893	$25,173 - $33,021	$30,354 - $37,356	$33,126 - $39,899	$37,188 - $41,269	$39,839 - $43,126	$44,477 - $47,266	$279,665 - $325,049
7% Annual Increase	2010 2008	$23,032 - $26,379	$12,338 - $15,007	$14,724 - $20,657	$21,669 - $27,875	$26,214 - $32,915	$31,613 - $37,608	$33,874 - $39,609	$37,765 - $40,940	$39,838 - $42,502	$43,913 - $45,853	$284,980 - $329,346
Max Net Benefits	2010 2008	$22,957 - $37,863	$12,048 - $19,134	$14,041 - $22,325	$20,683 - $27,959	$25,041 - $32,331	$30,738 - $36,993	$33,051 - $39,161	$36,667 - $40,882	$39,055 - $42,521	$42,885 - $46,196	$277,166 - $345,366
Total Cost = Total Benefit	2010 2008	$24,453 - $38,052	$12,561 - $19,464	$14,464 - $22,615	$20,294 - $28,399	$25,134 - $32,008	$31,031 - $36,242	$32,770 - $38,274	$36,340 - $40,140	$39,092 - $41,808	$42,851 - $45,723	$278,991 - $342,725

Table 8c
Present Value of Net Total Benefits by Alternative
Passenger Cars and Light Trucks Combined, (3% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$21,466 - $17,666	$12,748 - $10,986	$18,181 - $20,576	$33,299 - $32,781	$42,271 - $45,479	$54,574 - $56,266	$60,785 - $64,295	$69,691 - $70,056	$78,458 - $78,568	$83,990 - $86,539	$475,465 - $483,211
2% Annual Increase	2010 2008	$22,389 - $21,146	$11,693 - $11,804	$14,759 - $17,475	$22,408 - $24,370	$28,653 - $31,980	$33,528 - $37,931	$37,147 - $42,594	$42,453 - $47,389	$48,366 - $53,163	$51,225 - $57,301	$312,622 - $345,152
3% Annual Increase	2010 2008	$37,613 - $35,285	$16,413 - $16,106	$21,015 - $24,656	$32,391 - $36,009	$42,452 - $47,736	$50,308 - $55,519	$56,044 - $61,967	$64,339 - $67,462	$72,774 - $72,903	$78,871 - $78,157	$472,218 - $495,800
4% Annual Increase	2010 2008	$45,249 - $45,941	$19,082 - $21,167	$25,393 - $31,523	$39,568 - $44,607	$51,713 - $57,477	$63,691 - $66,844	$69,853 - $73,649	$77,902 - $80,131	$85,662 - $87,536	$94,151 - $95,026	$572,264 - $603,903
5% Annual Increase	2010 2008	$40,065 - $43,134	$22,700 - $24,450	$29,766 - $36,004	$45,498 - $50,746	$56,859 - $64,542	$67,362 - $73,426	$73,232 - $78,942	$81,391 - $84,330	$89,419 - $90,608	$97,936 - $98,975	$604,229 - $645,156
6% Annual Increase	2010 2008	$46,986 - $52,203	$26,527 - $28,019	$33,658 - $39,489	$49,227 - $53,740	$58,520 - $66,915	$68,141 - $74,362	$73,979 - $79,121	$79,361 - $82,285	$82,887 - $84,963	$96,136 - $95,623	$615,422 - $656,720
7% Annual Increase	2010 2008	$51,159 - $59,472	$28,616 - $31,358	$35,773 - $42,879	$50,194 - $56,046	$60,008 - $67,150	$68,701 - $72,352	$69,772 - $74,164	$73,418 - $77,262	$77,521 - $76,800	$91,292 - $91,402	$606,453 - $648,886
Max Net Benefits	2010 2008	$58,040 - $82,546	$30,965 - $38,194	$35,753 - $44,974	$49,059 - $53,667	$58,527 - $63,727	$68,412 - $73,015	$73,671 - $78,165	$80,858 - $82,722	$87,065 - $88,288	$96,405 - $97,002	$638,755 - $702,299
Total Cost = Total Benefit	2010 2008	$61,084 - $87,973	$32,057 - $38,762	$36,517 - $45,290	$48,309 - $54,354	$58,627 - $64,192	$68,098 - $72,796	$73,324 - $78,231	$79,429 - $83,259	$86,573 - $88,826	$97,107 - $98,826	$641,125 - $712,509

Table 9a
Incremental Total Costs by Societal Perspective[15], by Alternative
Passenger Cars, 7% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$5,498 - $4,044	$3,355 - $2,477	$4,965 - $4,447	$7,281 - $6,906	$9,168 - $10,289	$11,514 - $12,655	$12,753 - $14,595	$14,324 - $15,851	$17,123 - $18,522	$17,850 - $20,634	$103,831 - $110,419
2% Annual Increase	2010 2008	$2,243 - $2,644	$1,540 - $1,516	$2,696 - $2,702	$4,062 - $3,994	$5,502 - $5,682	$6,856 - $6,761	$7,602 - $7,630	$8,526 - $8,604	$10,178 - $10,105	$10,386 - $10,306	$59,593 - $59,945
3% Annual Increase	2010 2008	$6,478 - $5,519	$2,499 - $2,063	$3,733 - $3,944	$5,783 - $5,578	$7,514 - $8,222	$8,441 - $9,621	$9,617 - $11,102	$10,957 - $11,714	$13,260 - $12,982	$14,112 - $14,034	$82,393 - $84,778
4% Annual Increase	2010 2008	$10,587 - $7,919	$4,016 - $2,995	$5,551 - $5,323	$8,197 - $7,395	$10,686 - $10,734	$12,930 - $13,029	$14,136 - $14,912	$15,614 - $16,674	$17,596 - $19,172	$19,697 - $20,913	$119,009 - $119,066
5% Annual Increase	2010 2008	$7,470 - $6,473	$4,827 - $3,664	$6,803 - $6,339	$10,946 - $8,722	$14,099 - $14,004	$16,667 - $18,020	$18,814 - $20,498	$21,872 - $23,271	$25,652 - $28,263	$29,843 - $30,417	$156,994 - $159,671
6% Annual Increase	2010 2008	$8,043 - $9,494	$5,316 - $5,147	$7,721 - $8,251	$12,717 - $10,624	$16,184 - $15,934	$21,335 - $21,596	$23,434 - $28,209	$30,356 - $32,833	$40,764 - $42,046	$40,845 - $47,037	$206,714 - $221,170
7% Annual Increase	2010 2008	$13,115 - $12,596	$7,591 - $6,557	$10,642 - $10,734	$16,313 - $13,847	$19,019 - $19,415	$23,575 - $27,366	$33,324 - $37,574	$40,488 - $41,534	$48,484 - $53,763	$48,829 - $50,134	$261,379 - $273,520
Max Net Benefits	2010 2008	$14,783 - $16,835	$7,784 - $8,700	$9,029 - $9,797	$11,891 - $11,923	$14,665 - $14,443	$16,635 - $16,294	$17,461 - $17,112	$18,539 - $18,246	$21,393 - $20,451	$21,492 - $21,484	$153,672 - $155,284
Total Cost = Total Benefit	2010 2008	$17,050 - $22,974	$8,822 - $14,398	$10,222 - $15,128	$16,421 - $16,764	$18,352 - $19,928	$21,059 - $22,191	$22,786 - $24,248	$27,436 - $26,401	$31,393 - $29,570	$29,881 - $29,810	$203,423 - $221,413

[15] "Societal perspective" includes technology costs and societal costs, but does not include civil penalties.

Table 9b
Incremental Total Costs by Societal Perspective, by Alternative
Light Trucks, 7% Discount Rate
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$1,798 - $471	$1,019 - $612	$1,207 - $1,298	$2,759 - $2,381	$3,817 - $3,380	$5,534 - $4,640	$5,940 - $5,386	$6,559 - $5,774	$7,234 - $6,348	$7,090 - $7,365	$42,955 - $37,655
2% Annual Increase	2010 2008	$5,633 - $1,639	$2,394 - $992	$2,407 - $1,517	$2,990 - $2,055	$3,283 - $2,784	$3,600 - $3,330	$3,908 - $3,791	$4,218 - $3,878	$4,608 - $4,188	$4,559 - $4,239	$37,600 - $28,412
3% Annual Increase	2010 2008	$6,441 - $1,828	$2,783 - $1,289	$2,846 - $1,915	$3,687 - $2,957	$4,761 - $4,161	$5,649 - $5,037	$6,036 - $5,592	$6,665 - $5,906	$7,049 - $6,442	$7,291 - $6,735	$53,210 - $41,862
4% Annual Increase	2010 2008	$6,794 - $2,447	$2,979 - $1,995	$3,340 - $2,832	$4,343 - $4,389	$5,824 - $5,937	$6,860 - $7,340	$7,392 - $7,936	$8,118 - $8,510	$8,984 - $9,213	$10,071 - $9,606	$64,705 - $60,206
5% Annual Increase	2010 2008	$6,665 - $3,381	$3,127 - $2,519	$3,601 - $3,670	$5,437 - $5,720	$8,165 - $8,563	$10,169 - $10,280	$11,082 - $11,705	$12,447 - $12,370	$14,103 - $14,015	$14,659 - $14,251	$89,454 - $86,473
6% Annual Increase	2010 2008	$7,480 - $6,108	$3,472 - $3,410	$4,036 - $4,686	$6,183 - $6,899	$9,046 - $11,261	$11,710 - $13,105	$12,667 - $14,835	$14,069 - $15,587	$16,907 - $18,137	$18,519 - $18,611	$104,090 - $112,639
7% Annual Increase	2010 2008	$8,413 - $6,450	$4,201 - $3,613	$4,925 - $5,300	$7,165 - $7,973	$10,665 - $12,041	$12,753 - $14,821	$13,628 - $16,797	$14,898 - $18,758	$17,260 - $20,288	$17,928 - $21,560	$111,836 - $127,600
Max Net Benefits	2010 2008	$10,504 - $15,549	$4,610 - $6,512	$4,885 - $7,129	$6,688 - $8,250	$8,670 - $10,622	$10,343 - $11,891	$10,919 - $12,296	$11,989 - $12,433	$12,829 - $13,182	$14,026 - $13,003	$95,460 - $110,868
Total Cost = Total Benefit	2010 2008	$10,728 - $16,880	$4,785 - $7,150	$5,107 - $7,718	$6,570 - $8,884	$9,369 - $12,872	$10,951 - $14,218	$11,378 - $14,797	$12,481 - $15,499	$13,334 - $16,453	$13,994 - $15,904	$98,698 - $130,376

Table 9c
Incremental Total Costs by Societal Perspective, by Alternative
Passenger Cars and Light Trucks Combined, 7% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$7,297 - $4,515	$4,373 - $3,089	$6,172 - $5,745	$10,040 - $9,286	$12,985 - $13,669	$17,047 - $17,295	$18,693 - $19,981	$20,883 - $21,625	$24,356 - $24,871	$24,941 - $27,999	$146,786 - $148,074
2% Annual Increase	2010 2008	$7,876 - $4,283	$3,934 - $2,508	$5,103 - $4,219	$7,053 - $6,049	$8,786 - $8,466	$10,456 - $10,092	$11,510 - $11,420	$12,745 - $12,482	$14,786 - $14,292	$14,945 - $14,545	$97,193 - $88,357
3% Annual Increase	2010 2008	$12,919 - $7,347	$5,283 - $3,351	$6,578 - $5,859	$9,470 - $8,535	$12,275 - $12,383	$14,090 - $14,657	$15,653 - $16,694	$17,622 - $17,620	$20,310 - $19,425	$21,403 - $20,769	$135,603 - $126,639
4% Annual Increase	2010 2008	$17,381 - $10,366	$6,994 - $4,990	$8,891 - $8,155	$12,540 - $11,784	$16,510 - $16,670	$19,790 - $20,369	$21,528 - $22,847	$23,732 - $25,184	$26,579 - $28,385	$29,768 - $30,519	$183,713 - $179,271
5% Annual Increase	2010 2008	$14,135 - $9,853	$7,955 - $6,183	$10,403 - $10,009	$16,383 - $14,442	$22,264 - $22,568	$26,835 - $28,300	$29,896 - $32,203	$34,319 - $35,640	$39,754 - $42,278	$44,501 - $44,668	$246,447 - $246,144
6% Annual Increase	2010 2008	$15,523 - $15,602	$8,788 - $8,557	$11,757 - $12,937	$18,899 - $17,523	$25,230 - $27,196	$33,045 - $34,701	$36,101 - $43,044	$44,425 - $48,420	$57,671 - $60,183	$59,364 - $65,647	$310,804 - $333,810
7% Annual Increase	2010 2008	$21,528 - $19,046	$11,792 - $10,170	$15,567 - $16,034	$23,478 - $21,820	$29,683 - $31,456	$36,328 - $42,187	$46,952 - $54,371	$55,385 - $60,291	$65,744 - $74,051	$66,757 - $71,694	$373,215 - $401,120
Max Net Benefits	2010 2008	$25,287 - $32,384	$12,394 - $15,212	$13,914 - $16,926	$18,578 - $20,173	$23,334 - $25,066	$26,978 - $28,186	$28,379 - $29,408	$30,528 - $30,679	$34,222 - $33,633	$35,518 - $34,487	$249,132 - $266,152
Total Cost = Total Benefit	2010 2008	$27,779 - $39,854	$13,607 - $21,548	$15,329 - $22,847	$22,991 - $25,648	$27,721 - $32,800	$32,011 - $36,409	$34,163 - $39,045	$39,917 - $41,901	$44,727 - $46,024	$43,875 - $45,714	$302,120 - $351,789

Table 10a
Present Value of Lifetime Societal Benefits[16], by Alternative
Passenger Cars, (7% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$17,447 - $15,781	$10,334 - $8,655	$15,012 - $14,957	$23,133 - $22,270	$28,828 - $30,770	$35,972 - $36,237	$39,953 - $41,603	$45,658 - $45,486	$52,455 - $51,588	$56,245 - $56,963	$325,038 - $324,310
2% Annual Increase	2010 2008	$7,566 - $10,115	$4,677 - $5,557	$7,483 - $9,171	$11,549 - $12,740	$16,408 - $17,496	$20,157 - $20,737	$22,452 - $23,530	$25,841 - $27,112	$30,383 - $31,702	$32,229 - $34,247	$178,745 - $192,406
3% Annual Increase	2010 2008	$20,829 - $21,766	$7,942 - $7,573	$11,670 - $13,438	$18,135 - $19,002	$24,641 - $26,500	$28,397 - $30,408	$32,005 - $34,866	$37,166 - $38,115	$44,269 - $41,783	$48,191 - $45,232	$273,245 - $278,683
4% Annual Increase	2010 2008	$30,318 - $30,571	$11,136 - $10,695	$15,657 - $17,693	$24,012 - $23,968	$32,048 - $32,435	$39,147 - $38,150	$43,137 - $43,036	$48,184 - $47,472	$53,447 - $53,696	$59,160 - $59,305	$356,245 - $357,022
5% Annual Increase	2010 2008	$23,134 - $25,489	$13,908 - $12,850	$19,458 - $20,338	$29,536 - $27,425	$37,857 - $37,576	$44,307 - $44,735	$48,820 - $49,299	$54,476 - $53,930	$61,803 - $61,392	$69,366 - $67,739	$402,666 - $400,772
6% Annual Increase	2010 2008	$26,046 - $30,698	$16,132 - $15,675	$22,076 - $23,527	$33,519 - $30,413	$40,234 - $40,453	$48,036 - $47,588	$52,251 - $54,856	$59,027 - $60,173	$68,312 - $68,470	$75,414 - $78,069	$441,045 - $449,922
7% Annual Increase	2010 2008	$33,356 - $36,910	$19,324 - $18,543	$25,675 - $26,712	$36,384 - $34,102	$42,890 - $43,579	$49,291 - $50,549	$56,369 - $58,878	$62,145 - $63,596	$70,433 - $72,158	$78,659 - $78,378	$474,526 - $483,406
Max Net Benefits	2010 2008	$39,548 - $49,680	$21,104 - $22,376	$24,397 - $25,644	$33,058 - $30,088	$39,268 - $36,256	$44,064 - $41,354	$46,782 - $44,370	$50,172 - $47,796	$56,356 - $52,932	$60,041 - $57,739	$414,789 - $408,234
Total Cost = Total Benefit	2010 2008	$43,413 - $58,900	$22,925 - $27,356	$26,145 - $30,685	$36,061 - $34,701	$42,096 - $42,336	$47,221 - $47,746	$51,475 - $52,197	$57,373 - $56,534	$64,211 - $62,303	$68,482 - $67,503	$459,401 - $480,262

[16] These benefits are considered from a "societal perspective" because they include externalities. They are distinguished from a consumer perspective, because consumers generally would not think about the value of carbon dioxide, energy security, etc. Table 10 includes only social benefits; social costs are included in Table 9.

Table 10b
Present Value of Lifetime Societal Benefits, by Alternative
Light Trucks, (7% Discount Rate)
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$5,746 - $2,113	$3,483 - $2,717	$4,659 - $6,323	$11,863 - $11,755	$15,773 - $17,051	$21,876 - $23,171	$24,263 - $26,462	$27,545 - $28,570	$30,672 - $31,971	$31,831 - $35,544	$177,711 - $185,677
2% Annual Increase	2010 2008	$16,681 - $10,301	$7,876 - $5,967	$8,501 - $8,333	$12,207 - $11,826	$13,804 - $15,180	$15,354 - $18,036	$16,871 - $20,097	$18,816 - $21,262	$20,748 - $22,827	$21,338 - $23,821	$152,196 - $157,651
3% Annual Increase	2010 2008	$19,781 - $12,554	$9,501 - $8,089	$10,548 - $11,181	$15,614 - $16,944	$19,514 - $22,022	$23,555 - $26,195	$25,865 - $28,604	$29,058 - $30,552	$30,987 - $32,753	$32,859 - $34,631	$217,281 - $223,525
4% Annual Increase	2010 2008	$20,079 - $14,774	$9,850 - $10,355	$11,957 - $14,306	$18,008 - $21,512	$22,990 - $27,389	$28,231 - $32,172	$30,635 - $34,792	$33,899 - $37,484	$37,228 - $39,835	$40,950 - $42,000	$253,826 - $274,618
5% Annual Increase	2010 2008	$20,436 - $17,115	$10,773 - $11,800	$12,916 - $16,752	$20,389 - $25,134	$26,022 - $32,680	$31,743 - $37,282	$34,487 - $40,369	$39,018 - $42,905	$42,612 - $45,916	$45,828 - $48,356	$284,225 - $318,308
6% Annual Increase	2010 2008	$24,199 - $23,773	$12,305 - $13,754	$14,527 - $18,729	$21,451 - $27,027	$27,401 - $35,466	$33,690 - $40,400	$36,683 - $43,836	$41,065 - $45,533	$45,484 - $49,068	$50,495 - $52,752	$307,301 - $350,338
7% Annual Increase	2010 2008	$25,108 - $26,203	$13,224 - $14,883	$15,715 - $20,771	$23,066 - $28,680	$29,545 - $36,017	$35,540 - $41,993	$38,063 - $45,194	$42,203 - $47,828	$45,781 - $50,312	$49,578 - $54,010	$317,825 - $365,890
Max Net Benefits	2010 2008	$26,435 - $41,963	$13,506 - $20,101	$15,190 - $23,201	$21,984 - $28,917	$27,071 - $34,022	$32,702 - $38,482	$34,834 - $40,591	$38,712 - $41,985	$41,481 - $43,986	$46,103 - $46,417	$298,018 - $359,663
Total Cost = Total Benefit	2010 2008	$28,084 - $43,815	$13,867 - $21,281	$15,647 - $24,269	$21,490 - $29,835	$27,642 - $35,953	$33,617 - $40,412	$35,347 - $42,504	$39,097 - $44,555	$41,996 - $46,659	$45,532 - $49,342	$302,319 - $378,627

Table 10c
Present Value of Lifetime Societal Benefits, by Alternative
Passenger Cars and Light Trucks Combined, (7% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$23,194 - $17,894	$13,817 - $11,373	$19,671 - $21,280	$34,996 - $34,025	$44,601 - $47,821	$57,847 - $59,408	$64,216 - $68,065	$73,203 - $74,056	$83,127 - $83,560	$88,076 - $92,506	$502,749 - $509,987
2% Annual Increase	2010 2008	$24,247 - $20,416	$12,553 - $11,524	$15,984 - $17,504	$23,755 - $24,567	$30,212 - $32,676	$35,511 - $38,773	$39,322 - $43,626	$44,657 - $48,374	$51,131 - $54,529	$53,568 - $58,068	$330,940 - $350,058
3% Annual Increase	2010 2008	$40,611 - $34,320	$17,443 - $15,662	$22,218 - $24,619	$33,750 - $35,946	$44,155 - $48,523	$51,951 - $56,603	$57,870 - $63,470	$66,224 - $68,667	$75,256 - $74,537	$81,050 - $79,863	$490,527 - $502,208
4% Annual Increase	2010 2008	$50,397 - $45,345	$20,986 - $21,050	$27,614 - $31,998	$42,020 - $45,481	$55,037 - $59,824	$67,378 - $70,322	$73,771 - $77,828	$82,083 - $84,956	$90,675 - $93,531	$100,109 - $101,305	$610,071 - $631,640
5% Annual Increase	2010 2008	$43,571 - $42,604	$24,681 - $24,651	$32,374 - $37,090	$49,924 - $52,559	$63,879 - $70,256	$76,051 - $82,017	$83,307 - $89,667	$93,494 - $96,836	$104,415 - $107,308	$115,194 - $116,094	$686,890 - $719,081
6% Annual Increase	2010 2008	$50,245 - $54,471	$28,436 - $29,429	$36,602 - $42,256	$54,970 - $57,440	$67,635 - $75,919	$81,725 - $87,988	$88,934 - $98,691	$100,092 - $105,706	$113,797 - $117,538	$125,910 - $130,821	$748,347 - $800,259
7% Annual Increase	2010 2008	$58,464 - $63,113	$32,549 - $33,426	$41,389 - $47,483	$59,450 - $62,782	$72,435 - $79,596	$84,831 - $92,542	$94,433 - $104,072	$104,348 - $111,424	$116,214 - $122,470	$128,237 - $132,388	$792,351 - $849,296
Max Net Benefits	2010 2008	$65,983 - $91,643	$34,610 - $42,476	$39,587 - $48,846	$55,042 - $59,005	$66,339 - $70,278	$76,766 - $79,836	$81,616 - $84,960	$88,883 - $89,780	$97,837 - $96,917	$106,144 - $104,156	$712,807 - $767,897
Total Cost = Total Benefit	2010 2008	$71,496 - $102,715	$36,793 - $48,637	$41,792 - $54,954	$57,552 - $64,537	$69,738 - $78,290	$80,838 - $88,158	$86,822 - $94,701	$96,469 - $101,089	$106,207 - $108,963	$114,014 - $116,845	$761,720 - $858,888

Table 11a
Present Value of Net Total Benefits[17] by Alternative
Passenger Cars, (7% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$11,949 - $11,737	$6,980 - $6,178	$10,047 - $10,510	$15,852 - $15,365	$19,660 - $20,481	$24,458 - $23,581	$27,200 - $27,008	$31,335 - $29,635	$35,332 - $33,066	$38,395 - $36,329	$221,207 - $213,891
2% Annual Increase	2010 2008	$5,323 - $7,471	$3,137 - $4,041	$4,786 - $6,468	$7,486 - $8,746	$10,905 - $11,814	$13,301 - $13,976	$14,849 - $15,900	$17,314 - $18,507	$20,205 - $21,597	$21,843 - $23,941	$119,152 - $132,462
3% Annual Increase	2010 2008	$14,352 - $16,247	$5,442 - $5,511	$7,938 - $9,494	$12,353 - $13,423	$17,127 - $18,279	$19,956 - $20,787	$22,388 - $23,764	$26,209 - $26,401	$31,009 - $28,801	$34,079 - $31,198	$190,852 - $193,905
4% Annual Increase	2010 2008	$19,731 - $22,651	$7,120 - $7,700	$10,106 - $12,370	$15,815 - $16,573	$21,362 - $21,701	$26,217 - $25,121	$29,001 - $28,125	$32,570 - $30,798	$35,852 - $34,525	$39,463 - $38,392	$237,237 - $237,956
5% Annual Increase	2010 2008	$15,664 - $19,016	$9,081 - $9,186	$12,656 - $13,999	$18,589 - $18,703	$23,758 - $23,571	$27,641 - $26,715	$30,006 - $28,800	$32,603 - $30,659	$36,152 - $33,129	$39,523 - $37,322	$245,672 - $241,102
6% Annual Increase	2010 2008	$18,003 - $21,204	$10,816 - $10,528	$14,354 - $15,276	$20,802 - $19,789	$24,050 - $24,518	$26,700 - $25,992	$28,817 - $26,647	$28,671 - $27,340	$27,549 - $26,424	$34,569 - $31,032	$234,332 - $228,751
7% Annual Increase	2010 2008	$20,241 - $24,315	$11,733 - $11,986	$15,033 - $15,978	$20,071 - $20,255	$23,871 - $24,164	$25,717 - $23,182	$23,045 - $21,304	$21,657 - $22,062	$21,949 - $18,396	$29,830 - $28,244	$213,148 - $209,886
Max Net Benefits	2010 2008	$24,764 - $32,845	$13,320 - $13,675	$15,368 - $15,848	$21,168 - $18,165	$24,603 - $21,813	$27,428 - $25,060	$29,321 - $27,258	$31,633 - $29,550	$34,963 - $32,481	$38,549 - $36,255	$261,117 - $252,950
Total Cost = Total Benefit	2010 2008	$26,362 - $35,926	$14,103 - $12,958	$15,923 - $15,556	$19,641 - $17,938	$23,744 - $22,408	$26,161 - $25,555	$28,689 - $27,949	$29,937 - $30,132	$32,819 - $32,733	$38,600 - $37,693	$255,978 - $258,849

[17] This table is from a societal perspective, thus, civil penalties are deleted from the costs because they are a transfer payment.

Table 11b
Present Value of Net Total Benefits by Alternative
Light Trucks, (7% Discount Rate)
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$3,948 - $1,641	$2,464 - $2,105	$3,453 - $5,025	$9,105 - $9,374	$11,956 - $13,671	$16,342 - $18,531	$18,323 - $21,076	$20,986 - $22,796	$23,439 - $25,623	$24,740 - $28,178	$134,756 - $148,022
2% Annual Increase	2010 2008	$11,048 - $8,662	$5,482 - $4,975	$6,095 - $6,816	$9,217 - $9,771	$10,521 - $12,396	$11,753 - $14,705	$12,963 - $16,306	$14,598 - $17,384	$16,140 - $18,640	$16,779 - $19,582	$114,595 - $129,239
3% Annual Increase	2010 2008	$13,340 - $10,725	$6,718 - $6,800	$7,702 - $9,267	$11,927 - $13,987	$14,753 - $17,861	$17,906 - $21,158	$19,829 - $23,011	$22,393 - $24,647	$23,938 - $26,311	$25,568 - $27,896	$164,072 - $181,664
4% Annual Increase	2010 2008	$13,285 - $12,327	$6,872 - $8,360	$8,617 - $11,474	$13,664 - $17,123	$17,166 - $21,453	$21,371 - $24,832	$23,243 - $26,856	$25,781 - $28,974	$28,244 - $30,622	$30,878 - $32,393	$189,121 - $214,413
5% Annual Increase	2010 2008	$13,771 - $13,734	$7,646 - $9,281	$9,315 - $13,083	$14,952 - $19,414	$17,857 - $24,117	$21,574 - $27,002	$23,405 - $28,664	$26,572 - $30,536	$28,509 - $31,902	$31,169 - $34,104	$194,771 - $231,835
6% Annual Increase	2010 2008	$16,719 - $17,665	$8,833 - $10,344	$10,490 - $14,043	$15,268 - $20,129	$18,355 - $24,205	$21,980 - $27,294	$24,016 - $29,000	$26,996 - $29,946	$28,577 - $30,931	$31,977 - $34,142	$203,211 - $237,698
7% Annual Increase	2010 2008	$16,695 - $19,752	$9,023 - $11,270	$10,790 - $15,471	$15,901 - $20,707	$18,880 - $23,977	$22,787 - $27,172	$24,435 - $28,397	$27,306 - $29,071	$28,521 - $30,023	$31,650 - $32,450	$205,989 - $238,290
Max Net Benefits	2010 2008	$15,931 - $26,414	$8,896 - $13,589	$10,305 - $16,072	$15,296 - $20,667	$18,402 - $23,400	$22,360 - $26,590	$23,916 - $28,294	$26,723 - $29,552	$28,652 - $30,804	$32,077 - $33,414	$202,558 - $248,796
Total Cost = Total Benefit	2010 2008	$17,355 - $26,935	$9,082 - $14,130	$10,540 - $16,551	$14,920 - $20,951	$18,273 - $23,081	$22,666 - $26,195	$23,970 - $27,707	$26,616 - $29,056	$28,662 - $30,206	$31,538 - $33,438	$203,622 - $248,251

Table 11c
Present Value of Net Total Benefits by Alternative
Passenger Cars and Light Trucks Combined, (7% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$15,897 - $13,379	$9,444 - $8,284	$13,500 - $15,535	$24,957 - $24,739	$31,616 - $34,152	$40,800 - $42,112	$45,523 - $48,085	$52,320 - $52,431	$58,771 - $58,689	$63,135 - $64,507	$355,963 - $361,913
2% Annual Increase	2010 2008	$16,372 - $16,133	$8,620 - $9,016	$10,881 - $13,285	$16,703 - $18,517	$21,426 - $24,211	$25,054 - $28,681	$27,812 - $32,206	$31,912 - $35,892	$36,345 - $40,237	$38,622 - $43,523	$233,747 - $261,701
3% Annual Increase	2010 2008	$27,692 - $26,972	$12,160 - $12,311	$15,640 - $18,761	$24,279 - $27,411	$31,880 - $36,140	$37,862 - $41,945	$42,217 - $46,776	$48,602 - $51,047	$54,947 - $55,112	$59,647 - $59,094	$354,924 - $375,569
4% Annual Increase	2010 2008	$33,016 - $34,978	$13,992 - $16,060	$18,723 - $23,844	$29,479 - $33,696	$38,528 - $43,154	$47,588 - $49,952	$52,244 - $54,981	$58,351 - $59,772	$64,096 - $65,146	$70,341 - $70,785	$426,358 - $452,369
5% Annual Increase	2010 2008	$29,435 - $32,750	$16,727 - $18,467	$21,971 - $27,081	$33,541 - $38,117	$41,615 - $47,688	$49,215 - $53,718	$53,411 - $57,464	$59,175 - $61,195	$64,661 - $65,030	$70,693 - $71,426	$440,443 - $472,937
6% Annual Increase	2010 2008	$34,722 - $38,869	$19,649 - $20,872	$24,845 - $29,319	$36,071 - $39,917	$42,405 - $48,723	$48,680 - $53,287	$52,833 - $55,647	$55,667 - $57,286	$56,126 - $57,355	$66,546 - $65,174	$437,543 - $466,450
7% Annual Increase	2010 2008	$36,936 - $44,067	$20,756 - $23,256	$25,823 - $31,449	$35,973 - $40,962	$42,752 - $48,141	$48,504 - $50,355	$47,480 - $49,701	$48,963 - $51,133	$50,470 - $48,419	$61,480 - $60,694	$419,136 - $448,176
Max Net Benefits	2010 2008	$40,695 - $59,259	$22,216 - $27,264	$25,673 - $31,920	$36,464 - $38,832	$43,005 - $45,212	$49,788 - $51,650	$53,237 - $55,552	$58,356 - $59,101	$63,615 - $63,285	$70,627 - $69,669	$463,675 - $501,745
Total Cost = Total Benefit	2010 2008	$43,718 - $62,861	$23,185 - $27,089	$26,463 - $32,107	$34,561 - $38,889	$42,017 - $45,489	$48,827 - $51,749	$52,659 - $55,657	$56,553 - $59,188	$61,480 - $62,939	$70,138 - $71,131	$459,600 - $507,100

Table 12a
Millions of Gallons of Liquid Fuel Saved[18]
Passenger Cars, Undiscounted Over the Lifetime of the Model Year

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	6,093 - 5,501	3,547 - 2,949	5,106 - 5,073	7,826 - 7,524	9,672 - 10,365	11,993 - 12,117	13,215 - 13,828	14,983 - 15,005	17,150 - 16,980	18,282 - 18,999	107,867 - 108,342
2% Annual Increase	2010 2008	2,632 - 3,538	1,596 - 1,896	2,531 - 3,111	3,886 - 4,361	5,489 - 5,931	6,711 - 6,968	7,417 - 7,861	8,456 - 8,980	9,920 - 10,465	10,430 - 11,203	59,067 - 64,316
3% Annual Increase	2010 2008	4,498 - 4,954	2,725 - 2,581	3,964 - 4,560	6,127 - 6,407	8,257 - 8,898	9,452 - 10,139	10,568 - 11,560	12,166 - 12,533	14,437 - 13,720	15,612 - 14,926	87,805 - 90,279
4% Annual Increase	2010 2008	6,695 - 6,939	3,817 - 3,649	5,324 - 6,006	8,167 - 8,096	10,802 - 10,921	13,100 - 12,758	14,328 - 14,304	15,867 - 15,716	17,518 - 17,718	19,522 - 19,817	115,139 - 115,924
5% Annual Increase	2010 2008	8,073 - 8,891	4,764 - 4,382	6,615 - 6,904	10,126 - 9,275	12,905 - 12,903	15,011 - 15,323	16,585 - 16,889	18,437 - 18,451	20,851 - 21,139	24,127 - 23,683	137,494 - 137,839
6% Annual Increase	2010 2008	9,064 - 10,716	5,519 - 5,353	7,504 - 8,000	11,503 - 10,273	13,922 - 13,811	16,769 - 16,711	18,150 - 19,655	20,834 - 21,685	24,668 - 25,086	27,331 - 29,391	155,263 - 160,681
7% Annual Increase	2010 2008	11,633 - 12,885	6,618 - 6,337	8,751 - 9,174	12,632 - 11,686	14,967 - 15,211	17,207 - 18,453	20,381 - 22,239	22,867 - 23,933	26,147 - 27,806	29,403 - 30,154	170,607 - 177,878
Max Net Benefits (3% Discount Rate)	2010 2008	14,530 - 17,484	7,627 - 7,963	8,737 - 9,379	12,615 - 11,480	14,642 - 14,063	16,186 - 15,872	17,307 - 16,854	18,649 - 17,819	20,702 - 19,677	22,249 - 20,987	153,245 - 151,579
Max Net Benefits (7% Discount Rate)	2010 2008	13,815 - 17,387	7,226 - 7,811	8,296 - 8,889	11,286 - 10,522	13,605 - 12,702	15,221 - 14,334	16,022 - 15,266	17,014 - 16,293	19,009 - 17,955	20,149 - 19,550	141,643 - 140,709
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	15,169 - 20,614	7,851 - 9,965	8,895 - 11,053	12,896 - 12,455	14,937 - 15,193	16,720 - 16,982	18,078 - 18,446	20,255 - 19,837	22,500 - 21,787	23,844 - 23,687	161,144 - 170,020
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	15,169 - 20,614	7,851 - 9,965	8,895 - 11,053	12,896 - 12,455	14,937 - 15,193	16,720 - 16,982	18,078 - 18,446	20,255 - 19,837	22,500 - 21,787	23,844 - 23,687	161,144 - 170,020

[18] The choice of a 3 or 7 percent discount rate can impact the results of the Max Net Benefits and Total Cost = Total Benefits scenarios. The results of all other scenarios are not impacted by choice of discount rate. Results for both 3 and 7 percent discount rates are therefore presented for both Max Net Benefits and Total Cost = Total Benefit scenarios.

Table 12b
Millions of Gallons of Liquid Fuel Saved
Light Trucks, Undiscounted Over the Lifetime of the Model Year

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	2,041 - 750	1,219 - 954	1,640 - 2,211	4,215 - 4,084	5,575 - 5,864	7,697 - 7,929	8,444 - 8,986	9,482 - 9,616	10,438 - 10,664	10,729 - 11,785	61,480 - 62,845
2% Annual Increase	2010 2008	6,151 - 3,689	2,828 - 2,095	3,045 - 2,911	4,359 - 4,102	4,886 - 5,214	5,376 - 6,155	5,849 - 6,800	6,455 - 7,127	7,039 - 7,577	7,168 - 7,835	53,156 - 53,505
3% Annual Increase	2010 2008	7,259 - 4,510	3,408 - 2,847	3,766 - 3,910	5,541 - 5,890	6,889 - 7,591	8,229 - 8,971	8,955 - 9,715	9,959 - 10,280	10,520 - 10,917	11,046 - 11,475	75,571 - 76,105
4% Annual Increase	2010 2008	7,376 - 5,326	3,530 - 3,660	4,265 - 5,017	6,381 - 7,496	8,099 - 9,459	9,851 - 11,049	10,588 - 11,846	11,622 - 12,654	12,640 - 13,320	13,996 - 13,953	88,347 - 93,780
5% Annual Increase	2010 2008	7,493 - 6,168	3,857 - 4,177	4,602 - 5,881	7,238 - 8,776	9,318 - 11,391	11,304 - 12,900	12,215 - 13,950	13,707 - 14,701	14,826 - 15,606	15,821 - 16,620	100,382 - 110,171
6% Annual Increase	2010 2008	8,851 - 8,561	4,397 - 4,864	5,164 - 6,588	7,605 - 9,448	9,799 - 12,727	12,017 - 14,353	12,971 - 15,550	14,422 - 16,049	16,087 - 17,293	18,055 - 18,547	109,368 - 123,980
7% Annual Increase	2010 2008	9,181 - 9,475	4,730 - 5,273	5,616 - 7,322	8,216 - 10,050	10,808 - 12,723	12,926 - 14,802	13,724 - 15,992	15,102 - 16,936	16,395 - 17,684	17,649 - 19,237	114,346 - 129,494
Max Net Benefits (3% Discount Rate)	2010 2008	9,805 - 15,617	4,762 - 7,393	5,399 - 8,432	7,848 - 10,280	9,758 - 12,991	11,735 - 14,531	12,448 - 15,153	13,673 - 15,681	14,408 - 16,352	15,471 - 17,060	105,306 - 133,490
Max Net Benefits (7% Discount Rate)	2010 2008	9,673 - 15,206	4,828 - 7,180	5,404 - 8,227	7,843 - 10,161	9,694 - 12,048	11,589 - 13,521	12,230 - 14,134	13,475 - 14,481	14,289 - 15,026	15,913 - 15,726	104,938 - 125,711
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	10,271 - 15,875	4,953 - 7,592	5,561 - 8,598	7,660 - 10,479	9,937 - 13,211	11,936 - 14,679	12,463 - 15,302	13,664 - 15,902	14,527 - 16,504	15,757 - 17,285	106,730 - 135,426
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	10,271 - 15,875	4,953 - 7,592	5,561 - 8,598	7,660 - 10,479	9,937 - 13,211	11,936 - 14,679	12,463 - 15,302	13,664 - 15,902	14,527 - 16,504	15,757 - 17,285	96,459 - 119,552

Table 12c
Millions of Gallons of Liquid Fuel Saved
Passenger Cars and Light Trucks Combined
Undiscounted Over the Lifetime of the Model Year

Passenger Cars & Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	8,134 - 6,251	4,766 - 3,904	6,746 - 7,285	12,041 - 11,608	15,247 - 16,230	19,690 - 20,045	21,659 - 22,815	24,466 - 24,621	27,588 - 27,644	29,010 - 30,784	161,213 - 164,935
2% Annual Increase	2010 2008	8,784 - 7,227	4,424 - 3,992	5,576 - 6,022	8,244 - 8,463	10,375 - 11,145	12,086 - 13,123	13,266 - 14,661	14,911 - 16,107	16,958 - 18,042	17,598 - 19,038	103,439 - 110,594
3% Annual Increase	2010 2008	11,757 - 9,464	6,132 - 5,428	7,730 - 8,470	11,668 - 12,297	15,146 - 16,489	17,681 - 19,110	19,523 - 21,275	22,125 - 22,813	24,956 - 24,636	26,659 - 26,401	151,620 - 156,920
4% Annual Increase	2010 2008	14,070 - 12,265	7,347 - 7,309	9,588 - 11,023	14,548 - 15,592	18,901 - 20,380	22,951 - 23,807	24,916 - 26,150	27,489 - 28,370	30,157 - 31,038	33,519 - 33,770	189,416 - 197,439
5% Annual Increase	2010 2008	15,566 - 15,059	8,621 - 8,560	11,217 - 12,785	17,365 - 18,051	22,223 - 24,294	26,314 - 28,223	28,801 - 30,839	32,144 - 33,152	35,677 - 36,745	39,948 - 40,303	222,310 - 232,952
6% Annual Increase	2010 2008	17,914 - 19,278	9,916 - 10,217	12,668 - 14,589	19,108 - 19,721	23,721 - 26,538	28,786 - 31,064	31,121 - 35,205	35,256 - 37,734	40,755 - 42,379	45,386 - 47,938	246,717 - 265,384
7% Annual Increase	2010 2008	20,814 - 22,360	11,348 - 11,610	14,367 - 16,496	20,848 - 21,736	25,775 - 27,934	30,133 - 33,255	34,105 - 38,231	37,969 - 40,869	42,542 - 45,489	47,052 - 49,391	264,140 - 285,012
Max Net Benefits (3% Discount Rate)	2010 2008	24,335 - 33,102	12,389 - 15,356	14,136 - 17,811	20,463 - 21,760	24,401 - 27,054	27,921 - 30,403	29,755 - 32,007	32,322 - 33,500	35,110 - 36,029	37,719 - 38,046	234,216 - 251,968
Max Net Benefits (7% Discount Rate)	2010 2008	23,487 - 32,593	12,054 - 14,991	13,700 - 17,116	19,129 - 20,683	23,299 - 24,750	26,810 - 27,856	28,253 - 29,399	30,489 - 30,774	33,298 - 32,981	36,062 - 35,276	223,093 - 233,827
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	25,440 - 36,489	12,804 - 17,557	14,456 - 19,650	20,557 - 22,935	24,874 - 28,405	28,656 - 31,661	30,540 - 33,747	33,918 - 35,739	37,027 - 38,291	39,602 - 40,972	242,434 - 268,957
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	25,440 - 36,489	12,804 - 17,557	14,456 - 19,650	20,557 - 22,935	24,874 - 28,405	28,656 - 31,661	30,540 - 33,747	33,918 - 35,739	37,027 - 38,291	39,602 - 40,972	242,434 - 268,957

Table 12d
Change in Electricity Consumption (in GW-h)
Passenger Cars
Undiscounted Over the Lifetime of the Model Year

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	0.0 - 1,949.6	272.1 - 2,310.8	349.5 - 3,100.3	366.6 - 3,747.2	2,435.7 - 7,134.2	3,202.0 - 17,639.9	6,626.0 - 36,694.2
2% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 2,120.8	0.0 - 2,667.7	272.1 - 2,959.9	349.5 - 3,725.6	354.8 - 4,180.1	2,023.7 - 6,284.5	2,225.8 - 6,642.9	5,226.0 - 28,851.4
3% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	0.0 - 1,442.0	272.1 - 1,800.5	349.5 - 2,563.3	366.6 - 3,012.2	2,149.2 - 5,977.7	2,917.6 - 11,374.7	6,055.1 - 26,982.8
4% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	73.5 - 1,562.7	347.6 - 1,926.5	638.8 - 2,694.9	692.1 - 4,778.0	2,769.3 - 7,844.9	9,749.1 - 18,723.5	14,270.4 - 38,342.9
5% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	2,061.4 - 542.3	2,720.8 - 7,208.8	3,691.9 - 10,168.0	5,601.8 - 10,687.4	7,261.1 - 13,416.6	11,609.5 - 21,178.3	37,249.2 - 39,375.0	70,195.8 - 102,846.4
6% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	32.0 - 460.9	2,043.7 - 722.7	3,285.9 - 4,885.1	10,267.7 - 18,022.2	10,568.1 - 35,074.0	24,997.5 - 48,022.8	50,318.5 - 70,012.7	66,383.0 - 113,471.4	167,896.5 - 290,664.0
7% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	32.0 - 2,478.3	6,390.9 - 4,364.5	8,121.4 - 9,222.4	10,992.8 - 26,094.0	33,649.0 - 57,940.9	48,359.2 - 66,198.7	67,508.0 - 103,830.6	89,892.5 - 120,608.7	264,946.0 - 390,730.5
Max Net Benefits (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 1,312.3	32.0 - 1,806.7	11,498.8 - 10,940.9	14,406.0 - 15,351.4	14,865.4 - 16,358.0	16,048.4 - 17,690.9	17,136.1 - 19,094.8	23,751.5 - 24,440.4	29,033.2 - 28,581.6	126,771.5 - 135,576.9
Max Net Benefits (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 1,312.3	35.9 - 1,813.9	2,069.5 - 6,478.5	8,503.8 - 10,208.3	9,583.3 - 10,730.2	9,927.1 - 11,684.2	10,135.5 - 12,398.6	13,245.2 - 15,733.4	15,993.4 - 20,739.4	69,493.7 - 91,098.8
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 14,274.3	35.9 - 14,822.4	12,875.2 - 17,142.9	13,844.7 - 22,018.9	16,294.3 - 23,290.6	17,533.1 - 26,328.6	27,801.7 - 29,438.9	32,354.3 - 36,455.0	36,201.0 - 48,568.1	156,940.2 - 232,339.8
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 14,274.3	35.9 - 14,822.4	12,875.2 - 17,142.9	13,844.7 - 22,018.9	16,294.3 - 23,290.6	17,533.1 - 26,328.6	27,801.7 - 29,438.9	32,354.3 - 36,455.0	36,201.0 - 48,568.1	156,940.2 - 232,339.8

Table 12e
Change in Electricity Consumption (in GW-h)
Light Trucks
Undiscounted Over the Lifetime of the Model Year

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
2% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
3% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 1,144.6	0.0 - 1,144.6
4% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.2 - 0.0	0.2 - 0.0	0.2 - 0.0	0.2 - 206.5	0.2 - 211.8	5,304.2 - 1,357.4	5,305.2 - 1,775.7
5% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	487.2 - 1,160.2	485.4 - 1,151.8	497.8 - 1,159.1	532.7 - 1,362.6	537.6 - 1,397.1	990.0 - 9,681.6	3,530.8 - 15,912.4
6% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	540.4 - 7,952.7	538.1 - 8,220.3	551.4 - 9,244.6	585.1 - 9,425.2	6,062.8 - 12,799.0	11,659.0 - 14,257.4	19,936.8 - 61,899.2
7% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	33.0 - 239.8	32.8 - 230.5	4,341.9 - 1,399.0	4,325.8 - 1,713.8	4,435.7 - 3,719.9	5,299.1 - 6,955.8	9,644.8 - 7,510.5	9,543.2 - 16,715.0	37,656.3 - 38,484.2
Max Net Benefits (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 0.0	35.7 - 250.5	35.6 - 241.1	592.9 - 12,967.5	671.4 - 12,932.8	689.1 - 13,068.0	690.8 - 13,076.7	691.5 - 13,434.0	676.2 - 13,516.0	4,083.3 - 79,486.7
Max Net Benefits (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 0.0	35.7 - 250.5	35.6 - 241.1	35.5 - 5,338.1	35.4 - 5,342.0	36.3 - 5,412.8	35.9 - 5,427.5	36.8 - 5,599.8	4,327.7 - 5,642.3	4,578.9 - 33,254.0
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 45.8	35.7 - 299.2	35.6 - 288.3	519.8 - 13,443.1	517.6 - 13,387.7	1,253.5 - 13,468.4	1,254.9 - 13,461.2	1,304.3 - 13,837.1	5,116.0 - 13,920.2	10,037.3 - 82,151.1
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 45.8	35.7 - 299.2	35.6 - 288.3	519.8 - 13,443.1	517.6 - 13,387.7	1,253.5 - 13,468.4	1,254.9 - 13,461.2	1,304.3 - 13,837.1	5,116.0 - 13,920.2	10,037.3 - 82,151.1

Table 12f
Change in Electricity Consumption (in GW-h)
Passenger Cars and Light Trucks Combined
Undiscounted Over the Lifetime of the Model Year

Passenger Cars & Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	0.0 - 1,949.6	272.1 - 2,310.8	349.5 - 3,100.3	366.6 - 3,747.2	2,435.7 - 7,134.2	3,202.0 - 17,639.9	6,626.0 - 36,694.2
2% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 2,120.8	0.0 - 2,667.7	272.1 - 2,959.9	349.5 - 3,725.6	354.8 - 4,180.1	2,023.7 - 6,284.5	2,225.8 - 6,642.9	5,226.0 - 28,851.4
3% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	0.0 - 1,442.0	272.1 - 1,800.5	349.5 - 2,563.3	366.6 - 3,012.2	2,149.2 - 5,977.7	2,917.6 - 12,519.4	6,055.1 - 28,127.4
4% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	73.7 - 1,562.7	347.8 - 1,926.5	639.0 - 2,694.9	692.3 - 4,984.5	2,769.5 - 8,056.7	15,053.2 - 20,081.0	19,575.5 - 40,118.6
5% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	2,061.4 - 542.3	3,208.0 - 8,369.0	4,177.3 - 11,319.7	6,099.6 - 11,846.5	7,793.9 - 14,779.2	12,147.1 - 22,575.4	38,239.2 - 49,056.6	73,726.5 - 118,758.8
6% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	32.0 - 460.9	2,043.7 - 722.7	3,826.2 - 12,837.8	10,805.8 - 26,242.5	11,119.6 - 44,318.6	25,582.6 - 57,448.0	56,381.3 - 82,811.6	78,042.0 - 127,728.8	187,833.3 - 352,563.2
7% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	65.0 - 2,718.1	6,423.7 - 4,595.0	12,463.4 - 10,621.4	15,318.7 - 27,807.8	38,084.7 - 61,660.8	53,658.3 - 73,154.5	77,152.8 - 111,341.1	99,435.6 - 137,323.7	302,602.3 - 429,214.8
Max Net Benefits (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 1,312.3	67.8 - 2,057.2	11,534.4 - 11,182.0	14,999.0 - 28,318.9	15,536.9 - 29,290.8	16,737.6 - 30,759.0	17,826.8 - 32,171.5	24,443.0 - 37,874.5	29,709.4 - 42,097.6	130,854.7 - 215,063.6
Max Net Benefits (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 1,312.3	71.6 - 2,064.5	2,105.1 - 6,719.6	8,539.3 - 15,546.4	9,618.7 - 16,072.2	9,963.4 - 17,097.0	10,171.4 - 17,826.0	13,282.0 - 21,333.1	20,321.2 - 26,381.6	74,072.6 - 124,352.8
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 14,320.1	71.6 - 15,121.7	12,910.8 - 17,431.2	14,364.5 - 35,462.0	16,811.9 - 36,678.3	18,786.6 - 39,797.0	29,056.6 - 42,900.2	33,658.6 - 50,292.1	41,317.0 - 62,488.3	166,977.5 - 314,490.9
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 14,320.1	71.6 - 15,121.7	12,910.8 - 17,431.2	14,364.5 - 35,462.0	16,811.9 - 36,678.3	18,786.6 - 39,797.0	29,056.6 - 42,900.2	33,658.6 - 50,292.1	41,317.0 - 62,488.3	166,977.5 - 314,490.9

Breakdown of Costs and Benefits for the Preferred Alternative

Tables 13 and 14 provide breakdowns of the costs and benefits for the preferred alternative using a 3 percent and 7 percent discount rate, respectively.

Table 13
Preferred Alternative
Cost and Benefit Estimates, 3% Discount Rate
Passenger Cars and Light Trucks Combined
(Millions of 2010 Dollars)

	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Social Costs												
Technology Costs	2010 2008	($6,172) - ($3,654)	($3,722) - ($2,499)	($5,227) - ($4,589)	($8,256) - ($7,349)	($10,809) - ($11,059)	($14,033) - ($14,236)	($15,262) - ($16,447)	($16,883) - ($17,767)	($19,727) - ($20,552)	($20,015) - ($23,289)	($120,107) - ($121,441)
Maintenance Costs	2010 2008	($21) - ($0)	($13) - ($78)	($12) - ($228)	($237) - ($488)	($210) - ($592)	($551) - ($540)	($730) - ($689)	($946) - ($755)	($1,201) - ($800)	($1,303) - ($767)	($5,224) - ($4,939)
Congestion Costs	2010 2008	($917) - ($736)	($539) - ($447)	($779) - ($823)	($1,323) - ($1,291)	($1,669) - ($1,789)	($2,153) - ($2,198)	($2,390) - ($2,514)	($2,727) - ($2,743)	($3,097) - ($3,102)	($3,288) - ($3,440)	($18,881) - ($19,082)
Accident Costs	2010 2008	($419) - ($329)	($248) - ($204)	($355) - ($380)	($619) - ($602)	($785) - ($839)	($1,014) - ($1,036)	($1,125) - ($1,185)	($1,282) - ($1,291)	($1,455) - ($1,457)	($1,542) - ($1,618)	($8,843) - ($8,941)
Noise Costs	2010 2008	($17) - ($13)	($10) - ($8)	($14) - ($15)	($25) - ($24)	($31) - ($33)	($40) - ($41)	($44) - ($47)	($51) - ($51)	($58) - ($58)	($61) - ($64)	($351) - ($355)
Relative Value Loss (EVs)	2010 2008	$0 - $0	($0) - ($1)	($0) - ($5)	($0) - ($12)	($0) - ($40)	($4) - ($50)	($6) - ($59)	($7) - ($71)	($32) - ($110)	($42) - ($221)	($91) - ($570)
Total Social Costs	2010 2008	($7,545) - ($4,732)	($4,532) - ($3,239)	($6,388) - ($6,039)	($10,460) - ($9,765)	($13,504) - ($14,353)	($17,795) - ($18,100)	($19,558) - ($20,942)	($21,896) - ($22,677)	($25,569) - ($26,079)	($26,251) - ($29,401)	($153,497) - ($155,327)
Social Benefits												
Lifetime Fuel Expenditures (Pretax)	2010 2008	$22,020 - $16,856	$13,145 - $10,780	$18,750 - $20,246	$33,571 - $32,477	$42,751 - $45,654	$55,429 - $56,795	$61,476 - $65,088	$70,033 - $70,797	$79,580 - $79,981	$84,325 - $89,002	$481,078 - $487,675
Consumer Surplus from Additional Driving	2010 2008	$2,169 - $1,746	$1,255 - $1,037	$1,735 - $1,903	$3,063 - $2,995	$3,913 - $4,186	$5,083 - $5,141	$5,645 - $5,860	$6,484 - $6,429	$7,312 - $7,225	$7,774 - $8,006	$44,433 - $44,528

Refueling Time Value	2010 2008	$810 - $679	$472 - $421	$640 - $726	$1,045 - $1,105	$1,303 - $1,563	$1,625 - $1,936	$1,824 - $2,227	$2,055 - $2,384	$2,354 - $2,682	$2,450 - $2,893	$14,579 - $16,616
Petroleum Market Externalities	2010 2008	$1,227 - $938	$716 - $590	$1,010 - $1,099	$1,781 - $1,753	$2,242 - $2,449	$2,895 - $3,023	$3,193 - $3,442	$3,607 - $3,714	$4,079 - $4,175	$4,292 - $4,645	$25,042 - $25,826
Value of Reduced Fatalities	2010 2008	($10) - $41	$9 - $14	$12 - $39	($68) - $15	($39) - $81	$0 - $67	$5 - $86	$5 - $77	$38 - $100	$57 - $47	$9 - $568
CO2	2010 2008	$2,062 - $1,574	$1,257 - $1,030	$1,816 - $1,957	$3,298 - $3,176	$4,257 - $4,515	$5,585 - $5,694	$6,274 - $6,607	$7,233 - $7,267	$8,292 - $8,274	$8,870 - $9,226	$48,943 - $49,320
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$27 - $21	$16 - $13	$22 - $25	$40 - $40	$50 - $56	$68 - $69	$75 - $78	$84 - $85	$94 - $96	$100 - $110	$577 - $592
NOX	2010 2008	$60 - $47	$35 - $29	$50 - $53	$88 - $81	$110 - $111	$126 - $137	$140 - $156	$160 - $167	$180 - $183	$183 - $191	$1,132 - $1,154
PM	2010 2008	$344 - $265	$201 - $165	$284 - $306	$501 - $492	$632 - $681	$847 - $839	$929 - $952	$1,043 - $1,026	$1,168 - $1,147	$1,234 - $1,277	$7,183 - $7,150
SOX	2010 2008	$302 - $232	$177 - $146	$249 - $261	$441 - $413	$556 - $537	$710 - $666	$781 - $742	$883 - $787	$929 - $784	$955 - $542	$5,984 - $5,109
Total Social Benefits	2010 2008	$29,011 - $22,398	$17,281 - $14,224	$24,569 - $26,616	$43,759 - $42,546	$55,775 - $59,832	$72,369 - $74,366	$80,343 - $85,237	$91,587 - $92,733	$104,027 - $104,646	$110,241 - $115,940	$628,962 - $638,539
Net Total Benefits	2010 2008	$21,466 - $17,666	$12,748 - $10,986	$18,181 - $20,576	$33,299 - $32,781	$42,271 - $45,479	$54,574 - $56,266	$60,785 - $64,295	$69,691 - $70,056	$78,458 - $78,568	$83,990 - $86,539	$475,465 - $483,211

Table 14
Preferred Alternative
Cost and Benefit Estimates, 7% Discount Rate
Passenger Cars and Light Trucks Combined
(Millions of 2010 Dollars)

	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Social Costs												
Technology Costs	2010 2008	($6,172) - ($3,654)	($3,722) - ($2,499)	($5,227) - ($4,589)	($8,256) - ($7,349)	($10,809) - ($11,059)	($14,033) - ($14,236)	($15,262) - ($16,447)	($16,883) - ($17,767)	($19,727) - ($20,552)	($20,015) - ($23,289)	($120,107) - ($121,441)
Maintenance Costs	2010 2008	($15) - ($0)	($10) - ($58)	($9) - ($170)	($177) - ($365)	($156) - ($441)	($410) - ($402)	($543) - ($513)	($704) - ($562)	($894) - ($595)	($974) - ($571)	($3,892) - ($3,677)
Congestion Costs	2010 2008	($724) - ($581)	($426) - ($353)	($615) - ($650)	($1,044) - ($1,019)	($1,317) - ($1,412)	($1,698) - ($1,734)	($1,884) - ($1,983)	($2,149) - ($2,162)	($2,441) - ($2,445)	($2,591) - ($2,711)	($14,889) - ($15,049)
Accident Costs	2010 2008	($330) - ($260)	($196) - ($161)	($281) - ($300)	($489) - ($475)	($619) - ($662)	($799) - ($817)	($886) - ($934)	($1,010) - ($1,017)	($1,146) - ($1,148)	($1,214) - ($1,274)	($6,969) - ($7,047)
Noise Costs	2010 2008	($13) - ($11)	($8) - ($6)	($11) - ($12)	($19) - ($19)	($25) - ($26)	($32) - ($32)	($35) - ($37)	($40) - ($40)	($45) - ($45)	($48) - ($50)	($277) - ($280)
Relative Value Loss (EVs)	2010 2008	$0 - $0	($0) - ($1)	($0) - ($2)	($0) - ($5)	($0) - ($18)	($2) - ($22)	($3) - ($26)	($3) - ($31)	($14) - ($48)	($18) - ($96)	($40) - ($247)
Total Social Costs	2010 2008	($7,255) - ($4,505)	($4,361) - ($3,080)	($6,144) - ($5,723)	($9,986) - ($9,232)	($12,926) - ($13,618)	($16,974) - ($17,242)	($18,614) - ($19,939)	($20,789) - ($21,578)	($24,266) - ($24,833)	($24,860) - ($27,991)	($146,174) - ($147,740)
Social Benefits												
Lifetime Fuel Expenditures (Pretax)	2010 2008	$17,208 - $13,183	$10,280 - $8,431	$14,672 - $15,825	$26,221 - $25,369	$33,386 - $35,651	$43,261 - $44,319	$47,965 - $50,770	$54,624 - $55,213	$62,054 - $62,367	$65,738 - $69,369	$375,407 - $380,498
Consumer Surplus from Additional Driving	2010 2008	$1,696 - $1,367	$983 - $812	$1,361 - $1,491	$2,396 - $2,344	$3,060 - $3,275	$3,970 - $4,017	$4,405 - $4,574	$5,057 - $5,015	$5,700 - $5,634	$6,055 - $6,237	$34,684 - $34,765
Refueling Time Value	2010 2008	$640 - $537	$373 - $333	$506 - $573	$825 - $872	$1,028 - $1,233	$1,283 - $1,527	$1,440 - $1,757	$1,622 - $1,881	$1,859 - $2,117	$1,934 - $2,283	$11,509 - $13,112
Petroleum Market Externalities	2010 2008	$968 - $741	$565 - $465	$798 - $867	$1,404 - $1,382	$1,767 - $1,930	$2,282 - $2,383	$2,517 - $2,713	$2,843 - $2,928	$3,216 - $3,291	$3,384 - $3,662	$19,744 - $20,363
Value of Reduced Fatalities	2010 2008	($9) - $32	$7 - $10	$9 - $30	($54) - $11	($32) - $63	($1) - $52	$3 - $66	$2 - $60	$28 - $77	$43 - $37	($3) - $438

CO2	2010 2008	$2,062 - $1,574	$1,257 - $1,030	$1,816 - $1,957	$3,298 - $3,176	$4,257 - $4,515	$5,585 - $5,694	$6,274 - $6,607	$7,233 - $7,267	$8,292 - $8,274	$8,870 - $9,226	$48,943 - $49,320
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$22 - $17	$13 - $11	$18 - $20	$32 - $32	$40 - $45	$54 - $55	$60 - $63	$67 - $68	$76 - $76	$80 - $88	$462 - $473
NOX	2010 2008	$49 - $38	$29 - $24	$41 - $43	$72 - $66	$90 - $90	$104 - $112	$115 - $127	$132 - $136	$148 - $149	$151 - $154	$929 - $938
PM	2010 2008	$276 - $212	$161 - $132	$228 - $245	$401 - $394	$507 - $546	$676 - $672	$742 - $763	$833 - $822	$934 - $918	$986 - $1,018	$5,743 - $5,722
SOX	2010 2008	$239 - $183	$139 - $115	$197 - $206	$348 - $326	$439 - $423	$560 - $524	$616 - $584	$696 - $620	$732 - $617	$753 - $426	$4,717 - $4,024
Total Social Benefits	2010 2008	$23,152 - $17,884	$13,805 - $11,363	$19,643 - $21,258	$34,942 - $33,970	$44,542 - $47,770	$57,774 - $59,354	$64,137 - $68,024	$73,110 - $74,009	$83,037 - $83,521	$87,994 - $92,499	$502,136 - $509,653
Net Total Benefits	2010 2008	$15,897 - $13,379	$9,444 - $8,284	$13,500 - $15,535	$24,957 - $24,739	$31,616 - $34,152	$40,800 - $42,112	$45,523 - $48,085	$52,320 - $52,431	$58,771 - $58,689	$63,135 - $64,507	$355,963 - $361,913

Cumulative Impacts

Table 15 shows the cumulative impacts of the fuel economy rules from MY 2011 through MY 2025 compared to a MY 2010 baseline. The baseline is assumed to be the MY 2010 standards of 27.5 mpg for passenger cars and 23.5 mpg for light trucks. We did not add the estimates from previous analyses of MY 2011 and MY 2012 - 2016 rulemakings to this FRIA analysis for 2017-2025. These estimates are all from the most up-to-date current analysis using the 2010 baseline fleet. The costs and benefits are not the same as shown throughout the rest of the analysis, since the baseline assumes that the 2010 standards would continue, whereas the rest of the analysis starts with the MY 2016 standards.

Table 15
Cumulative Impacts of All Fuel Economy Standards
From MY 2011-2025

	Passenger Cars	Light Trucks	Combined
Baseline Required mpg in MY 2010	27.5	23.5	25.9
Achieved mpg with AC in MY 2025	52.1	37.6	46.2
Consumer Cost[19] - MY 2025 vs. MY 2010 vehicle (per vehicle)	($1,885)	($1,903)	($1,891)
Lifetime Fuel Savings - MY 2025 vs. MY 2010 vehicle (per vehicle) Discounted at 3%	$8,906	$12,341	$10,033
Lifetime Fuel Savings - MY 2025 vs. MY 2010 vehicle (per vehicle) Discounted at 7%	$6,986	$9,558	$7,830
Net Consumer Savings (per vehicle) Discounted at 3%	$7,021	$10,438	$8,142
Net Consumer Savings (per vehicle) Discounted at 3%	$5,101	$7,655	$5,939
Total technology costs – All	($151.4)	($93.2)	($244.6)

[19] Includes technology costs and fines

model years 2011 through 2025 (Billions of 2010 dollars)			
Total fuel savings – Over the lifetime of All model years 2011 through 2025 (Billions of Gallons)	251	186	437
Total CO_2 savings – Over the lifetime of All model years 2011 through 2025 (Billions of Metric Tons)	2.7	2.0	4.7
Net savings – All model years 2011 through 2025 (Billions of 2010 dollars) Discounted at 3%	733	558	1,291
Net savings – All model years 2011 through 2025 (Billions of 2010 dollars) Discounted at 7%	558	424	982

I. INTRODUCTION

The purpose of this study is to analyze the effects of extending the National Program of Federal and corporate average fuel economy (CAFE) standards to model years (MYs) 2017 and beyond for passenger cars and light trucks. This study includes a discussion of the technologies that can improve fuel economy, the potential impacts on retail prices, safety, the discounted lifetime net benefits of fuel savings, and the potential gallons of fuel saved, among other things.

EPA and NHTSA, on behalf of the Department of Transportation, are issuing final rules to further reduce greenhouse gas emissions and improve fuel economy for light-duty vehicles for model years 2017 and beyond. On May 21, 2010, President Obama issued a Presidential Memorandum requesting that NHTSA and EPA develop through notice and comment rulemaking a coordinated National Program to improve fuel economy and reduce greenhouse gas emissions of light-duty vehicles for model years 2017-2025, building on the success of the first phase of the National Program for these vehicles for model years 2012-2016[20]. This Final Rule, consistent with the President's request, responds to the country's critical need to address global climate change and to reduce oil consumption. NHTSA is finalizing Corporate Average Fuel Economy standards for model years 2017-2021 and issuing augural[21] standards for model years 2022-2025 under the Energy Policy and Conservation Act, as amended by the Energy Independence and Security Act. EPA is finalizing greenhouse gas emissions standards for model years 2017-2025 under the Clean Air Act. These standards apply to passenger cars, light-duty trucks, and medium-duty passenger vehicles, and represent the continuation of a harmonized and consistent National Program. Under the National Program automobile manufacturers will be

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[20] Final Rule published in the Federal Register on May 7, 2010 (75FR 25324).

[21] For the NPRM/PRIA/Draft EIS, NHTSA described the proposed standards for MYs 2022-2025 as "conditional." "Conditional" was understood and objected to by some readers as implying that the future proceeding would consist merely of a confirmation of the conclusions and analysis of the current rulemaking, which would be incorrect and inconsistent with the agency's obligations under both EPCA/EISA and the Administrative Procedures Act. The agency must conduct a de novo rulemaking for model years 2022-2025. To avoid creating an incorrect impression, the agency is changing the descriptor for the 2022-2025 standards that are presented and discussed in these documents. The descriptor must convey that the standards we are now presenting for MYs 2022-2025 reflect the agency's current estimate of what we would have set at this time had we the authority to do so, but also avoid suggesting that the future process for establishing final standards for 2022-2025 would be anything other than a rulemaking based on a totally white-sheet-of-paper evaluation looking at all of the freshly gathered and solicited information before the agency at that future time and reflecting a fresh balancing of all statutorily relevant factors, in light of the considerations existing at the time of the evaluation. The agency deliberated extensively, considering many alternative descriptors, and concluded that the best descriptor was "augural," from the verb "to augur," meaning to foretell future events based on current information (as in, "these standards may augur well for what the agency might establish in the future"). This is precisely what the MYs 2022-2025 standards presented in these documents are – our best estimate of what we would set, based on the information before us today, but knowing that future information and thus our future decision may just as well be different as not.

able to continue building a single light-duty national fleet that satisfies all requirements under both programs while ensuring that consumers still have the full range of vehicle choices that are available today.

Continuing the National Program would ensure that all manufacturers can build a single fleet of U.S. vehicles that would satisfy all requirements under both programs as well as under California's program, helping to reduce costs and regulatory complexity while providing significant energy security and environmental benefits. President Obama announced plans for these rules on July 29, 2011 and NHTSA and EPA issued a Supplemental Notice of Intent (NOI) outlining the agencies' plans for proposing the MY 2017-2025 standards and program.[22] The State of California and thirteen auto manufacturers representing over 90 percent of U.S. vehicle sales provided letters of support for the program concurrent with the Supplemental NOI.[23] The United Auto Workers (UAW) also supported the announcement.[24]

In a notice of proposed rulemaking (NPRM)[25], NHTSA proposed CAFE standards and EPA Proposed greenhouse gas (GHG) emissions standards for MYs 2017-2025. Supporting that NPRM was a Preliminary Regulatory Impact Analysis.[26] These standards take into consideration significant public input that was received in response to the NPRM from the regulated industry, consumer groups, labor unions, states, environmental organizations, a military security non-profit organization, industry suppliers and dealers, as well as other organizations and by thousands of U.S. citizens.

One aspect of this phase of the National Program that is unique for NHTSA, however, is that the passenger car and light truck CAFE standards for MYs 2022-2025 are augural, while EPA's (and also California's) standards for those model years will be legally binding. Consistent with its statutory authority, NHTSA is establishing two phases of passenger car and light truck standards for MYs 2017-2025 in this rulemaking action. The first phase, from MYs 2017-2021, includes final standards that are required. The second phase of the CAFE program, from MYs 2022-2025, includes standards that are not final due to the statutory provision that NHTSA shall issue regulations prescribing average fuel economy standards for at least 1 but not more than 5 model years at a time. The MYs 2022-2025 CAFE standards, then, are not final based on this rulemaking, but rather are augural, meaning that they represent the agency's current best estimate, based on the information available to the agency today, of what levels of stringency might be maximum feasible in those model years. NHTSA notes that these estimated combined

[22] 76 FR 48758 (August 9, 2011).
[23] Commitment letters are available at http://www.nhtsa.gov/fuel-economy (last accessed Aug. 24, 2011).
[24] The UAW's support was expressed in a statement on July 29, 2011, which can be found at http://www.uaw.org/articles/uaw-supports-administration-proposal-light-duty-vehicle-cafe-and-greenhouse-gas-emissions-r (last accessed September 19, 2011)
[25] 76 FR 74854, December 1, 2011, also in NHTSA Docket No. 2010 -0131-0183.
[26] "Preliminary Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2017-2025 Passenger Cars and Light Trucks", November 2011, NHTSA Docket No. 2010-0131-0167

fleet average mpg levels are projections and, in fact NHTSA establishes separate standards for passenger cars and trucks, based on a vehicle's size or "footprint," and the actual average achieved fuel economy and GHG emissions levels are determined by the actual footprints and production volumes of the vehicle models that are produced.

NHTSA will undertake a de novo rulemaking at a later date to set legally binding standards for MYs 2022-2025. Concurrent with that de novo rulemaking, the agencies intend to conduct a comprehensive mid-term evaluation and agency decision-making process for the MYs 2022-2025 standards. The mid-term evaluation reflects the rules' long time frame and, for NHTSA, the agency's statutory obligation to conduct a separate rulemaking in order to establish final standards for vehicles for those model years.

NHTSA examined regulatory alternatives in two ways. First, we examined these alternatives considering how maximum feasible standards can be set within the limitations of EPCA/EISA. In conducting this "estimated required" or "standard setting" analysis, NHTSA assumes manufacturers *do not* use dedicated alternative fuel vehicles, electric vehicles, plug-in electric vehicles, dual-fueled alternative fuel vehicles (through MY 2020), or credits earned for over-compliance to meet the required mpg levels, as directed by 49 U.S.C. 32902(h).

Second, we conducted more of a real-world analysis of what manufacturers are likely to do under CAFE standards and taking advantage of flexibilities and adjustments offered under CAFE standards, as actually provided by EPCA/EISA. In conducting this "projected achieved" or "real world under EPCA/EISA" analysis, NHTSA assumes manufacturers *will* use dedicated alternative fuel vehicles, electric vehicles, plug-in electric vehicles, dual-fueled alternative fuel vehicles (for all model years), and flexibilities allowed in the final rule and credits earned for over-compliance to meet the required mpg levels.

Under both types of analysis, NHTSA assumes some manufacturers will continue, as they have done historically, not to meet the standards and instead pay civil penalties for non-compliance, as permitted by EPCA. NHTSA also assumes manufacturers will apply A/C efficiency improvements and off-cycle technology improvements to meet the standards.

The analysis contained in this document reflects the impacts that NHTSA believes would result from manufacturers increasing the fuel economy of their vehicles in order to meet the stringency levels required or projected to be achieved under the different regulatory alternatives. When the agency was examining issues that relate to standard setting, then the analysis is based on the "estimated required" mpg levels. Thus, analyses in Chapter V on technology relate to the amount of technology needed to get to the "estimated required" mpg level. Analyses in Chapter X relating to Sensitivity Analyses and Chapter XI on probabilistic uncertainties relate to the "estimated required" mpg level. However, estimates of the levels to be achieved by manufacturers (Chapter VI), costs and sales (Chapter VII), benefits and fuel savings (Chapter VIII), impact of weight reduction on safety (Chapter IX),and net benefits (Chapter X) are based on the more real world “projected achieved” mpg levels that are more likely to be achieved by the manufacturers.

II. NEED OF THE NATION TO CONSERVE ENERGY

The Energy Policy and Conservation Act (EPCA) states that:

> "When deciding maximum feasible average fuel economy … the Secretary of Transportation shall consider technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy."[27]

Thus, EPCA specifically directs the Department to balance the technological and economic challenges related to fuel economy with the Nation's need to conserve energy. The concerns about energy security and the effects of energy prices and supply on National economic well-being that led to the enactment of EPCA persist today. The demand for petroleum grew in the U.S. up through the year 2005, peaking at 20.8 million barrels per day, and has since declined to an average of 19.2 million barrels per day in 2010.[28] World demand, however, is expected to continue to rise until 2035.[29]

Since 1970, there have been a series of events that suggest that the behavior of petroleum markets is a matter for public concern.

- Average annual crude oil prices rose from $68 per barrel in 2007 to $95 per barrel in 2008, having peaked at $129 per barrel in July 2008. Prices declined to $37 per barrel in January 2009, but then rose to $113 per barrel in April 2011.[30] As recently as 1998, crude prices averaged about $13 per barrel.[31] Gasoline prices more than tripled during this ten-year period, from an annual average of $1.07 in 1998 to $3.30 in 2008. As the price of oil fluctuates, the price of gasoline also rises and falls, hitting an average of $3.96 in April of 2012.[32]

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[27] 49 U.S.C. § 32902(f)

[28] U.S. Department of Energy, Energy Information Administration, *International Energy Statistics,* Total Petroleum Consumption. *See* http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=5&aid=2 (last accessed, May 16, 2012).

[29] U.S Department of Energy, Energy Information Administration, *International Energy Outlook 2011*. *See* http://www.eia.gov/oiaf/ieo/highlights.html (last accessed May 16, 2012).

[30] U.S. Department of Energy, Energy Information Administration, *Short-Term Energy Outlook*, U.S. Refiner Average Acquisition Cost per Barrel of Crude Oil. *See* http://www.eia.gov/emeu/steo/pub/cf_query/index.cfm (last accessed May 16, 2012).

[31] *Ibid.*

[32] U.S. Department of Energy, Energy Information Administration, *Weekly Retail and Gasoline Diesel Prices*. *See* http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_m.htm (last accessed, May 16, 2012).

- U.S. domestic petroleum production stood at 10 million barrels per day in 1975, rose slightly to 10.6 million barrels per day in 1985, and by 2009 had declined to 7.3 million barrels per day.[33] Domestic production is predicted to increase through 2020, after which it is projected to decrease through 2035, although remaining above current levels.[34] Between 1975 and 2005, U.S. petroleum consumption increased from 16.3 million barrels per day to 20.8 million barrels per day.[35] In 2009, vehicle miles traveled and consumption fell compared to the 2005 levels. Net petroleum imports accounted for 51.5 percent of U.S. domestic petroleum consumption in 2009.[36] Worldwide oil demand is fairly inelastic: declining prices do not induce large increases in consumption, while higher prices do not significantly restrain consumption. For example, the price of unleaded regular gasoline rose from an average of $2.57 in 2006 to $3.25 in 2008 (a 26.5 percent increase)[37] and vehicle miles traveled decreased by 1.3 percent.[38] Within the United States, demand for gasoline, diesel, and jet fuel within the transportation sector is particularly inelastic.
- Demand for oil is projected to increase significantly worldwide in the next several decades, resulting in upward oil cost pressure. Between 2007 and 2035, total world petroleum consumption is expected to grow from 85.9 to 112.2 million barrels per day.[39]
- Foreign oil production facilities, refineries, and supply chains have been disrupted from time to time, either by wars, political action by oil producers, civil unrest, or natural disasters.
- High oil prices, sometimes induced by disruptions in oil markets, have often coincided with rising inflation and subsequent economic recessions.
- Greenhouse gas emissions from the consumption of petroleum have become a subject of increasing public policy concern, both in the United States and internationally. Greenhouse gases in general and carbon dioxide were first regulated in the United States in the joint EPA and NHTSA greenhouse gas emissions and improve fuel economy rulemaking for model years 2012-2016 light-duty vehicles.[40] In addition, EPA and NHTSA have finalized rules for greenhouse gas emissions and fuel efficiency of model years 2014-2018 medium- and heavy-duty engines and vehicles.[41] Studies by multiple sources suggest that rising atmospheric concentrations of greenhouse gases will damage

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[33] U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review, April 2012*. *See* http://www.eia.gov/totalenergy/data/monthly/pdf/sec3_3.pdf (last accessed May 16, 2012).
[34] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2012 Early Release*, Table A11. *Available at* http://www.eia.gov/forecasts/aeo/er/pdf/tbla11.pdf (last accessed May 16, 2012).
[35] U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review, April 2012*. *See* http://www.eia.gov/totalenergy/data/monthly/pdf/sec3_7.pdf (last accessed May 16, 2012).
[36] *Ibid.*
[37] U.S. Department of Energy, Energy Information Administration, *Weekly Retail and Gasoline Diesel Prices*. *See* http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_nus_m.htm (last accessed, May 16, 2012).
[38] U.S. Department of Transportation, Federal Highway Administration, Office of Highway Policy Information, *Quick Find: Vehicle Miles of Travel*, Table VM-2 (2006 and 2008). *Available at* http://www.fhwa.dot.gov/policyinformation/quickfinddata/qftravel.cfm (last accessed May 16, 2012).
[39] U.S. Department of Energy, Energy Information Administration, *International Energy Outlook 2011*, Table A5. *Available at* http://www.eia.gov/forecasts/ieo/pdf/ieoreftab_5.pdf (last accessed May 16, 2012).
[40] Final Rule published in the Federal Register on May 7, 2010 (75FR 25324).
[41] Final Rule published in the Federal Register on September 15, 2011 (76FR 57106).

> human health and welfare.[42] There is a direct linkage between the consumption of fossil energy and emissions of the greenhouse gas carbon dioxide, as essentially all of the carbon in hydrocarbon fuels is oxidized into carbon dioxide when the fuel is combusted. Reducing U.S. fossil petroleum consumption will generally induce a proportional reduction in carbon dioxide emissions.

Energy is an essential input to the U.S. economy, and having a strong economy is essential to maintaining and strengthening our National security. Secure, reliable, and affordable energy sources are fundamental to economic stability and development. Rising energy demand poses a challenge to energy security, given increased reliance on global energy markets. As noted above, approximately half of the petroleum consumed in the U.S. is imported.

Conserving energy, especially reducing the Nation's dependence on petroleum, benefits the U.S. in several ways. Improving energy efficiency has benefits for economic growth and the environment, as well as other benefits, such as reducing pollution and improving security of energy supply. More specifically, reducing total petroleum use decreases our economy's vulnerability to oil price shocks. Reducing dependence on oil imports from regions with uncertain conditions enhances our energy security and can reduce the flow of oil profits to certain states now hostile to the U.S.

These final CAFE standard for MYs 2017-2021 and augural standards for MYs 2022-2025 encourage conservation of petroleum for transportation by the application of broader use of fuel saving technologies, resulting in more fuel-efficient vehicles, *i.e.*, vehicles requiring less fuel consumption per unit mile.

Table II-1 presents historical trend data and projections of the production and consumption of petroleum. Increases in domestic petroleum production are expected through 2025 as technological advances further the economic recoverability of oil from conventional and unconventional resources. Despite the projected increase in domestic production, by 2035 the U.S. is expected to remain reliant on foreign sources for over 36 percent of its oil needs.

Although not shown in Table II-1, the U.S. petroleum consumption is equivalent to U.S. petroleum supply. The Energy Information Administration's measure of U.S. petroleum supply exceeds the sum of domestic production and net imports because the EIA's measure of total supply includes renewable fuel and oxygenate plant net production, refinery and blender net production, changes in suppliers' reserve stocks, and adjustments for crude oil, fuel ethanol,

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[42] IPCC 2007: Climate Change 2007: Synthesis Report: Contributions of Working Groups I, II, and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, [Core writing team, Pachauri, R.K. and Reisinger, A. 9eds.)] (Published by the Intergovernmental Panel on Climate Change, 2008). A*vailable at* http://www.ipcc.ch/pdf/assessment-report/ar4/syr/ar4_syr.pdf (last accessed May 16, 2012).

motor gasoline blending components, and distillate fuel oil.

Table II-1
Petroleum Production and Supply
(Million Barrels per Day)

	Domestic Petroleum Production [43]	**Net Petroleum Imports**[44]	**U.S. Petroleum Consumption** [45]	**World Petroleum Consumption** [46]	**Net Imports as a Share of U.S. Consumption** [47]
1975	10.0	5.8	16.3	56.2	35.8%
1985	10.6	4.3	15.7	60.1	27.3%
1995	8.3	7.9	17.7	70.1	44.5%
2005	6.9	12.5	20.8	84.1	60.3%
2010	7.5	9.4	19.2	85.7	49.2%
DOE Predictions[48, 49]					
2015	8.8	8.2	19.2	93.3	42.7%
2025	9.2	7.4	19.5	103.2	37.9%
2035	8.9	7.3	20.1	112.2	36.3%

[43] U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review, April 2012*. *See* http://www.eia.gov/totalenergy/data/monthly/pdf/sec3_3.pdf (last accessed May 16, 2012).
[44] *Ibid.*
[45] *Ibid.*
[46] U.S. Department of Energy, Energy Information Administration, *International Energy Statistics,* Total Petroleum Consumption. *See* http://www.eia.gov/cfapps/ipdbproject/IEDIndex3.cfm?tid=5&pid=5&aid=2 (last accessed, May 16, 2012).
[47] U.S. Department of Energy, Energy Information Administration, *Monthly Energy Review, April 2012*. *See* http://www.eia.gov/totalenergy/data/monthly/pdf/sec3_7.pdf (last accessed May 16, 2012).
[48] Source of Predictions of Domestic Petroleum Production, Net Petroleum Imports, and U.S. Petroleum Consumption: U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2012 Early Release*, Table A11. *Available at* http://www.eia.gov/forecasts/aeo/er/pdf/tbla11.pdf (last accessed May 16, 2012).
[49] Source of Predictions of World Petroleum Consumption: U.S. Department of Energy, Energy Information Administration, *International Energy Outlook 2011*, Table A5. *Available at* http://www.eia.gov/forecasts/ieo/pdf/ieoreftab_5.pdf (last accessed May 16, 2012).

Table II-2 shows that light vehicle petroleum consumption made up 74.1 percent of all transportation petroleum consumption in 2009. Therefore, reductions in light vehicle petroleum consumption resulting from increases in CAFE fuel economy standards will substantively support the Nation's efforts to conserve energy.

Table II-2

Petroleum

Transportation Consumption by Mode

(Thousand Barrels per Day)[50]

	Passenger Cars	**Light Trucks**	**Total Light Vehicles**	**Total Transportation**	**Light Vehicles as % of Trans.**
1975	4,836	1,245	6,081	8,472	71.8%
1985	4,665	1,785	6,450	9,536	67.6%
1995	4,440	2,975	7,415	11,346	65.4%
2005	5,050	3,840	8,890	14,020	63.4%
2009	4,662	4,019	8,681	11,708	74.1%

[50] U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, *Transportation Energy Data Book,* Table 1.13. *Available at* http://cta.ornl.gov/data/chapter1.shtml (last accessed May 16, 2012).

III. BASELINE AND ALTERNATIVES

A. The Baseline Vehicle Fleet

1. Why establish a baseline vehicle fleet?

In order to calculate the impacts of the final rule, it is necessary to estimate the composition of the future vehicle fleet absent the new standards. EPA and NHTSA have developed a baseline/reference fleet in three steps. The first step was to develop a “baseline” fleet. The agencies create a baseline fleet in order to track the volumes and types of fuel economy-improving and CO_2-reducing technologies that are already present in the existing vehicle fleet. Creating a baseline fleet helps to keep, to some extent, the agencies’ models from adding technologies to vehicles that already have these technologies, which would result in “double counting” of technologies’ costs and benefits. The second step was to project the baseline fleet sales into MYs 2017-2025. This is called the “reference” fleet, and it represents the fleet volumes (but, until later steps, not additional levels of technology) that the agencies believe would exist in MYs 2017-2025 absent any change due to regulation in 2017-2025. The third step was to add technologies to that fleet such that each manufacturer’s average car and truck CO_2 levels are in compliance with MY 2016 CAFE standards, assuming that manufacturers would not make fuel economy improvements beyond what is required by the MY 2016 standards. This final “reference case” is the light duty fleet estimated to exist in MYs 2017-2025 without the final CAFE standards. All of the agency’s estimates of fuel economy improvements, costs, and societal impacts are developed in relation to the respective reference cases.

2. Why did the agencies develop two fleet projections for the final rule?

Although much of the discussion in this and following sections describes the methodology for creating a single baseline and reference fleet, for this final rule the agencies actually developed two baseline and reference fleets. In the NPRM, the agencies used 2008 MY CAFE certification data to establish the “2008-based fleet projection.”[51] The agencies noted that MY 2009 CAFE

[51] 2008 based fleet projection is a new term that is the same as the reference fleet. The term is added to clarify when we are using the 2008 baseline and reference fleet vs. the 2010 baseline and reference fleet.

certification data was not likely to be representative since it was so dramatically influenced by the economic recession (Joint Draft TSD section 1.2.1). The agencies further noted that MY 2010 CAFE certification data might be available for use in the final rulemaking for purposes of developing a baseline fleet (id.). The agencies also stated that a copy of the MY 2010 CAFE certification data would be put in the public docket if it became available during the comment period. The MY 2010 data was reported by the manufacturers throughout calendar year 2011 as the final sales figures were compiled and submitted to the EPA database. Due to the lateness of the CAFE data submissions[52], it was not possible to submit the new 2010 data into the docket during the public comment period. As explained below, however, consistent with the agencies' expectations at proposal, and with the agencies' standard practice of updating relevant information as practicable between proposals and final rules, the agencies are using these data in one of the two fleet-based projections we are using to estimate the impacts of the final rules.

For analysis supporting the NPRM, the agencies developed a forecast of the light vehicle market through MY 2025 based on (a) the vehicle models in the MY 2008 CAFE certification data, (b) the AEO2011 interim projection of future fleet sales volumes, and (c) the future fleet forecast conducted by CSM in 2009. In the proposal, the agencies stated we planned to use MY 2010 CAFE certification data, if available, for analysis supporting the final rule (Joint Draft TSD, p. 1-2). The agencies also indicated our intention to, for analysis supporting the final rule, use the most recent version of EIA's AEO, and a market forecast updated relative to that purchased from CSM (Joint Draft TSD section 1.3.5).

For this final rulemaking, the agencies have analyzed the costs and benefits of the standards using two different forecasts of the light vehicle fleet through MY 2025. The agencies have concluded that the significant uncertainty associated with forecasting sales volumes, vehicle technologies, fuel prices, consumer demand, and so forth out to MY 2025, makes it reasonable and appropriate to evaluate the impacts of the final CAFE and GHG standards using two baselines. One market forecast, similar to the one used for the NPRM, uses corrected data regarding the MY2008 fleet, information from AEO 2011, and information purchased from CSM. The agencies received comments regarding the market forecast used in the NPRM suggesting that updates in several respects could be helpful to the agencies' analysis of final standards; given those comments and since the agencies were already planning to produce an updated market forecast, the final rule also contains another market forecast using MY 2010 CAFE certification data, information from AEO 2012, and information purchased from LMC Automotive (formerly JD Powers Forecasting).

[52] Partly due to the earthquake and tsunami in Japan and the significant impact this had on their facilities, some manufacturers requested and were granted an extension on the deadline to submit their CAFE data.

Thus, given the volume of information that goes into creating a baseline forecast and given the significant uncertainty in any projection out to MY 2025, the agencies think that a reasonable way to illustrate the possible impacts of that uncertainty for purposes of this rulemaking is the approach taken here of analyzing the effects of the final standards under both the MY 2008-based baseline and the MY 2010-based baseline.

3. How was the 2008-based vehicle fleet developed?

The baseline that EPA developed in consultation with NHTSA for the 2012-2016 final rule was comprised of model year 2008 CAFE compliance data (specifically, individual vehicles with sales volumes disaggregated at the level of specific engine/transmission combinations) submitted by manufacturers to EPA, in part because full MY 2009 data was not available at the time. For this NPRM, the agencies chose again to use MY 2008 vehicle data as the basis of the baseline fleet, but for different reasons than in the 2012-2016 final rule. First, when the NPRM was issued, MY 2008 was the most recent model year for which the industry had what the agencies would consider "normal" sales levels. Complete MY 2009 data was available for the industry, but in the agencies' judgment, that model year was disrupted by the economic downturn and the bankruptcies of both General Motors and Chrysler. CAFE compliance data shows that there was a significant reduction in the number of vehicles sold by both companies and by the industry as a whole. These abnormalities led the agencies to conclude that MY 2009 data was likely not representative for projecting the future fleet for purposes of this analysis. And second, while MY 2010 data is likely more representative for projecting the future fleet, it was not complete and available in time for it to be used for the NPRM analysis. Therefore, for purposes of the NPRM analysis, the agencies chose to use MY 2008 CAFE compliance data for the baseline since it was the latest, most representative transparent data set that we had available. More details about how the agencies constructed this baseline fleet can be found in Chapter 1.3 of the Joint TSD.

Between the NPRM and the final rule, the agencies found discrepancies in footprint values for a number of vehicles in the MY 2008 CAFE certification data. Specifically, contractors to DOT employed to develop a market share model for incorporation into the CAFE model noted that out of 1,302 vehicles in the MY 2008-based input file used in the agencies' NPRM analysis, in 554 cases, the wheelbase value in the CAFE certification data did not match wheelbase data from Ward's Automotive that the contractor had obtained separately. While wheelbase is not a direct input to the models used in developing the standards, it is a component of footprint, which is a key input in the modeling process.

Of the reported differences, 287 (51.8%) were less than or equal to 0.1 inch, and 115 (20.8%) were greater than 0.1 inch but less than or equal to 0.5 inch. The former set of differences is most likely attributable to differences in the number of significant digits in the reported raw data. The latter set of differences may also be due to reporting differences or actual measurement differences, but would not have a significant impact on the computed footprint value, all other things being equal. These differences were not considered further.

Of the remaining differences, 14 (2.5%) were greater than 0.5 inch but less than 1 inch. Most significantly, 138 (24.9%) of the differences were greater than 1 inch, ranging in value from 1.1 inch to 23.8 inches.

To verify these findings, the Ward's data used by the contractor on wheelbase for the 152 vehicles with a discrepancy greater than 0.5 inches were compared to wheelbase data from Edmunds, cars.com, Motor Trend, and product plans where available, and values reflecting the agencies' best judgment about actual average values was selected.

As discussed further in the joint TSD, footprint for the 152 vehicles was thus recalculated based on corrected wheelbase. In the process of validating the wheelbase data, the agencies noted that there were many discrepancies in the track width values, which the agencies also corrected in the calculation of the corrected footprints.

The baseline vehicle fleet for the analysis informing these final rules is the same except for the footprint changes to the baseline vehicle fleet used in the MYs 2012-2016 rulemaking, and like that baseline, is comprised of publicly-available data to the largest extent possible. Some of the technology data included in the MYs 2012-2016 analysis' baseline fleet was based on confidential product plan information about MY 2008 vehicles, specifically, data about which vehicles already have low friction lubricants, electric power steering, improved accessories, and low rolling resistance tires applied, the agencies no longer consider that information as needing to be withheld, because by now all MY 2008 vehicle models are already in the on-road fleet. As a result, the agencies are able to make public the exact baseline used in this rulemaking analysis.

4. How was the projected MY 2017-2025 fleet (the MY2008-based reference fleet) developed?

EPA and NHTSA have based the projection of total car and total light truck sales for MYs 2017-2025 on projections made by the Department of Energy's Energy Information Administration (EIA). EIA publishes a mid-term projection of national energy use called the Annual Energy Outlook (AEO). This projection utilizes a number of technical and econometric models which are designed to reflect both economic and regulatory conditions expected to exist in the future. In support of its projection of fuel use by light-duty vehicles, EIA projects sales of new cars and light trucks.

EPA and NHTSA have based the projection of total car and light truck sales projections available made by the Energy Information Administration (EIA). EIA publishes a projection of national energy use annually called the Annual Energy Outlook (AEO).[53] EIA published its Early Annual Energy Outlook for 2011 in December 2010. EIA released updated data to NHTSA in February (Interim AEO). The final release of AEO for 2011 came out in April 2011, but by that time EPA/NHTSA had already prepared modeling runs for the 2017-2025 NPRM using the interim data release to NHTSA. Today's analysis continues to apply the AEO2011 early release to the MY2008-based fleet. For the MY2010-based fleet, we have applied the AEO2012 early release, which EIA published January 2012. Although EIA has since published the final version of AEO2012, it did so in June, after we had already completed our analysis supporting today's final rule.

Similar to the analyses supporting the MYs 2012-2016 rulemaking, the agencies have used the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) to estimate the future relative market shares of passenger cars and light trucks. However, NEMS methodology includes shifting vehicle sales volume, starting after 2007, away from fleets with lower fuel economy (the light-truck fleet) towards vehicles with higher fuel economies (the passenger car fleet) in order to facilitate compliance with CAFE and GHG MYs 2012-2016 standards.

[53] Department of Energy, Energy Information Administration, Annual Energy Outlook (AEO) 2011, Early Release. *Available at* http://www.eia.gov/forecasts/aeo/ (last accessed Aug. 15, 2011).

Because we use our market projections as baselines relative to which we measure the effects of new standards, and we attempt to estimate the industry's ability to comply with new standards without changing product mix (*i.e.*, we analyze the effects of potential new standards assuming manufacturers will not change fleet composition as a compliance strategy, as opposed to changes that might happen due to market forces), the Interim AEO 2011-projected shifts in passenger car market share as a result of required fuel economy improvements creates a circularity. Therefore, for the current analysis, the agencies developed new projections of passenger car and light truck sales shares by running scenarios from the Interim AEO 2011 reference case that first deactivate the above-mentioned sales-volume shifting methodology and then hold post-2017 CAFE standards constant at MY 2016 levels. This is referred to as the Unforced Reference Case. Incorporating these changes reduced the projected passenger car share of the light vehicle market by an average of about 5% during 2017-2025.

In 2017, car and light truck sales are projected to be 10.0 and 5.8 million units, respectively, in the MY2008-based fleet. While the total level of sales of 15.8 million units is similar to pre-2008 levels, the forecast fractions of car sales in 2017 and beyond are projected to be higher than in the 2000-2007 timeframe. Note that EIA's definition of cars and trucks follows that used by NHTSA prior to the MY 2011 CAFE final rule. The MY 2011 CAFE final rule reclassified approximately 1 million 2-wheel drive sport utility vehicles from the truck fleet to the car fleet and car and truck sales shown above reflect this reclassification.

In addition to a shift towards more car sales, sales of segments within both the car and truck markets have also been changing and are expected to continue to change in the future. Manufacturers are continuing to introduce more crossover models which offer much of the utility of SUVs but use more car-like designs and unibody structures. In order to reflect these changes in fleet makeup shown in the MY2008-based forecast used for the NPRM, EPA and NHTSA used a custom long range forecast purchased from CSM Worldwide (CSM). CSM is a well-known industry analyst, that provided the forecast used by the agencies for the 2012-2016 final rule.

As part of the basis for the market forecast we used in the 2017-2025 NPRM, NHTSA and EPA decided to use the forecast from CSM for several reasons. One, CSM uses a ground up approach (e.g., looking at the number of plants and capacity for specific engines, transmissions, and vehicles) for their forecast, which the agencies believe is a robust forecasting approach. Two, CSM agreed to allow us to publish their high level data, on which the forecast is based, in the public domain. Three, the CSM forecast covered all the timeframe of greatest relevance to this analysis (2017-2025 model years). Four, it provided projections of vehicle sales both by manufacturer and by market segment. And five, it utilized market segments similar to those used in the EPA emission certification program and fuel economy guide, such that the agencies could include only the vehicle types covered by the new standards.

The agencies combined the CSM forecast with data from other sources to create the reference fleet projections. The process of producing the 2017-2025 reference fleet involved combining the baseline fleet with the projection data. This was a complex multistep procedure, which is described in more detail in Chapter 1 of the Joint TSD. This procedure was the same as that used for the 2012-2016 rule.

We then projected the CSM forecasts for relative sales of cars and trucks by manufacturer and by market segment onto the total sales estimates of AEO 2011. Tables III.A.3-1 and III.A.3-2 show the resulting projections for the reference 2025 model year and compare these to actual sales that occurred in baseline 2008 model year. Both tables show sales using the traditional definition of cars and light trucks.

Table III-1

Annual Sales of Light-Duty Vehicles by Manufacturer in 2008 and Estimated for 2025 – MY2008-Based Market Forecast

	Cars		Light Trucks		Total	
	2008 MY	2025 MY	2008 MY	2025 MY	2008 MY	2025 MY
Aston Martin	1,370	1,182			1,370	1,182
BMW	291,796	405,256	61,324	145,409	353,120	550,665
Daimler	208,195	340,719	79,135	101,067	287,330	441,786
Fiat/Chrysler	542,003	381,829	1,119,397	394,070	1,661,400	775,899
Ford	654,539	989,401	1,116,354	1,235,185	1,770,893	2,224,586
Geely/Volvo	55,600	88,039	42,797	55,657	98,397	143,696
General Motors	1,659,086	1,737,321	1,436,102	1,460,623	3,095,188	3,197,943
Honda	899,498	1,233,439	612,281	664,579	1,511,779	1,898,018
Hyundai	270,293	479,443	120,734	365,943	391,027	845,386
Kia	145,863	260,649	135,589	199,787	281,452	460,436
Lotus	252	316			252	316
Mazda	191,326	250,553	111,220	117,619	302,546	368,172
Mitsubishi	76,701	54,092	24,028	55,600	100,729	109,692
Nissan	653,121	895,341	370,294	545,889	1,023,415	1,441,229
Porsche	18,909	40,696	18,797	11,219	37,706	51,915

Spyker/Saab	21,706	23,130	4,250	3,475	25,956	26,605
Subaru	85,629	230,101	112,952	101,592	198,581	331,692
Suzuki	68,720	96,728	45,938	27,800	114,658	124,528
Tata	9,596	65,418	55,584	56,805	65,180	122,223
Tesla	800	31,974			800	31,974
Toyota	1,143,696	1,942,012	1,067,804	1,376,057	2,211,500	3,318,069
Volkswagen	291,483	630,163	26,999	154,284	318,482	784,447
Total	6,981,307	9,836,330	6,870,454	7,414,129	13,851,761	17,250,459

Table III-2

Annual Sales of Light-Duty Vehicles by Market Segment in 2008 and Estimated for 2025 – MY2008-Based Market Forecast

Cars			Light Trucks		
	2008 MY	2025 MY		2008 MY	2025 MY
Full-Size Car	829,896	245,355	Full-Size Pickup	1,332,335	1,002,806
Luxury Car	1,048,341	1,637,410	Mid-Size Pickup	452,013	431,272
Mid-Size Car	2,103,108	2,713,078	Full-Size Van	33,384	88,572
Mini Car	617,902	1,606,114	Mid-Size Van	719,529	839,452
Small Car	1,912,736	2,826,190	Mid-Size MAV*	110,353	548,457
Specialty Car	469,324	808,183	Small MAV	231,265	239,065
			Full-Size SUV*	559,160	46,978
			Mid-Size SUV	436,080	338,849
			Small SUV	196,424	71,827
			Full-Size CUV*	264,717	671,665
			Mid-Size CUV	923,165	1,259,483
			Small CUV	1,612,029	1,875,703
Total Sales**	6,981,307	9,836,330		6,870,454	7,414,129

* MAV – Multi-Activity Vehicle, SUV – Sport Utility Vehicle, CUV – Crossover Utility Vehicle

**Total Sales are based on the classic Car/Truck definition.

Determining which traditionally-defined trucks will be defined as cars for purposes of this analysis using the revised definition established by NHTSA for MYs 2011 and beyond requires more detailed information about each vehicle model. This is described in greater detail in Chapter 1 of the TSD.

The forecasts obtained from CSM provided estimates of car and truck sales by segment and by manufacturer, but not by manufacturer for each market segment. Therefore, NHTSA and EPA needed other information on which to base these more detailed projected market splits. For this task, the agencies used as a starting point each manufacturer's sales by market segment from model year 2008, which is the baseline fleet. Because of the larger number of segments in the truck market, the agencies used slightly different methodologies for cars and trucks.

The first step for both cars and trucks was to break down each manufacturer's 2008 sales according to the market segment definitions used by CSM. For example, the agencies found that Ford's cars sales in 2008 were broken down as shown in Table III-3:

Table III-3

Breakdown of Ford's 2008 Car Sales – MY2008 - Based Market Forecast

Full-size cars	160,857 units
Mid-size Cars	170,399 units
Small/Compact Cars	180,249 units
Subcompact/Mini Cars	None
Luxury cars	87,272 units
Specialty cars	110,805 units

EPA and NHTSA then adjusted each manufacturer's sales of each of its car segments (and truck segments, separately) so that the manufacturer's total sales of cars (and trucks) matched the total estimated for each future model year based on AEO and CSM forecasts. For example, as indicated in Table III-3, Ford's total car sales in 2008 were 709,583 units, while the agencies project that they will increase to 1,222,532 units by 2025. This represents an increase of 72.3 percent. Thus, the agencies increased the 2008 sales of each Ford car segment by 72.3 percent. This produced estimates of future sales which matched total car and truck sales per AEO and the manufacturer breakdowns per CSM. However, the sales splits by market segment would not necessarily match those of CSM (shown for 2025 in Table III-1).

In order to adjust the market segment mix for cars, the agencies first adjusted sales of luxury, specialty and other cars. Since the total sales of cars for each manufacturer were already set, any changes in the sales of one car segment had to be compensated by the opposite change in another segment. For the luxury, specialty and other car segments, it is not clear how changes in sales would be compensated. For example, if luxury car sales decreased, would sales of full-size cars increase, mid-size cars, and so on? The agencies have assumed that any changes in the sales of cars within these three segments were compensated for by proportional changes in the sales of the other four car segments. For example, for 2025, the figures in Table III-2 indicate that luxury car sales in 2025 are 1,633,410 units. Luxury car sales are 1,048,341 units in 2008. However, after adjusting 2008 car sales by the change in total car sales for 2025 projected by EIA and a change in manufacturer market share per CSM, luxury car sales decreased to 1,539,165 units. Thus, overall for 2025, luxury car sales had to increase by 98,245 units or 6 percent. The agencies accordingly increased the luxury car sales by each manufacturer by this percentage. The absolute decrease in luxury car sales was spread across sales of full-size, mid-size, compact and subcompact cars in proportion to each manufacturer's sales in these segments in 2008. The same adjustment process was used for specialty cars and the "other cars" segment defined by CSM.

The agencies used a slightly different approach to adjust for changing sales of the remaining four car segments. Starting with full-size cars, the agencies again determined the overall percentage change that needed to occur in future year full-size car sales after 1) adjusting for total sales per AEO 2010, 2) adjusting for manufacturer sales mix per CSM and 3) adjusting the luxury, specialty and other car segments, in order to meet the segment sales mix per CSM. Sales of each manufacturer's large cars were adjusted by this percentage. However, instead of spreading this change over the remaining three segments, the agencies assigned the entire change to mid-size vehicles. The agencies did so because the CSM data followed the trend of increasing volumes of smaller cars while reducing volumes of larger cars. If a consumer had previously purchased a full-size car, we thought it unlikely that their next purchase would decrease by two size categories, down to a subcompact. It seemed more reasonable to project that they would drop one vehicle size category smaller. Thus, the change in each manufacturer's sales of full-size cars was matched by an opposite change (in absolute units sold) in mid-size cars.

The same process was then applied to mid-size cars, with the change in mid-size car sales being matched by an opposite change in compact car sales. This process was repeated one more time for compact car sales, with changes in sales in this segment being matched by the opposite change in the sales of subcompacts. The overall result was a projection of car sales for model years 2017-2025--the reference fleet--which matched the total sales projections of the AEO forecast and the manufacturer and segment splits of the CSM forecast.

As mentioned above, the agencies applied a slightly different process to truck sales, because the agencies could not confidently project how the change in sales from one segment preferentially went to or came from another particular segment. Some trend from larger vehicles to smaller vehicles would have been possible. However, the CSM forecasts indicated large changes in total sport utility vehicle, multi-activity vehicle and cross-over sales which could not be connected. Thus, the agencies applied an iterative, but straightforward process for adjusting 2008 truck sales to match the AEO and CSM forecasts. The first three steps were exactly the same as for cars. EPA and NHTSA broke down each manufacturer's truck sales into the truck segments as defined by CSM. The agencies then adjusted all manufacturers' truck segment sales by the same factor so that total truck sales in each model year matched AEO projections for truck sales by model year. The agencies then adjusted each manufacturer's truck sales by segment proportionally so that each manufacturer's percentage of total truck sales matched that forecast by CSM. This again left the need to adjust truck sales by segment to match the CSM forecast for each model year.

In the fourth step, the agencies adjusted the sales of each truck segment by a common factor so that total sales for that segment matched the combination of the AEO and CSM forecasts. For example, projected sales of large pickups across all manufacturers were 932,610 units in 2025 after adjusting total sales to match AEO's forecast and adjusting each manufacturer's truck sales to match CSM's forecast for the breakdown of sales by manufacturer. Applying CSM's forecast of the large pickup segment of truck sales to AEO's total sales forecast indicated total large pickup sales of 1,002,086 units. Thus, we increased each manufacturer's sales of large pickups by 7 percent. The agencies applied the same type of adjustment to all the other truck segments at the same time. The result was a set of sales projections which matched AEO's total truck sales projection and CSM's market segment forecast. However, after this step, sales by manufacturer no longer met CSM's forecast. Thus, we repeated step three and adjusted each manufacturer's truck sales so that they met CSM's forecast. The sales of each truck segment (by manufacturer) were adjusted by the same factor. The resulting sales projection matched AEO's total truck sales projection and CSM's manufacturer forecast, but sales by market segment no longer met CSM's forecast. However, the difference between the sales projections after this fifth step was closer to CSM's market segment forecast than it was after step three. In other words, the sales projection was converging to the desired result. The agencies repeated these adjustments, matching manufacturer sales mix in one step and then market segment in the next a total of 19 times. At this point, we were able to match the market segment splits exactly and the manufacturer splits were within 0.1 percent of our goal, which is well within the needs of this analysis.

The next step in developing the reference fleets was to characterize the vehicles within each manufacturer-segment combination. In large part, this was based on the characterization of the specific vehicle models sold in 2008 -- *i.e.*, the vehicles comprising the baseline fleet. EPA and NHTSA chose to base our estimates of detailed vehicle characteristics on 2008 sales for several reasons. One, these vehicle characteristics are not confidential and can thus be published here for careful review by interested parties. Two, because it is constructed beginning with actual sales data, this vehicle fleet is limited to vehicle models known to satisfy consumer demands in light of price, utility, performance, safety, and other vehicle attributes.

As noted above, the agencies gathered most of the information about the 2008 baseline vehicle fleet from EPA's emission certification and fuel economy database. The data obtained from this source included vehicle production volume, fuel economy, engine size, number of engine cylinders, transmission type, fuel type, etc. EPA's certification database does not include a detailed description of the types of fuel economy-improving/CO_2-reducing technologies considered in this final rule. Thus, the agencies augmented this description with publicly available data which includes more complete technology descriptions from Ward's Automotive Group.[54] In a few instances when required vehicle information (such as vehicle footprint) was not available from these two sources, the agencies obtained this information from publicly accessible internet sites such as Motortrend.com and Edmunds.com.[55]

The projections of future car and truck sales described above apply to each manufacturer's sales by market segment. The EPA emissions certification sales data are available at a much finer level of detail, essentially vehicle configuration. As mentioned above, the agencies placed each vehicle in the EPA certification database into one of the CSM market segments. The agencies then totaled the sales by each manufacturer for each market segment. If the combination of AEO and CSM forecasts indicated an increase in a given manufacturer's sales of a particular market segment, then the sales of all the individual vehicle configurations were adjusted by the same factor. For example, if the Prius represented 30 percent of Toyota's sales of compact cars in 2008 and Toyota's sales of compact cars in 2025 was projected to double by 2025, then the sales of the Prius were doubled, and the Prius sales in 2025 remained 30 percent of Toyota's compact car sales.

[54] Note that WardsAuto.com is a fee-based service, but all information is public to subscribers.
[55] Motortrend.com and Edmunds.com are free, no-fee internet sites.

5. How was the 2010-based vehicle fleet developed?

Before the agencies began conducting analysis in support of today's final rule, CAFE certification data for the MY2010 fleet became available. Judging this fleet, though somewhat impacted by the recession, to provide a reasonable foundation for the construction of a forecast of the future light vehicle market, the agencies developed such a forecast. In doing so, the agencies followed the same basic approach, and relied on the same types of supplementing publicly- and commercially-available information as applied in developing the MY2008-based market forecast.

As discussed above, similar to the MY2008-based market forecast, most of the information about the vehicles that make up the MY2010-based market forecast was gathered from EPA's emission certification and fuel economy database, most of which is available to the public. These data included, by individual vehicle model produced in MY 2010, vehicle production volume, fuel economy rating for CAFE certification, carbon dioxide emissions, fuel type, fuel injection type, EGR, number of engine cylinders, displacement, intake valves per cylinder, exhaust valves per cylinder, variable valve timing, variable valve lift, engine cycle, cylinder deactivation, transmission type, drive (rear-wheel, all-wheel, etc.), hybrid type (if applicable), and aspiration (naturally-aspirated, turbocharged, etc.). In addition to this information about each vehicle model produced in MY 2010, the agencies augmented this description with publicly-available data which includes more complete technology descriptions from Ward's Automotive Group.[56,57] As with the 2008 baseline, the agencies also used Edmunds.com and Motortrend.com[58,59,60] Like the MY 2008 baseline fleet and the baseline vehicle fleet used in the MYs 2012-2016 rulemaking, the MY 2010 baseline vehicle fleet is developed using publicly-available data to the largest extent possible.

The process for creating the 2010 baseline fleet Excel file was streamlined when compared with the past rulemaking. EPA and NHTSA worked together to create the baseline using 2010 CAFE

[58] Motortrend.com and Edmunds.com: Used as a source for footprint and vehicle weight data.
[59] Motortrend.com and Edmunds.com are free, no-fee internet sites.
[60] A small amount of footprint data from manufacturers' MY 2008 product plans submitted to the agencies was used in the development of the baseline.

certification data from EPA's Verify database. EPA contracted LMC Automotive (formerly JD Powers Forecasting) to produce an up to date long range forecast of volumes for the future fleet. Using information sources discussed below, NHTSA identified technology and footprint information for every vehicle model in the 2010 CAFE certification data. EPA used the forecast from LMC Automotive to project the future fleet's volume projections (a detailed discussion of the method used to project the future fleet volumes is in section 1.4.2 of the joint TSD.)

EPA and NHTSA have based the projection of total car and light truck sales on the most recent projections available made by the Energy Information Administration (EIA). EIA's Annual Energy Outlook (AEO) projects future energy production, consumption and prices.[61] EIA issued an "early release" version of AEO 2012 in January 2012. The complete final version of AEO 2012 was released June 25, 2012, but by that time EPA/NHTSA had already completed analyses supporting the final 2017-2025 standards using the interim data release. Similar to the analyses supporting the MYs 2012-2016 rulemaking and for the 2008 based fleet projection, the agencies have used the Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) to estimate the future relative market shares of passenger cars and light trucks. However, as explained above, NEMS shifts the market toward passenger cars in order to ensure compliance with EISA's requirement that CAFE standards cause the fleet to achieve 35 mpg by 2020. Because we use our market projection as a baseline relative to which we measure the effects of new standards, and we attempt to estimate the industry's ability to comply with new standards without changing product mix (*i.e.*, we analyze the effects of the final rules assuming manufacturers will not change fleet composition as a compliance strategy), using the Interim AEO 2012-projected shift in passenger car market share as provided by EIA would cause the agencies to understate the cost of achieving compliance through additional technology, alone. Therefore, for the current analysis, the agencies developed a new projection of passenger car and light truck sales shares by using NEMS to run scenarios from the Interim AEO 2012 reference case, after first deactivating the above-mentioned sales-volume shifting methodology and holding post-2017 CAFE standards constant at MY 2016 levels. Incorporating these changes reduced the projected passenger car share of the light vehicle market by an average of about 5% during 2017-2025.

In addition to a shift towards more car sales, sales of segments within both the car and truck markets have also been changing and are expected to continue to change in the future. The

[61] Department of Energy, Energy Information Administration, Annual Energy Outlook (AEO) 2011 2012, Early Release. *Available at* http://www.eia.gov/forecasts/aeo/ (last accessed Aug. 15, 2011April 9, 2012).

agencies also wanted to use the most updated information on Chrysler projections, as the older NPRM projection conducted by CSM showed Chrysler sales to be very low in 2025. The agencies agree with the Chrysler comments that the NPRM projections are most likely outdated and too low with respect to Chrysler's market share. In order to reflect these changes in fleet makeup, EPA and NHTSA used a custom long range forecast purchased from LMC Automotive (formerly J.D. Powers Forecasting). . J.D. Powers is a well-known industry analyst. NHTSA and EPA decided to use the forecast from LMC Automotive (J.D. Powers Forecasting) for MY2010-based market forecast for several reasons. First, Like CSM, LMC Automotive uses a ground up approach (*e.g.*, looking at the number of plants and capacity for specific engines, transmissions, and vehicles) for their forecast, which the agencies believe is a robust forecasting approach. Second, LMC Automotive allows us to publish their entire forecast in the public domain. Third, the LMC Automotive forecast covered all the timeframe of greatest relevance to this analysis (2017-2025 model years). Fourth, it provided projections of vehicle sales both by manufacturer and by market segment. Fifth, it utilized market segments similar to those used in the EPA emission certification program and fuel economy guide, such that the agencies could include only the vehicle types covered by the final standards. And finally, it had a more updated projection of Chrysler sales.

LMC Automotive created a forecast that covered model years 2010-2025. Since the agencies used this forecast to generate the reference fleet (*i.e.*, the fleet expected to be sold absent any increases in the stringency regulations after the 2016 model year), it is important for the forecast to be independent of increases during 2017-2025 in the stringency of CAFE/ GHG standards. LMC Automotive does not use the CAFE or GHG standard as an input to their model, and specifically had no assumption of increase in stringency in the 2017-2025 time frame.

The agencies combined the LMC Automotive forecast with data from other sources to create the 2010 baseline reference fleet projections.

6. How was the projected MY 2017-2025 fleet (the MY2010-based reference fleet) developed?

The process of producing the MY 2010 baseline 2017-2025 reference fleet involved combining the baseline fleet with the projection data described above. This was a complex multistep procedure, which is described in this section. The procedure is new and some of the steps are different than those used with the MY2008 baseline fleet projection.

EPA and NHTSA employed a different method from the method used in the NPRM for mapping certification vehicles to LMC Automotive (LMC) vehicles. Merging the 2010 baseline data with the 2017-2025 LMC data required a thorough mapping of certification vehicles to LMC vehicles by individual make and model. One challenge that the agencies faced when determining a reference case fleet was that the sales data projected by LMC had different market segmentation than the data contained in EPA's internal database. The joint TSD explains the side-by-side comparison of each vehicle model to map the two datasets.

In the combined EPA certification and LMC data, all 2010 vehicle models were assumed to continue out to 2025, though their volumes changed in proportion to LMC projections. Also, any new models expected to be introduced within the 2011-2025 timeframe are not included in the data. These volumes are reassigned to the existing models to keep the overall fleet volume the same. All MYs 2017-2025 vehicles are mapped to the existing vehicles by a process of mapping to manufacturer's future segment volumes.

As with the comparable step in the MY 2008 baseline 2017-2025 reference fleet process, the next step in the agencies' generation of the reference fleet is one of the more complicated steps to explain. First, the 2010 CAFE data was mapped to the LMC segments. Second, the breakdown of segment volumes by manufacturer was compared between the LMC and CAFE data sets. Third, a correction was applied for Class 2B vehicles (Large Pickup Trucks) in the LMC data. Fourth, the individual manufacturer segment multipliers were created by year. And finally, the absolute volumes of cars and trucks were normalized (set equal) to the total sales estimates of the Early Release of the 2012 Annual Energy Outlook (AEO). The process and results are presented in detail in the joint TSD.

2. How are the baselines for today's final rule different quantitatively from the baselines that NHTSA used for the NPRM?

As discussed above, the current baseline was developed from adjusted MY 2008 compliance data and covers MY 2017-2025. This section describes, for the reader's comparison, some of the differences between the current baseline and the MY 2012-2016 CAFE rule baseline. This comparison provides a basis for understanding general characteristics and measures of the difference between the two baselines. The current baseline, while developed using the same methods as the baseline used for MY 2012-2016 rulemaking, reflects updates to the underlying commercially-available forecast of manufacturer and market segment shares of the future light vehicle market. The differences are in input assumptions rather than the basic approach and methodology. It also includes changes in various macro economic assumptions underlying the AEO forecasts and the use of the AEO Unforced Reference Case. Another change in the market input data from the last rulemaking involved our redefinition of the list of manufacturers to account for realignment taking place within the industry.

Estimated vehicle sales:

The sales forecasts, based on the Energy Information Administration's (EIA's) Early Annual Energy Outlook for 2011 (Interim AEO 2011) and 2012 (Interim AEO 2012), used in the current baselines indicate that the total number of light vehicles expected to be sold during MYs 2012-2016 is 74.3-79.0 million, or 14.9-15.8 million vehicles annually. NHTSA's MY 2012-2016 final rule forecast, based on AEO 2010, of the total number of light vehicles likely to be sold during MY 2012 through MY 2016 was 80 million, or about 16 million vehicles annually. Light trucks are expected to make up 36-37 percent of the MY 2016 baseline market forecast in the current baseline, compared to 34 percent of the baseline market forecast in the MY 2012-2016 final rule. These changes in both the overall size of the light vehicle market and the relative market shares of passenger cars and light trucks reflect changes in the economic forecast underlying AEO, changes in AEO's forecast of future fuel prices, and use of the Unforced Reference Case.

Estimated manufacturer market shares:

These changes are reflected below in Table III-4, which shows the agency's sales forecasts for passenger cars and light trucks under the current baseline and the MY 2012-2016 final rule. There has been a general decrease in MY 2016 forecast overall sales and for all manufacturers, with the exception of Chrysler, when the current baseline is compared to that used in the MY 2012-2016 rulemaking. There were no significant shifts in manufacturers' market shares between the baseline applied for the 2012-2016 final rule and the MY2008-based baseline applied for today's final rule. However, compared to these MY2008-based baselines, the MY2010-based baseline applied for today's final rule shows significantly different market shares for some manufacturers (*e.g.*, Fiat/Chrysler). The effect of including the low volume specialty manufacturers and accounting for known corporate realignments in the current baseline appear to be negligible. There has been a shift in the shares of passenger and non passenger vehicles as would be expected given that the agency is relying on different underlying assumptions as discussed above and in Chapter 1 of the joint TSD.

Table III-4

Sales Forecasts (Production for U.S. Sale in MY 2016, Thousand Units)

Manufacturer	Fleet MY Basis	Passenger Cars NPRM	Passenger Cars Final	Light Trucks NPRM	Light Trucks Final
Aston Martin	2008 2010	1	1 - 1	-	-
BMW	2008 2010	383	383 - 317	184	184 - 107
Daimler	2008 2010	245	245 - 250	136	136 - 97
Fiat/Chrysler	2008 2010	392	394 - 725	498	495 - 794
Ford	2008 2010	1,393	1,393 - 1,354	930	930 - 1,039
Geely	2008 2010	94	94 - 58	50	50 - 34
General Motors	2008 2010	1,391	1,444 - 1,672	1,444	1,391 - 1,222
Honda	2008 2010	862	862 - 1,127	588	588 - 531
Hyundai	2008 2010	489	489 - 847	99	99 - 136
KIA	2008 2010	512	512 - 333	124	124 - 46
Lotus	2008 2010	0	-	-	-
Mazda	2008 2010	393	378 - 258	78	93 - 60
Mitsubishi	2008 2010	80	98 - 57	60	42 - 13
Nissan	2008 2010	869	869 - 907	410	410 - 310
Porsche	2008 2010	30	30 - 19	18	18 - 20
Spyker	2008 2010	18	18 -	2	2 -
Subaru	2008 2010	236	236 - 213	74	74 - 94
Suzuki	2008 2010	94	94 - 43	21	21 - 3
Tata	2008 2010	59	59 - 29	46	46 - 53
Tesla	2008 2010	27	27 -	-	-
Toyota	2008 2010	2,043	2,043 - 1,532	1,159	1,159 - 970
Volkswagen	2008 2010	528	528 - 486	134	134 - 104
Total	**2008 2010**	**10,140**	**10,198 - 10,227**	**6,055**	**5,997 - 5,635**

<u>Estimated achieved fuel economy levels</u>:

The corrected MY2008-based market forecast shows an industry-wide combined (passenger car and light truck) average fuel economy level of 27.03 mpg, as for the NPRM. Because corrections included changes to the regulatory classification of a small number of General Motors vehicle models, the industry-wide passenger car average fuel economy decreased slightly (from 30.65 mpg to 30.60 mpg), and the industry-wide light truck average fuel economy increased slightly (from 22.55 mpg to 22.56 mpg). For nearly all manufacturers' fleets, the new MY2010-based market forecast shows higher baseline CAFE levels than under the corrected MY2008-based market forecast, consistent with progress in manufacturers' application of technology to improve fuel economy between MY2008 and MY2010. As a result, the MY2010-based market forecast shows higher industry-wide average fuel economy levels of 31.6 mpg for passenger cars, 23.1 mpg for light trucks, and 27.9 mpg for the combined fleet. These fuel economy levels are shown in detail below in Table III-5, which shows manufacturer-specific CAFE levels (not counting FFV credits that some manufacturers expect to earn) from the current baselines versus the baseline applied for the NPRM.

Table III-5

Current Baseline CAFE Levels in MY 2016 versus MY 2012-2016 Rule Making CAFE Levels
(Passenger Car and Light Truck)

	NPRM			Final Rule		
	Passenger Car	Light Truck	Combined	Passenger Car	Light Truck	Combined
Aston Martin	18.83		18.83	19.03 - 18.83	.00 - .00	19.03 - 18.83
BMW	27.19	23.03	25.68	27.39 - 27.19	24.07 - 23.01	26.46 - 25.68
Daimler	25.50	21.13	23.75	24.71 - 25.50	21.03 - 21.12	23.56 - 23.75
Fiat/Chrysler	27.74	22.19	24.33	28.20 - 27.69	21.70 - 22.20	24.38 - 24.34
Ford	28.24	21.32	24.99	30.26 - 28.23	22.17 - 21.33	26.12 - 24.99
Geely/Volvo	25.89	21.08	23.99	28.20 - 25.89	22.80 - 21.07	25.91 - 23.98
General Motors	28.38	21.45	24.37	30.35 - 28.16	22.47 - 21.38	26.43 - 24.37
Honda	33.83	25.02	29.61	34.54 - 33.83	25.12 - 25.03	30.84 - 29.61
Hyundai	31.74	24.29	30.18	32.90 - 31.75	28.19 - 24.28	32.15 - 30.18
Kia	32.70	23.74	30.46	35.15 - 32.72	25.00 - 23.76	33.51 - 30.48
Lotus	29.66		29.66	26.72 - 29.66	.00 - .00	26.72 - 29.66
Mazda	30.77	26.40	29.95	32.04 - 31.27	25.20 - 25.59	30.48 - 29.96
Mitsubishi	28.86	23.57	26.33	32.47 - 27.52	28.15 - 23.91	31.58 - 26.33
Nissan	31.98	22.10	27.97	32.57 - 31.98	23.57 - 22.09	29.68 - 27.96
Porsche	26.22	19.98	23.48	25.40 - 26.21	20.51 - 19.99	22.63 - 23.49
Spyker/Saab	26.54	19.79	25.70	.00 - 26.57	.00 - 19.81	.00 - 25.73
Subaru	29.59	27.37	29.03	29.66 - 29.57	30.69 - 27.34	29.97 - 29.00
Suzuki	30.77	23.29	29.04	33.14 - 30.78	26.15 - 23.32	32.52 - 29.06
Tata	24.58	19.71	22.19	23.33 - 24.58	18.94 - 19.71	20.28 - 22.19
Tesla	244.00		244.00	.00 - 244.00	.00 - .00	.00 - 244.00
Toyota	35.22	24.26	30.27	35.39 - 35.22	24.13 - 24.25	29.97 - 30.27
Volkswagen	28.90	20.24	26.60	31.82 - 28.91	24.05 - 20.22	30.10 - 26.60
Average	30.65	22.56	27.03	31.58 - 30.60	23.12 - 22.55	27.94 - 27.03

3. How else has NHTSA looked at the baseline for the final rule?

NHTSA has also developed an alternative "market-driven" baseline which assumes that manufacturers may adopt some fuel-saving measures beyond what is required by the MY 2016 rule. This baseline, discussed in Section X, below, assumes that manufacturers will compare the cost of fuel-saving technologies to consumers to the fuel savings in the first year of operation and decide to voluntarily apply those technologies to their vehicles when benefits for the first year exceeded costs for the consumer.

NHTSA sought comment on whether this baseline more accurately predicts the likely state of the market in MY 2017 to 2025 than the flat baseline assumption, or whether even more fuel technologies would be likely to be adopted in the absence of the proposed rule. Several environmental organizations submitted comments on NHTSA's analysis. The Center for Biological Diversity (CBD) commented that the agency's baseline "suggests a much lower fuel efficiency increase driven solely by market forces than actual experience demonstrates occurs."[62] The Natural Resources Defense Council (NRDC) commented that manufacturers might add more technology than required by standards, but that such decisions are too uncertain to be included in NHTSA's baseline projection. The Environmental Defense Fund (EDF) commented that, given relatively stable future fuel prices, and given provisions allowing credit transfers between manufacturers, manufacturers will not likely overcomply with MY2016 standards, on average, after MY2016. The American Council for an Energy-Efficient Economy (ACEEE) commented that the historical record contains little evidence of sustained fuel economy increases absent sustained increases in fuel economy standards. ACEEE also commented that an alternative "non-flat" baseline would reduce NHTSA's estimates of the benefits (and costs) of the new standards, the net effect being a reduction in the cost-effectiveness of the standards, because the most cost-effective technologies are the ones that will appear in the alternative baseline scenario, leaving the more expensive technologies for the rule to bring into the market.

In addition, several stakeholders on the "payback period" NHTSA should apply in its analysis. EDF indicated that any payback period shorter than five years would not accurately reflect the current and forecasted buying trends of consumers. The Sierra Club also submitted comments suggesting a five-year payback period. Volkswagen commented that buyers' preferences will suggest payback periods of less than four years. The International Council on Clean Transportation (ICCT) commented that analysis in 2010 by David Greene supported an average payback period of three years.[63] NADA commented that analysis based on a payback period

[62] CBD, p. 6.
[63] Greene, David 2010. "Uncertainty, loss aversion, and markets for energy efficiency", Energy Economics.

oversimplifies the calculation of consumer benefits, but did not comment on the payback period as basis to estimate the potential that manufacturers might add technology beyond that required by regulation.

NHTSA recognizes the uncertainty inherent in forecasting whether and to what extent the average fuel economy level of light-duty vehicles will continue to increase beyond the level necessary to meet regulatory standards. However, because market forces could independently result in changes to the future light-duty vehicle fleet even in the absence of agency action, to the extent they can be estimated, those changes should be incorporated into the baseline. As a result, today's final rule continues to present impacts in terms of two sets of analyses: one assuming that the average fleetwide fuel economy for light-duty vehicles will not exceed the minimum level necessary to comply with CAFE standards, and one assuming continued improvement in average fleetwide fuel economy for light-duty vehicles due to higher market demand for fuel-efficient vehicles.

NHTSA also considered developing and using a vehicle choice model to estimate the extent to which sales volumes would shift in response to changes in vehicle prices and fuel economy levels. As discussed Chapter V, the agency is currently sponsoring research directed toward developing such a model. However, that effort has not yet yielded a choice model ready for integration into NHTSA's analysis. If that effort is successful in the future, the agency will consider integrating the model into the CAFE modeling system and using the integrated system for future analysis of potential CAFE standards. If the agency does so, we expect that the vehicle choice model would impact estimated fleet composition not just under new CAFE standards, but also under baseline CAFE standards.

B. Alternatives examined by the agency, and why NHTSA is proposing the Preferred Alternative

1. What regulatory alternatives has NHTSA considered in this analysis, and why?

In developing today's MY 2017-25 standards, the agency developed and examined a wide variety of alternatives. The No-Action Alternative assumes continuation of MY 2016 standards. All other alternatives begin with curves resulting from the agency's updated curve fitting analysis (discussed in Chapter V). Curves defining all regulatory alternatives have the same constrained linear form (linear on a fuel consumption basis), and define fuel economy targets applicable to each vehicle model, based on the vehicle's footprint:

$$Target = MAX\left[MIN\left(\frac{1}{Slope\ \times Footprint + Intercept}, MaxTarget\right), MinTarget\right]$$

Required CAFE level depends not only on the footprints of specific vehicle models, but also on the numbers of units produced for sale in the U.S.:

$$RequiredCAFE = \frac{\sum_i PRODUCTION_i}{\sum_i \frac{PRODUCTION_i}{FuelEconomy_i}}$$

The curves defining fuel economy targets do not depend on fleet mix, and are therefore not subject to uncertainty because NHTSA cannot predict with certainty what mix of vehicle manufacturers will sell through MY 2025. However, future average required fuel economy levels cannot be predicted with certainty, because average fuel economy levels depend on fleet mix.

The agency selected a range of candidate curves that increased in stringency by 2% to 7% annually.[64] Thus, the majority of the alternatives considered in this rulemaking are defined as annual increases in curve stringency—2 percent per year, 3 percent per year, 4 percent per year, and so on. NHTSA believes that this approach clearly communicates the requirements of each alternative and allows us to identify alternatives that represent different ways to balance NHTSA's statutory requirements under EPCA/EISA. NHTSA has also estimated average required fuel economy levels under each alternative, but notes that these estimates are based on fleet mix projections that are subject to uncertainty.

[64] The fitted curves from NHTSA's analysis reflect the maximum application of most technologies, in order to adjust for differences in technologies in the MY 2008 fleet. Before applying these annual stringency increases, NHTSA adjusted these curves to levels that would produce the same average required fuel economy levels in MY 2016 as would the actual MY 2016 standards the agency recently promulgated.

Each of the listed alternatives represents, in part, a different way in which NHTSA could conceivably balance different policies and considerations in setting the standards. The agency needs to weigh and balance many factors, such as technological feasibility, economic practicability, including lead time considerations for the introduction of technologies and impacts on the auto industry, the impacts of the standards on fuel savings and CO_2 emissions, and fuel savings by consumers, as well as other relevant factors such as safety. For example, the 7% Alternative weighs energy conservation and climate change considerations more heavily and technological feasibility and economic practicability less heavily. In contrast, the 2% Alternative, the least stringent alternative (aside from the No-Action Alternative), places more weight on technological feasibility and economic practicability. The "feasibility" of the alternatives also may reflect differences and uncertainties in the way in which key economic (*e.g.*, the price of fuel and the social cost of carbon) and technological inputs could be assessed and estimated or valued. Some technologies will not be available for more than limited commercial use in earlier model years, and that even those technologies that could be more widely commercialized through MY 2025 cannot all be deployed on every vehicle model in MY 2017 but require a realistic schedule for more widespread commercialization to be within the realm of economically practicability. The preferred alternative, discussed below in Section B.2, represents the agency's tentative conclusion as to how these factors should be balanced to produce the maximum feasible standards for MYs 2017-2025.

In addition to the alternatives defined by curves with stringency that increases evenly at annual rates ranging from 2% to 7%, NHTSA is also considering alternatives developed using benefit-cost criteria. The agency emphasized benefit-cost-related alternatives in its rulemakings for MY 2008-2011 and, subsequently, MY 2011 standards. By including such alternatives in its analysis, the agency is providing a degree of analytical continuity between the two approaches to defining alternatives in an effort to illustrate the similarities and dissimilarities. To that end, we have included and analyzed two additional alternatives, one that sets standards at the point where net benefits are maximized (labeled "MNB" in the table below), and another that sets standards at the point at which total costs are most nearly equal to total benefits (labeled "TCTB" in the table below).[65] With respect to the first of those alternatives, we note that Executive Order 12866

[65] The stringency indicated by each of these alternatives depends on the value of inputs to NHTSA's analysis. Results presented here for these two alternatives are based on NHTSA's reference case inputs, which underlie the central analysis of the proposed standards. In the accompanying FRIA, the agency presents the results of that analysis to explore the sensitivity of results to changes in key economic inputs. Because of numerous changes in model inputs (*e.g.*, discount rate, rebound effect, CO_2 value, technology cost estimates), our analysis often exhausts all available technologies before reaching the point at which total costs equal total benefits. In these cases, the stringency that exhausts all available technologies is considered. Also, because the agency's analysis "carries forward" technologies applied in one model year, and also simulates "multiyear planning" (manufacturers' early application of technology to facilitate compliance in later model years), the agency's estimates of the net benefit maximizing and "TCTB" stringencies are subject to interactions between model years.

focuses attention on an approach that maximizes net benefits. Further, since NHTSA has previously set attribute-based CAFE standards at the point at which net benefits are maximized, we believe it will be useful and informative to consider the potential impacts of that approach as compared to the new approach, which the agency also applied in 2010 for MYs 2012-2016.

All of the above alternatives were developed in terms of the 2-cycle test that has, to date, provided the basis for determining fuel economy levels used to calculate manufacturers' CAFE levels. EPA is responsible for determining these test procedures and calculation methods, and is today promulgating changes to fuel economy calculation methods to include adjustments reflecting any increases in the efficiency of automotive air conditioners. NHTSA and EPA have estimated the average extent to which manufacturers will apply such improvements, and NHTSA has adjusted all regulatory alternatives accordingly.

Table III-6
Estimated Average Adjustments (g/mi CO_2) Reflecting Air Conditioner Efficiency Increases

Model Years	Passenger Cars	Light Trucks
2017	5.0	5.0
2018	5.0	6.5
2019-2025	5.0	7.2

NHTSA applied these adjustments as follows:

$$Target_{AC} = \frac{1}{\frac{1}{Target} + \frac{AC\ Adjustment}{8887\ \frac{grams\ CO_2}{gallon}}}$$

Where $Target_{AC}$ is the fuel economy target reflecting AC adjustments, and the 8,887 grams of CO_2 per gallon reflects the characteristics of indolene, the test fuel used to certify the fuel economy of gasoline vehicles. In terms of coefficients defining CAFE standards, NHTSA applied the additive adjustment to the *Intercept*, *MinTarget*, and *MaxTarget* terms as follows:

$$Intercept_{AC} = Intercept + \frac{AC\ Adjustment}{8887\ \frac{grams\ CO_2}{gallon}}$$

$$MinTarget_{AC} = \frac{1}{\frac{1}{MinTarget} + \frac{AC\ Adjustment}{8887\ \frac{grams\ CO_2}{gallon}}}$$

$$MaxTarget_{AC} = \frac{1}{\frac{1}{MaxTarget} + \frac{AC\ Adjustment}{8887\ \frac{grams\ CO_2}{gallon}}}$$

For purposes of estimating the incremental effects of new CAFE standards, NHTSA defined a No-Action Alternative that assumed MY 2016 standards would remain in effect through MY 2025, and adjusted these standards based on the assumption that, on average, manufacturers would implement AC efficiency improvements reflecting a 4.8 g/mi adjustment. The following table presents the range of targets spanned by the resultant curves, as well as NHTSA's estimates of the resultant average required fuel economy levels. As discussed above, while curves are fixed, average required fuel economy levels depend on fleet composition, and are therefore subject to change. For example, the No-Action Alternative for light trucks is a curve (unchanging during MY 2017-2025) specifying a maximum fuel economy target (for the smallest light trucks) of 35.07 mpg, a minimum fuel economy target (for the largest light trucks) of 25.08 mpg, with targets decreasing between these limits as footprint increases. Based on the market agency's market forecast discussed above, NHTSA estimates that this curve would result in average required fuel economy levels that increase gradually from 28.93-29.25 mpg in MY 2017 to 28.91-29.43 mpg in MY2025, as the light truck fleet mix shifts among models with different footprints.

This table and the ten ensuing tables show the maximum range spanned by the target curve defining the standard applicable to each fleet in each model year (*e.g.*, 31.49-42.03 for the baseline passenger car standard), as well as the range between results under the two baseline market forecasts examined by the agency (*e.g.*, for the MY2017 passenger car fleet, 34.61 under the MY2008-based market forecast, and 34.30 under the MY2010-based market forecast, resulting in a range of 34.61-34.30 between the two forecasts).

The standards themselves are not uncertain (except insofar as the MY2022-2025 standards must be put in place through a de novo rulemaking, and the MY2017-2021 standards could conceivably be revised through rulemaking between now and early MY2015), because, as required by EISA/EPCA, they are expressed as mathematical functions defined in terms of an attribute related to fuel economy. However, the resultant average required fuel economy levels are uncertain, because the average required fuel economy levels will depend on the future composition of the new light vehicle market, and the future composition of the new light vehicle market is uncertain. While the ranges in average required fuel economy levels shown in the following eleven tables show the range between the two baseline market forecasts examined in detail by NHTSA, these ranges do not show the full range of uncertainty. In NHTSA's judgment, the composition of the light vehicle market is much more uncertain than reflected by the range between the MY2008-based and MY2010-based baseline market forecasts. NHTSA's probabilistic uncertainty analysis, presented below in Chapter XII, accounts for one aspect of uncertainty regarding the future fleet's composition—the relative overall market shares of passenger cars and light trucks.

Table III-7
No-Action Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	31.49 - 42.03	(38.19 - 38.68)	25.08 - 35.07	(28.93 - 29.25)	25.08 - 42.03	(34.30 - 34.61)
2018	2010 2008	31.49 - 42.03	(38.17 - 38.69)	25.08 - 35.07	(28.91 - 29.29)	25.08 - 42.03	(34.29 - 34.68)
2019	2010 2008	31.49 - 42.03	(38.15 - 38.70)	25.08 - 35.07	(28.91 - 29.32)	25.08 - 42.03	(34.29 - 34.76)
2020	2010 2008	31.49 - 42.03	(38.15 - 38.67)	25.08 - 35.07	(28.91 - 29.30)	25.08 - 42.03	(34.33 - 34.79)
2021	2010 2008	31.49 - 42.03	(38.12 - 38.70)	25.08 - 35.07	(28.90 - 29.30)	25.08 - 42.03	(34.35 - 34.82)
2022	2010 2008	31.49 - 42.03	(38.15 - 38.71)	25.08 - 35.07	(28.90 - 29.31)	25.08 - 42.03	(34.39 - 34.86)
2023	2010 2008	31.49 - 42.03	(38.11 - 38.67)	25.08 - 35.07	(28.90 - 29.36)	25.08 - 42.03	(34.40 - 34.92)
2024	2010 2008	31.49 - 42.03	(38.15 - 38.70)	25.08 - 35.07	(28.92 - 29.40)	25.08 - 42.03	(34.47 - 35.02)
2025	2010 2008	31.49 - 42.03	(38.12 - 38.71)	25.08 - 35.07	(28.91 - 29.43)	25.08 - 42.03	(34.47 - 35.08)

This table also shows that although there is no CAFE standard for the combined (passenger car and light truck) fleet, the lowest possible requirement would be 25.08 mpg (if the market shifted entirely to the very largest light trucks), the highest possible requirement would be 42.08 (if the market shifted entirely to the very smallest passenger cars), and NHTSA estimates that the overall average fuel economy required of the industry under the No Action Alternative increases gradually from 34.53 mpg in MY 2017 to 34.98 mpg in MY 2025, as the market gradually shifts toward away from light trucks and toward passenger cars.

The remaining tables in this section present equivalent information for the other regulatory alternatives. For each regulatory alternative, the first table presents the alternative as actually examined by the agency, and the second table presents the underlying alternative absent adjustments for improvements to automotive air conditioner efficiency for the reader's easier comparison to the CAFE increases analyzed in the MY 2012-2016 rulemaking. As above, for each fleet and model year, the fuel economy targets specified by the target curve are presented as a range, and the estimated average required fuel economy is presented in parentheses (and subject to uncertainty and change related to uncertainty in the agency's market forecast).

The "preferred alternative" represents the rates of increase which the agency has tentatively concluded are maximum feasible under EPCA/EISA for passenger cars and light trucks manufactured in MYs 2017-2025. Section B.2 below discusses why the agency has tentatively concluded that the preferred alternative standards are maximum feasible.

Table III-8
Preferred Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	32.65 - 43.61	(39.61 - 40.10)	25.09 - 36.26	(29.08 - 29.44)	25.09 - 43.61	(35.11 - 35.42)
2018	2010 2008	33.84 - 45.21	(41.05 - 41.59)	25.20 - 37.36	(29.57 - 30.02)	25.20 - 45.21	(36.10 - 36.52)
2019	2010 2008	35.07 - 46.87	(42.53 - 43.12)	25.25 - 38.16	(30.03 - 30.60)	25.25 - 46.87	(37.08 - 37.66)
2020	2010 2008	36.47 - 48.74	(44.18 - 44.82)	25.25 - 39.11	(30.65 - 31.19)	25.25 - 48.74	(38.30 - 38.89)
2021	2010 2008	38.02 - 50.83	(46.05 - 46.76)	25.25 - 41.80	(32.64 - 33.31)	25.25 - 50.83	(40.34 - 41.00)
2022	2010 2008	39.79 - 53.21	(48.24 - 48.96)	26.29 - 43.79	(34.22 - 34.90)	26.29 - 53.21	(42.32 - 43.00)
2023	2010 2008	41.64 - 55.71	(50.47 - 51.24)	27.53 - 45.89	(35.82 - 36.62)	27.53 - 55.71	(44.34 - 45.14)
2024	2010 2008	43.58 - 58.32	(52.86 - 53.65)	28.83 - 48.09	(37.53 - 38.45)	28.83 - 58.32	(46.51 - 47.42)
2025	2010 2008	45.61 - 61.07	(55.32 - 56.18)	30.19 - 50.39	(39.34 - 40.28)	30.19 - 61.07	(48.74 - 49.74)

NHTSA also considered alternatives under which the mathematical functions (*i.e.*, curves) defining fuel economy targets were advanced in stringency at constant annual rates ranging from 2% to 7%, which we believed represented a reasonable range of possible alternative ways the agency could balance the required statutory factors to determine the maximum feasible levels of improvement in fuel economy that manufacturers could achieve during MYs 2017-2025. Because NHTSA developed these curves mathematically (*i.e.*, calculating the gpm-based coefficients defining a given model year's curve by multiplying the coefficients applicable to the prior model year by one minus the rate of increase), yet average required fuel economy levels depend also on fleet composition, the resultant average required fuel economy levels do not progress at precisely the same rates of increase as do the underlying mathematical functions – that is, a reader will not be able to calculate the same fuel economy levels by multiplying the initial mpg number times 1.03, 1.04, etc., as the agency calculates based on multiplying the curve coefficients. While NHTSA recognizes that alternatives based on multiplying mpg levels may be easier for some readers to understand, we considered alternatives in terms of multiplying curve coefficients instead because it is the actual target curves that are the standards with which industry has to comply, and not the estimated mpg levels that result from those target curves in the agency's analysis. Characteristics of these alternatives are summarized in the twelve tables appearing below:

Table III-9
2% Annual Increase Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	32.16 - 42.95	(39.00 - 39.51)	25.09 - 37.52	(29.67 - 30.10)	25.09 - 42.95	(35.09 - 35.47)
2018	2010 2008	32.83 - 43.85	(39.83 - 40.35)	25.20 - 38.55	(30.31 - 30.79)	25.20 - 43.85	(35.85 - 36.29)
2019	2010 2008	33.51 - 44.76	(40.61 - 41.18)	25.25 - 39.48	(30.94 - 31.54)	25.25 - 44.76	(36.58 - 37.16)
2020	2010 2008	34.21 - 45.70	(41.45 - 42.04)	25.25 - 40.32	(31.54 - 32.12)	25.25 - 45.70	(37.36 - 37.95)
2021	2010 2008	34.92 - 46.66	(42.30 - 42.94)	25.25 - 41.17	(32.20 - 32.80)	25.25 - 46.66	(38.17 - 38.77)
2022	2010 2008	35.65 - 47.64	(43.19 - 43.85)	25.25 - 42.03	(32.84 - 33.51)	25.25 - 47.64	(38.99 - 39.64)
2023	2010 2008	36.39 - 48.63	(44.09 - 44.72)	25.77 - 42.92	(33.53 - 34.25)	25.77 - 48.63	(39.84 - 40.53)
2024	2010 2008	37.15 - 49.65	(45.04 - 45.69)	26.31 - 43.83	(34.27 - 35.06)	26.31 - 49.65	(40.75 - 41.51)
2025	2010 2008	37.92 - 50.70	(45.96 - 46.68)	26.86 - 44.76	(34.96 - 35.81)	26.86 - 50.70	(41.60 - 42.45)

Table III-10
3% Annual Increase Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	32.50 - 43.40	(39.43 - 39.93)	25.09 - 37.92	(29.90 - 30.34)	25.09 - 43.40	(35.43 - 35.80)
2018	2010 2008	33.52 - 44.78	(40.67 - 41.19)	25.20 - 39.37	(30.92 - 31.41)	25.20 - 44.78	(36.59 - 37.04)
2019	2010 2008	34.58 - 46.20	(41.91 - 42.52)	25.25 - 40.76	(31.90 - 32.51)	25.25 - 46.20	(37.73 - 38.34)
2020	2010 2008	35.67 - 47.67	(43.24 - 43.83)	25.26 - 42.06	(32.86 - 33.47)	25.26 - 47.67	(38.96 - 39.56)
2021	2010 2008	36.79 - 49.18	(44.58 - 45.23)	26.06 - 43.41	(33.90 - 34.58)	26.06 - 49.18	(40.21 - 40.86)
2022	2010 2008	37.96 - 50.75	(46.02 - 46.70)	26.88 - 44.80	(34.99 - 35.70)	26.88 - 50.75	(41.54 - 42.22)
2023	2010 2008	39.16 - 52.36	(47.45 - 48.16)	27.73 - 46.24	(36.09 - 36.88)	27.73 - 52.36	(42.88 - 43.64)
2024	2010 2008	40.40 - 54.03	(48.99 - 49.70)	28.61 - 47.72	(37.25 - 38.15)	28.61 - 54.03	(44.32 - 45.16)
2025	2010 2008	41.67 - 55.75	(50.55 - 51.33)	29.52 - 49.26	(38.45 - 39.39)	29.52 - 55.75	(45.76 - 46.69)

Table III-11
4% Annual Increase Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	32.84 - 43.87	(39.87 - 40.38)	25.09 - 38.32	(30.16 - 30.61)	25.09 - 43.87	(35.79 - 36.17)
2018	2010 2008	34.24 - 45.74	(41.54 - 42.09)	25.20 - 40.22	(31.56 - 32.07)	25.20 - 45.74	(37.37 - 37.83)
2019	2010 2008	35.69 - 47.70	(43.24 - 43.89)	25.28 - 42.09	(32.89 - 33.57)	25.28 - 47.70	(38.92 - 39.58)
2020	2010 2008	37.21 - 49.74	(45.11 - 45.74)	26.36 - 43.91	(34.31 - 34.94)	26.36 - 49.74	(40.66 - 41.29)
2021	2010 2008	38.79 - 51.87	(47.03 - 47.72)	27.48 - 45.80	(35.76 - 36.47)	27.48 - 51.87	(42.42 - 43.09)
2022	2010 2008	40.45 - 54.10	(49.05 - 49.77)	28.65 - 47.78	(37.31 - 38.05)	28.65 - 54.10	(44.28 - 45.01)
2023	2010 2008	42.17 - 56.43	(51.15 - 51.90)	29.87 - 49.86	(38.91 - 39.77)	29.87 - 56.43	(46.23 - 47.04)
2024	2010 2008	43.97 - 58.85	(53.36 - 54.14)	31.15 - 52.02	(40.60 - 41.57)	31.15 - 58.85	(48.28 - 49.20)
2025	2010 2008	45.85 - 61.39	(55.61 - 56.48)	32.48 - 54.28	(42.33 - 43.39)	32.48 - 61.39	(50.36 - 51.39)

Table III-12
5% Annual Increase Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	33.19 - 44.34	(40.28 - 40.79)	25.09 - 38.73	(30.47 - 30.92)	25.09 - 44.34	(36.16 - 36.53)
2018	2010 2008	34.98 - 46.73	(42.43 - 43.00)	25.20 - 41.10	(32.19 - 32.77)	25.20 - 46.73	(38.14 - 38.65)
2019	2010 2008	36.85 - 49.26	(44.66 - 45.32)	26.10 - 43.48	(33.96 - 34.66)	26.10 - 49.26	(40.20 - 40.87)
2020	2010 2008	38.84 - 51.93	(47.06 - 47.75)	27.51 - 45.85	(35.79 - 36.45)	27.51 - 51.93	(42.42 - 43.09)
2021	2010 2008	40.93 - 54.75	(49.64 - 50.36)	28.99 - 48.36	(37.73 - 38.47)	28.99 - 54.75	(44.77 - 45.47)
2022	2010 2008	43.13 - 57.72	(52.33 - 53.10)	30.55 - 51.01	(39.80 - 40.58)	30.55 - 57.72	(47.24 - 48.01)
2023	2010 2008	45.46 - 60.86	(55.14 - 55.95)	32.20 - 53.81	(41.96 - 42.88)	32.20 - 60.86	(49.84 - 50.72)
2024	2010 2008	47.92 - 64.18	(58.17 - 59.03)	33.94 - 56.78	(44.28 - 45.34)	33.94 - 64.18	(52.64 - 53.65)
2025	2010 2008	50.51 - 67.69	(61.32 - 62.26)	35.78 - 59.91	(46.69 - 47.86)	35.78 - 67.69	(55.53 - 56.66)

Table III-13
6% Annual Increase Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	33.55 - 44.82	(40.70 - 41.23)	25.09 - 39.15	(30.78 - 31.24)	25.09 - 44.82	(36.54 - 36.92)
2018	2010 2008	35.74 - 47.76	(43.37 - 43.96)	25.26 - 42.01	(32.88 - 33.44)	25.26 - 47.76	(38.98 - 39.48)
2019	2010 2008	38.07 - 50.90	(46.14 - 46.83)	26.96 - 44.93	(35.08 - 35.79)	26.96 - 50.90	(41.53 - 42.22)
2020	2010 2008	40.55 - 54.24	(49.16 - 49.87)	28.72 - 47.91	(37.37 - 38.11)	28.72 - 54.24	(44.30 - 45.02)
2021	2010 2008	43.21 - 57.82	(52.38 - 53.19)	30.60 - 51.10	(39.85 - 40.65)	30.60 - 57.82	(47.26 - 48.03)
2022	2010 2008	46.03 - 61.64	(55.83 - 56.69)	32.61 - 54.50	(42.50 - 43.35)	32.61 - 61.64	(50.42 - 51.26)
2023	2010 2008	49.05 - 65.72	(59.52 - 60.41)	34.75 - 58.15	(45.30 - 46.31)	34.75 - 65.72	(53.81 - 54.76)
2024	2010 2008	52.28 - 70.08	(63.48 - 64.45)	37.03 - 62.04	(48.32 - 49.48)	37.03 - 70.08	(57.45 - 58.56)
2025	2010 2008	55.72 - 74.74	(67.68 - 68.71)	39.47 - 66.22	(51.54 - 52.83)	39.47 - 74.74	(61.29 - 62.55)

Table III-14
7% Annual Increase Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	33.92 - 45.32	(41.17 - 41.70)	25.09 - 39.58	(31.13 - 31.58)	25.09 - 45.32	(36.95 - 37.33)
2018	2010 2008	36.53 - 48.82	(44.33 - 44.90)	25.82 - 42.94	(33.62 - 34.20)	25.82 - 48.82	(39.84 - 40.35)
2019	2010 2008	39.34 - 52.60	(47.70 - 48.39)	27.86 - 46.45	(36.26 - 37.00)	27.86 - 52.60	(42.93 - 43.63)
2020	2010 2008	42.37 - 56.69	(51.37 - 52.11)	30.01 - 50.09	(39.06 - 39.80)	30.01 - 56.69	(46.30 - 47.04)
2021	2010 2008	45.64 - 61.10	(55.36 - 56.19)	32.33 - 54.03	(42.12 - 42.97)	32.33 - 61.10	(49.95 - 50.76)
2022	2010 2008	49.17 - 65.87	(59.67 - 60.58)	34.83 - 58.29	(45.41 - 46.34)	34.83 - 65.87	(53.88 - 54.79)
2023	2010 2008	52.98 - 71.03	(64.31 - 65.26)	37.53 - 62.90	(48.97 - 50.06)	37.53 - 71.03	(58.15 - 59.18)
2024	2010 2008	57.10 - 76.61	(69.38 - 70.41)	40.45 - 67.89	(52.83 - 54.11)	40.45 - 76.61	(62.80 - 64.01)
2025	2010 2008	61.54 - 82.64	(74.79 - 75.97)	43.60 - 73.30	(57.00 - 58.42)	43.60 - 82.64	(67.75 - 69.15)

NHTSA also considered a regulatory alternative under which the stringency in each model year was set at a level estimated to maximize net benefits. Executive Order 12866 states that in choosing among regulatory alternatives in rulemakings, agencies should select the approach that maximizes net benefits (including potential economic, environmental, public health and safety, and other advantages; distributive impacts; and equity), unless a statute requires another approach. Executive Order 13563, signed by President Obama on January 18, 2011, reiterates that agencies should focus on approaches that maximize net benefits, to the extent consistent with applicable law.

In the context of CAFE rulemakings, NHTSA has long considered regulatory alternatives that approximate the levels at which net benefits are maximized. Because EPCA/EISA requires that CAFE standards be set separately for cars and trucks in each model year, finding the precise level at which net benefits are maximized for each fleet, for each year, taking into account all of the considerations enumerated by EOs 12866 and 13563, is challenging to say the least. While NHTSA accounts for many costs and benefits associated with setting CAFE standards through its modeling analysis, we are careful to emphasize that the modeling analysis does not, and indeed, cannot capture all possible impacts – some impacts, such as lifecycle maintenance and repair costs, for example, are currently too uncertain to quantify and include in the analysis. That uncertainty affects our ability to determine the absolute single level of stringency for each fleet, for each model year, which reflects perfect maximization of net benefits.

We have, nevertheless, done our best over multiple rulemakings to approximate in our modeling analysis a regulatory alternative that maximizes net benefits. In the rulemaking to establish the MY 2011 standards for cars and trucks, for example, NHTSA used the CAFE model to test a wide range of potential stringencies for cars and trucks separately, calculating the net benefits (*i.e.*, social benefits of standards minus total costs of standards) at each stringency, and then identifying the stringency that yielded the highest level of net benefits for that fleet, for that single model year and using that as the regulatory alternative that maximized net benefits.

Because the CAFE model has evolved since that rulemaking, the agency's ability to use it to determine the regulatory alternative that maximizes net benefits has also had to evolve. As the CAFE model exists today, it includes the ability to simulate multiyear planning effects—that is, the potential that a manufacturer might apply "extra" technology in earlier model years if doing so would facilitate compliance with standards in later model years. As discussed below, consideration of these effects reveals interdependencies the net benefit maximizing stringencies in different model years.

Thus, for this rulemaking, as for the MYs 2012-2016 rulemaking, the maximum net benefit and "total cost = total benefit" regulatory alternatives were developed using the CAFE model to perform corresponding optimizations on a year-by-year basis. For example, when estimating stringencies at which net benefits are maximized, the model begins by examining MY 2017, seeking the car and truck stringencies that would maximize net benefits in MY 2017, without any information regarding post-MY 2017 standards. The model then performs a compliance simulation for MY 2017; carries resultant technology forward into MY 2018; seeks car and truck stringencies that would maximize net benefits in MY 2018; and continues the sequence through MY 2025. However, once standards throughout MYs 2017-2025 are "known" at the end of that sequence, the compliance simulation in earlier model years is revisited and influenced by standards in later model years. For example, the model might add "extra" technology in MY 2015 to facilitate compliance with expected MY 2019 standards, and carry that technology forward to MY 2016 and MY 2017. This extra carried-forward technology could increase the net benefits attributed to the MY 2017 standards that had previously been estimated to maximize net benefits, *absent information regarding post-MY 2017 standards*. As a result, standards estimated to maximize net benefits on a year-by-year basis do not necessarily produce maximum net benefits—in any specific model year or over a series of model years—when standards in all model years are defined.[66] Given economic and technology-related inputs to the agency's analysis, opportunities to add fuel-saving technologies are sometimes "exhausted" before total costs reach the level of total benefits; when this occurs in a given model year, this regulatory alternative is defined by the stringency leading to this exhaustion of available technology. We believe, nevertheless, that this is an appropriate approach given that manufacturers seeking to comply with CAFE standards do not consider each model year in isolation, but rather within the context of a product plans spanning multiple model years—in other words, manufacturers engage in multiyear planning. For example, if a manufacturer is redesigning a vehicle model in MY 2012, and does not plan to redesign the vehicle again until MY 2019, the manufacturer is likely to consider what standards will be in place between MY 2012 and MY 2019, and factor that information into decisions about what technologies to apply to that vehicle. Insofar as manufacturers actually engage in such planning, the costs and benefits of new standards over time will be affected, and the net benefit maximizing stringencies will also be affected.

[66] As a potential means to address these interactions between model years when standards are defined and multiyear planning effects are simulated, Volpe Center staff has experimented with techniques to optimize a steady rate of increase. Under this approach, when a given level of stringency in MY 2017 is tested, the post-MY 2017 standards are also defined, because they are set at levels reflecting a constant rate of increase in stringency. However, EISA's requirement that the standards be set at the maximum feasible levels in each specific model year precludes the presumption that the stringency of standards would increase at a constant rate. On the other hand, testing a wide range of both profiles and levels of increases over nine model years poses a technical challenge the agency has not determined how best to address for purposes of maximizing net benefits. In the agency's judgment, further conceptual work may be required regarding the maximization of net benefits in each model year when net benefits in any given model year depend on the stringency of standards in earlier and later model years.

Table III-15
Maximum Net Benefit Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	36.95 - 49.33	(44.60 - 45.39)	27.00 - 44.91	(31.97 - 35.72)	27.00 - 49.33	(39.12 - 41.31)
2018	2010 2008	38.62 - 51.66	(46.93 - 47.52)	28.27 - 47.17	(32.90 - 37.51)	28.27 - 51.66	(40.78 - 43.35)
2019	2010 2008	40.50 - 54.10	(49.10 - 49.80)	29.59 - 49.29	(35.25 - 39.26)	29.59 - 54.10	(43.13 - 45.47)
2020	2010 2008	41.76 - 55.90	(50.64 - 51.35)	30.75 - 51.46	(37.48 - 40.86)	30.75 - 55.90	(45.13 - 47.13)
2021	2010 2008	42.60 - 57.08	(51.95 - 52.46)	31.80 - 53.09	(40.94 - 42.18)	31.80 - 57.08	(47.55 - 48.36)
2022	2010 2008	43.54 - 58.25	(52.75 - 53.55)	32.54 - 54.51	(41.61 - 43.31)	32.54 - 58.25	(48.32 - 49.52)
2023	2010 2008	44.38 - 59.42	(53.85 - 54.64)	32.96 - 55.05	(42.47 - 43.85)	32.96 - 59.42	(49.37 - 50.44)
2024	2010 2008	45.33 - 60.70	(56.14 - 55.80)	33.59 - 56.14	(43.36 - 44.87)	33.59 - 60.70	(51.10 - 51.62)
2025	2010 2008	46.27 - 61.99	(58.20 - 56.99)	34.86 - 58.33	(44.49 - 46.55)	34.86 - 61.99	(52.79 - 53.08)

Finally, and as mentioned above, NHTSA considered a regulatory alternative under which the stringency in each model year was set at a level estimated to produce incremental costs most closely equal to incremental benefits. The agency also used the CAFE model to progressively estimate stringencies defining this "Total Cost = Total Benefit" or "Zero Net Benefit" alternative.[67] As above, when technologies are exhausted before total costs reach the level of total benefits, this regulatory alternative is defined by the stringency leading to this exhaustion of available technology.

[67] The optimization procedures used to develop this regulatory alternative are also subject to the uncertainties and inter-MY dependencies discussed in the preceding footnote.

Table III-16
Total Cost = Total Benefit Alternative

Model Year	Fleet MY Basis	Passenger Cars		Light Trucks		Fleet	
		Max. Range	Est. Range	Max. Range	Est. Range	Max. Range	Est. Range
2017	2010 2008	38.10 - 50.92	(45.30 - 46.83)	27.31 - 45.33	(32.26 - 36.12)	27.31 - 50.92	(39.63 - 42.26)
2018	2010 2008	39.67 - 53.04	(47.17 - 48.78)	28.48 - 47.39	(33.26 - 37.71)	28.48 - 53.04	(41.10 - 44.12)
2019	2010 2008	40.92 - 54.74	(49.10 - 50.33)	29.70 - 49.62	(35.25 - 39.46)	29.70 - 54.74	(43.13 - 45.86)
2020	2010 2008	42.39 - 56.76	(50.64 - 52.14)	31.06 - 52.00	(37.48 - 41.27)	31.06 - 56.76	(45.13 - 47.75)
2021	2010 2008	43.23 - 57.93	(52.47 - 53.28)	32.11 - 53.63	(41.16 - 42.63)	32.11 - 57.93	(47.93 - 49.02)
2022	2010 2008	45.12 - 60.38	(54.14 - 55.53)	32.43 - 54.18	(41.81 - 43.09)	32.43 - 60.38	(49.18 - 50.51)
2023	2010 2008	46.48 - 62.31	(55.54 - 57.26)	33.06 - 55.27	(42.69 - 44.08)	33.06 - 62.31	(50.41 - 51.99)
2024	2010 2008	47.96 - 64.24	(58.53 - 59.09)	34.12 - 57.13	(43.36 - 45.58)	34.12 - 64.24	(52.40 - 53.79)
2025	2010 2008	48.91 - 65.64	(60.67 - 60.34)	34.96 - 58.55	(44.72 - 46.81)	34.96 - 65.64	(54.23 - 55.12)

IV. IMPACT OF OTHER GOVERNMENTAL VEHICLE STANDARDS ON FUEL ECONOMY

Introduction

The Energy Policy and Conservation Act (EPCA or the Act) requires that fuel economy standards for passenger cars and light trucks be set at the maximum feasible level after considering the following criteria: (1) technological feasibility, (2) economic practicability, (3) the impact of other Government standards on fuel economy, and (4) the need of the Nation to conserve energy. This section discusses the effects of other government regulations on model year (MY) 2017-2025 passenger car and light truck weight, using both MYs 2008 and 2010 as a baseline. These effects have not been included in the agency's analysis of potential manufacturer compliance pathways under different regulatory alternatives, because the agency is assuming that the manufacturers will be able to reduce overall weight by different amounts depending upon the alternative being analyzed. If weight is added to meet the requirements imposed by the regulations discussed here, we assume that manufacturers will nevertheless remove enough weight from vehicles in order to reach the assumed net weight reduction. This assumption was made in the analysis for the NPRM, and no comments were received on it.

The Impact on Weight of Safety Standards and Voluntary Safety Improvements

To the extent that safety improvements affect a manufacturer's ability to improve fuel economy, they will typically occur because of adding the necessary technologies to improve safety. The necessary technologies to improve safety typically increase vehicle weight, which reduces the fuel economy of the vehicle – a heavier vehicle has to do more work (and consume more fuel) to travel the same distance as a lighter vehicle. The agency's estimates of how much weight various safety improvements might add are based on cost and weight tear-down studies of a few vehicles and are not meant to represent all the variations in all the manufacturers' fleets, but instead represent rough averages of potential per-vehicle weights that could be incurred.

Consistent with prior analyses, we have broken down our analysis of the impact of safety standards that might affect the MY 2017-25 fleets into two parts: 1) those NHTSA final rules with known effective dates between 2008 and 2017 (or 2010 and 2017) depending upon the baseline fleet, and 2) proposed rules or potential rules in NHTSA's priority plan that could become effective before MY 2025, but do not have effective dates at this time.

Weight Impacts of Required Safety Standards (Final Rules with Known Effective Dates)

NHTSA has issued several safety standards that become effective for passenger cars and light trucks between MY 2008 and MY 2018. We will examine the potential impact on passenger car and light truck weights for these final rules using MY 2008 as a baseline and using MY 2010 as a baseline.

1. FMVSS 126, Electronic Stability Control
2. FMVSS 202a, Head Restraints
3. FMVSS 206, Door Locks
4. FMVSS 208, 5th Female 35 mph Tests
5. FMVSS 214, Side Impact Oblique Pole Test
6. FMVSS 216, Roof Crush
7. FMVSS 226, Ejection Mitigation
8. FMVSS 301, Fuel System Integrity

FMVSS 126, Electronic Stability Control
The phase-in schedule for vehicle manufacturers is:

Table IV-1

Electronic Stability Control Effective Dates Phase-in Schedule

Model Year	**Production Beginning Date**	**Requirement**
2009	September 1, 2008	55% with carryover credit
2010	September 1, 2009	75% with carryover credit
2011	September 1, 2010	95% with carryover credit
2012	September 1, 2011	All light vehicles

The final rule requires all light vehicles to meet the ESC requirements by MY 2012. In comparison, the MY 2008 voluntary compliance was estimated as shown in Table IV-2.

Table IV-2

MY 2008 Voluntary Compliance

	Passenger Cars	**Light Trucks**
ABS and ESC	36%	64%
ABS alone	46%	35%
No systems	18%	1%

The agency's analysis[68] of weight impacts found that ABS adds 10.7 lb. and ESC adds 1.8 lb. per vehicle for a total of 12.5 lb. Based on confidential manufacturers' plans for voluntary installation of ESC in MY 2008, 82 percent of passenger cars would have ABS and 36 percent would have ESC. Thus, the MY 2008 weight added by the manufacturers' plans for passenger cars would be 9.42 lb. (0.82*10.7 + 0.36*1.8) and for light trucks would be 11.75 lb. (0.99*0.7 + 0.64*1.8).

The incremental weight for the period of MY 2017-2025 compared to the MY 2008 baseline is 3.08 lb. for passenger cars (12.5 – 9.42 lb.) and 0.75 lb. for light trucks (12.5 – 11.75 lb.) for the ESC requirements.

For the MY 2010 baseline, ESC was required in 95 percent of all light vehicles for MY 2010, so that left 5 percent of the fleet that might need ESC. Thus, the weight increase in MY 2010 would have been 12.0 pounds for passenger cars (12.5 lb.*.95) and 12.3 pounds for light trucks (0.99*10.7 + 0.95*1.8). Thus, the incremental weight for the period of MY 2017-2025 compared to the MY 2010 baseline is 0.5 lb. for passenger cars (12.5 – 12.0 lb.) and 0.2 lb. for light trucks (12.5 – 12.3 lb.) for the ESC requirements.

[68] "Final Regulatory Impact Analysis, FMVSS 126, Electronic Stability Control Systems", March 2007, NHTSA, Docket No. 2007-27662-2.

FMVSS 202a, Head Restraints

An amendment to the head restraints rule increased the height of head restraint by an estimated 1.3 inches and reduced backset, which brought the head restraint closer to the back of the head. The phase-in starts with MY 2010 when 80 percent of the passenger cars and light trucks must comply. The average weight increase is estimated by NHTSA to be about 3 pounds for both passenger cars and light trucks. Thus, an increase of 3 pounds is assumed for the MY 2008 baseline (since none of the MY 2008 vehicles would have had this change applied) and 0.6 pounds for the MY 2010 baseline for both passenger cars and light trucks (3 lb. * (1-0.8)).

FMVSS 206, Door locks

A new door lock test for sliding doors took effect in MY 2009. This test was expected to require those sliding doors that used a latch/pin mechanism to change to two latches to help keep sliding doors closed during crashes. The increase in weight is estimated to be 1.0 lb. Several van models had two sliding doors, which would require 2 lb. for two doors. Out of 1.4 million MY 2003 vans, an estimated 1.2 million doors would be required to change to the two latch system. Given that vans were 13.2 percent of light truck sales in MY 2007, it is estimated that in MY 2009, average light truck weight would be increased by 0.11 lb. for sliding door latches (1.2/1.4 million * 0.132 * 1 lb.). No increase in weight is anticipated for passenger cars, since no known vehicle design that has sliding doors would qualify as a passenger car for CAFE purposes. For the MY 2010 baseline, in contrast, there would be no increase in weight resulting from this requirement, because the latches were required to be on all vehicles already by MY 2009.

FMVSS 208, Occupant Crash Protection – 35 mph belted 50th percentile male and 5th percentile female testing

The agency phase-in requirements for 35 mph belted testing with the 50th percentile male were 35 percent for MY 2008, 65 percent for MY 2009, and 100 percent for MY 2010. The agency phase-in requirements for 35 mph belted testing with the 5th percentile female were 35 percent for MY 2010, 65 percent for MY 2011, and 100 percent for MY 2012. Several different technologies could be used to pass this test, but the agency's analysis of these countermeasures showed no increase in weight was needed, which means that we did not estimate any effect of this safety standard on fuel economy for purposes of this analysis.

FMVSS 214, Oblique Pole Side Impact Test

Based on the phase-in requirements for the side impact oblique pole test, all vehicles must meet the test by MY 2017. A teardown study of five thorax air bags resulted in an average weight increase per vehicle of 4.77 pounds (2.17 kg).[69] A second study[70] performed teardowns of 5 window curtain systems. One of the window curtain systems was very heavy (23.45 pounds). The other four window curtain systems had an average weight increase per vehicle of 6.78 pounds (3.08 kg), a figure which we assumed to be average for all vehicles in the future.

Based on MY 2008 confidential information supplied by manufacturers to NHTSA, most vehicles already currently provide head and thorax protection. The estimated percentage of vehicles with side air bags with head protection was 99.5 percent of passenger cars and 97.2 percent of light trucks and torso protection was estimated at 93.0 percent of passenger cars and 82.5 percent of light trucks. This information indicates that the weight increases for the head and thorax air bag countermeasures for the FMVSS 214 oblique pole test for the MY 2017 and later vehicles compared to a MY 2008 baseline are 0.37 lb. for passenger cars and 1.02 lb. for light trucks.

During make/model testing, the agency noted that some vehicles did not pass the chest deflection criteria even with thorax air bags. This means that additional structure may have to be added for some vehicles. Based on confidential information provided in the last fuel economy rulemaking from several manufacturers, the side structure of many vehicles has been increased due to the side oblique pole test. Based on the confidential information, an average estimate of the weight added per vehicle is 12.85 pounds for both passenger cars and light trucks. Based on MY 2008 certification data, an estimated 6.1 percent of passenger cars and 17.9 percent of light trucks certified compliance to the oblique pole test requirements. Because the relative percent of sales of certifying models decreased in MY 2010 compared to MY 2008, MY 2010 certification data showed slightly less but essentially the same percent of vehicles certified compliance as in MY 2008 (MY 2010 certification data showed 5.9 percent for passenger cars and 17.6 percent for light trucks). Thus, an estimate of the increased structural weight that will be added between MY 2008 or MY 2010 and MY 2017 is 12.07 pounds for passenger cars and 10.55 pounds for light trucks {(1 - .061)*12.85 pounds and (1 - .179)*12.85 pounds}.

Combined, the total weight added for FMVSS 214 oblique pole test between MY 2008 or MY 2010 and MY 2017 is estimated to be 12.43 pounds (0.37 + 10.05) for passenger cars and 11.57 pounds (1.02 + 10.55) for light trucks.

FMVSS 216, Roof Crush

On May 12, 2009, NHTSA issued a final rule amending the roof crush standard from 1.5 times the vehicle weight to 3.0 times the vehicle weight for passenger cars and light trucks of 6,000 lb.

[69] Khadilkar, et al. “Teardown Cost Estimates of Automotive Equipment Manufactured to Comply with Motor Vehicle Standard – FMVSS 214(D) – Side Impact Protection, Side Air Bag Features”, April 2003, DOT HS 809 809.

[70] Ludtke & Associates, “Perform Cost and Weight Analysis, Head Protection Air Bag Systems, FMVSS 201”, page 4-3 to 4-5, DOT HS 809 842.

GVWR or less.[71] Vehicles over 6,000 lb. and less than 10,000 lb. GVWR will be required to meet the same test, but at 1.5 times the vehicle weight. This rule will apply to all passenger cars and light trucks by MY 2017. In the FRIA for that rulemaking, the average passenger car and light truck weight was estimated to increase weight by 7.9 to 15.4 lb. The average weight of 11.65 lb. will be used in this analysis for both the MY 2008 and MY 2010 baselines.

FMVSS 226 Ejection Mitigation

On January 19, 2011, the agency published a final rule on ejection mitigation.[72] The final rule will result in larger window curtain side air bags and for a rollover sensor to be installed. Based on cost/weight tear down studies, the agency estimates that there will be an incremental weight increase of 0.73 pounds for air bag material and 1.27 pounds for a larger inflator for a total of 2.0 pounds for passenger cars compared to the side air bags needed for the oblique side pole test. The rollover sensor has a very minor weight. For light trucks, of which about 72 percent will have 3 rows of curtain coverage instead of 2 rows in most passenger cars, this estimate is increased by 25 percent to 2.5 pounds. Thus, for the average light truck the estimate is 2.36 pounds (0.72*2.5 + 0.28* 2.0) for both the MY 2008 and MY 2010 baselines.

FMVSS 301 Fuel System Integrity

NHTSA issued a final rule changing the rear impact test procedure to a 50 mph offset test. The phase-in effective dates are 40 percent for MY 2007, 70 percent for MY 2008, and 100 percent for MY 2009. Thus, an incremental 30 percent of the fleet needs to meet the standard in comparison to the MY 2008 baseline, while all of the MY 2010 vehicles must comply. Several different countermeasures could be used to meet the standard. Averaging the most likely two countermeasures in the analysis for that rulemaking resulted[73] in an estimated 3.7 lb. to passenger cars and light trucks. Assuming an incremental 30 percent of the fleet for MY 2009 at 3.7 lb., results in an increase of 1.11 lb. for the average vehicle under the MY 2008 baseline.

Weight Impacts of proposed or potential rules that might affect MY 2017 and later vehicles

Based on NPRMs that the agency has issued, and based on projects in the priority plan, the agency has selected a list of rulemakings that might also affect weight in the rulemaking time

[71] Final Regulatory Impact Analysis, FMVSS 216 Upgrade Roof Crush Resistance, (Docket No. NHTSA-2009-0093-0004) (May 12, 2009) (74 FR 22347)
[72] 76 FR 3212, January 19, 2011, The Final Regulatory Impact Analysis is in Docket No. NHTSA-2011-0004-0003.
[73] Improvements in the fuel filler neck and redesigning areas around the fuel tank shield, for example a deformed gusset plate punctured the fuel tank wall.

frame. However, we note that there is no guarantee that these projects will become final rules, and therefore estimates of additional weight that might be due to these potential rules are included in order to be conservative as to the impacts of other standards on fuel economy. Additionally, unless an NPRM has been issued, the weight estimates for these projects remain even more uncertain, since we would not have an actual proposed alternative to determine the stringency of the proposal.

1. FMVSS 111, Rear Visibility (Cameras)
2. Pedestrian Protection
3. Forward Collision Warning and Crash Imminent Braking
4. Lane Departure Warning
5. Oblique/Low Offset Frontal Collision
6. Event Data Recorders (EDR)

FMVSS 111, Rear Visibility

On December 7, 2008, the agency issued a notice of proposed rulemaking (NPRM) on rear visibility for passenger cars and light trucks. At this point it appears that cameras are the only countermeasure that could meet all the criteria of the proposal. Based on the results of a tear down study[74], we estimate the weight of a camera assembly with the display in the mirror at 0.68 lb., and a camera assembly with the display on the dash at 0.26 lb. Assuming a 50-50 split in these two display methods, the average weight increase would be 0.47 lb. Based on sales information, only a small percent of passenger cars had cameras for MY 2008 and about 5 percent of the light trucks had cameras. While a larger percent of the fleet has cameras as an option in MY 2008, the agency does not have sales figures or take rates on those optional systems to update those percentages. Thus, the incremental weights are estimated to be 0.47 lb. for passenger cars and 0.45 lb. for light trucks for MY 2008.

For MY 2010, an estimated 10.5 percent of passenger cars have cameras and 30.1 percent of light trucks have cameras, thus, the incremental weights are estimated to be 0.42 lb. for passenger cars and 0.33 lb. for light trucks.

Pedestrian Protection

[74] Will be added to Docket No. NHTSA-2011-0066.

The agency currently expects to propose the Global Technical Regulation on pedestrian protection. The effective dates have not been decided. Potential weight increases for pedestrian head and leg protection have not yet been identified, but the leg protection part of the standard has the potential to add an unknown amount of weight to the front of the vehicle by changing the material used on front end to a softer material.

Forward Collision Warning and Crash Imminent Braking

This is a research project in the priority plan that examines forward collision warning, dynamic brake support and crash imminent braking. The agency has underway a cost tear down study of a variety of these systems. Preliminary information from this cost tear down study shows that the forward collision warning system has a camera and adds 0.64 lb., the forward collision warning with dynamic brake support systems have radar and add 2.61 to 3.27 lb., and the forward collision warning with dynamic brake support and crash imminent braking have radar and a camera and add 4.09 to 6.00 lb. Not knowing where the technology might go voluntarily or what rulemakings the agency might consider in the future, we put the range of weights into the analysis at 0.64 lb. to 6.00 lb. for both MY 2008 and MY 2010 baselines.

Lane Departure Warning

This is another research project that could add 0.64 pounds to each vehicle. It could use the same camera behind the mirror that might be used for a forward collision warning system discussed above. But not all systems discussed above used a camera, some only used radar. However, all systems that made up the range of weights in the 0.64 to 6.00 lb. above used cameras, thus this weight would not be additive to the weight assumed for forward collision warning.

Oblique or Small Offset Frontal Collision

The agency has made no decisions on this research project yet, but it does have the potential to add many pounds to the front of the vehicle (20-40 lb.) to have structure on the corners of the vehicle.

Part 563 Event Data Recorders

The agency anticipates about 1.0 pound of additional wiring or modules will be required by some manufacturers to meet future potential standards in this area. At this time, this only includes requiring the current voluntary standard and does not include other potential updates which have not been proposed. Since 92 percent of the current new vehicle fleet has event data recorders, the average incremental weight for the fleet is estimated at 0.08 lb.

Voluntary Measures that could affect weight

There are other voluntary measures that some manufacturers have identified as potentially increasing weight substantially. These include:

New NCAP tests – these have yet to be proposed, so their impact is not known.

IIHS testing of a narrow frontal pole test – how much overlap there is between meeting this test and the oblique/low offset frontal collision is not known. Potentially the same countermeasures could be designed to meet both projects.

Summary – Overview of Anticipated Weight Increases

Table IV-3a summarizes estimates made by NHTSA regarding the weight added by the above discussed standards or potential rulemakings with a MY 2008 baseline and Table IV-3b summarizes the same for a MY 2010 baseline. NHTSA currently estimates that weight additions required by final rules will add 32.31 pounds for passenger cars and 30.09 pounds for light trucks. With more uncertainty, we have estimated weight impacts of potential NHTSA regulations that would be effective by MY 2025, compared to the MY 2008 fleet, would increase weight by 21.19 to 46.55 pounds for passenger cars and 21.17 to 46.53 pounds for light trucks. The combined weight increase of these safety standards are estimated at 53.50 to 78.86 pounds for passenger cars and 51.26 to 76.62 pounds for light trucks.

With a MY 2010 baseline, the estimated weight increases required by final rules will add 27.18 pounds for passenger cars and 26.38 pounds for light trucks. With more uncertainty, we have estimated weight impacts of potential NHTSA regulations that would be effective by MY 2025, compared to the MY 2010 fleet, would increase weight by 21.14 to 46.50 pounds for passenger cars and 21.05 to 46.41 pounds for light trucks. The combined weight increase of these safety standards are estimated at 48.32 to 73.68 pounds for passenger cars and 47.43 to 72.79 pounds for light trucks.

Table IV-3a

NHTSA ESTIMATES

Weight Additions Due to Final Rules or Potential NHTSA Regulations
Comparing MY 2025 to the MY 2008 Baseline fleet

Final Rules by FMVSS No.	Passenger Cars Added Weight (pounds)	Passenger Cars Added Weight (kilograms)	Light Trucks Added Weight (pounds)	Light Trucks Added Weight (kilograms)
126 ESC	2.12	0.96	0.29	0.13
202a Head Restraints	3.00	1.36	3.00	1.36
206 Door Locks	0.00	0.00	0.11	0.05
208 5th Female 35 mph Test	0.00	0.00	0.00	0.00
214 Side Pole Test	12.43	5.64	11.57	5.25
216 Roof Crush	11.65	5.28	11.65	5.28
226 Ejection Mitigation	2.00	0.91	2.36	1.07
301 Fuel Tank	1.11	0.50	1.11	0.50
Final Rules Subtotal	32.31	14.66	30.09	13.64

Potential Rules				
111 Rear Cameras	0.47	0.21	0.45	0.20
Pedestrian Protection	?	?	?	?
Forward Collision Warning	0.64 to 6.00	0.29 to 2.72	0.64 to 6.00	0.29 to 2.72
Lane Departure Warning	Included above	Included above	Included above	Included above
Oblique/Offset Frontal	20.00 - 40.00	9.07 - 18.14	20.00 - 40.00	9.07 - 18.14
Part 563 EDR	0.08	0.04	0.08	0.04
Potential Rules Subtotal	21.19 – 46.55	9.61 – 21.11	21.17 – 46.53	9.60 – 21.10
Total	53.50 – 78.86	24.27 – 35.77	51.26 – 76.62	23.24 – 34.74

Table IV-3b

NHTSA ESTIMATES

Weight Additions Due to Final Rules or Potential NHTSA Regulations
Comparing MY 2025 to the MY 2010 Baseline fleet

Final Rules by FMVSS No.	**Passenger Cars Added Weight (pounds)**	**Passenger Cars Added Weight (kilograms)**	**Light Trucks Added Weight (pounds)**	**Light Trucks Added Weight (kilograms)**
126 ESC	0.50	0.23	0.20	0.09
202a Head Restraints	0.60	0.27	0.60	0.27
206 Door Locks	0.00	0.00	0.00	0.00
208 5th Female 35 mph Test	0.00	0.00	0.00	0.00
214 Side Pole Test	12.43	5.64	11.57	5.25
216 Roof Crush	11.65	5.28	11.65	5.28
226 Ejection Mitigation	2.00	0.91	2.36	1.07
301 Fuel Tank	0	0	0	0
Final Rules Subtotal	27.18	12.33	26.38	11.96

Potential Rules				
111 Rear Cameras	0.42	0.19	0.33	0.15
Pedestrian Protection	?	?	?	?
Forward Collision Warning	0.64 to 6.00	0.29 to 2.72	0.64 to 6.00	0.29 to 2.72
Lane Departure Warning	Included above	Included above	Included above	Included above
Oblique/Offset Frontal	20.00 - 40.00	9.07 - 18.14	20.00 - 40.00	9.07 - 18.14
Part 563 EDR	0.08	0.04	0.08	0.04
Potential Rules Subtotal	21.14 – 46.50	9.59 – 21.09	21.05 – 46.41	9.55 – 21.05
Total	48.32 – 73.68	21.92 – 33.42	47.43 – 72.79	21.51 – 33.01

[CONFIDENTIAL

Table IV-4 provides a comparison of NHTSA estimates to those provided confidentially by].

V. FUEL ECONOMY ENHANCING TECHNOLOGIES AND THE CAFE MODEL

What attribute and mathematical function do the agencies use, and why?

As in the MYs 2012-2016 CAFE rule, and as NHTSA did in the MY 2011 CAFE rule, NHTSA is proposing to set attribute-based CAFE standards that are defined by a mathematical function. EPCA, as amended by EISA, expressly requires that CAFE standards for passenger cars and light trucks be based on one or more vehicle attributes related to fuel economy, and be expressed in the form of a mathematical function.[75] Public comments on the MYs 2012-2016 rulemaking widely supported attribute-based standards.

Under an attribute-based standard, every vehicle model has a fuel economy target, the level of which depends on the vehicle's attribute (for this final rule, footprint, as discussed below). The manufacturers' fleet average performance is determined by the harmonic production-weighted[76] average of those targets.

NHTSA believes an attribute-based standard is preferable to a single-industry-wide average standard in the context of CAFE standards for several reasons. First, if the shape is chosen properly, every manufacturer is more likely to be required to continue adding more fuel efficient technology each year across their fleet, because the stringency of the compliance obligation will depend on the particular product mix of each manufacturer. Therefore a maximum feasible attribute-based standard will tend to require greater fuel savings and CO_2 emissions reductions overall than would a maximum feasible flat standard (that is, a single mpg level applicable to every manufacturer).

Second, depending on the attribute, attribute-based standards reduce the incentive for manufacturers to respond to CAFE standards in ways harmful to safety.[77] Because each vehicle model has its own target (based on the attribute chosen), properly fitted attribute-based standards provide little, if any, incentive to build smaller vehicles simply to meet a fleet-wide average, because the smaller vehicles will be subject to more stringent compliance targets.[78]

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[75] 49 U.S.C. 32902(a)(3)(A).

[76] Production for sale in the United States.

[77] The 2002 NAS Report described at length and quantified the potential safety problem with average fuel economy standards that specify a single numerical requirement for the entire industry. *See* 2002 NAS Report at 5, finding 12. Ensuing analyses, including by NHTSA, support the fundamental conclusion that standards structured to minimize incentives to downsize all but the largest vehicles will tend to produce better safety outcomes than flat standards.

[78] Assuming that the attribute is related to vehicle size.

Third, attribute-based standards provide a more equitable regulatory framework for different vehicle manufacturers.[79] A single industry-wide average standard imposes disproportionate cost burdens and compliance difficulties on the manufacturers that need to change their product plans to meet the standards, and puts no obligation on those manufacturers that have no need to change their plans. As discussed above, attribute-based standards help to spread the regulatory cost burden for fuel economy more broadly across all of the vehicle manufacturers within the industry.

Fourth, attribute-based standards better respect economic conditions and consumer choice, as compared to single-value standards. A flat, or single-value standard, encourages a certain vehicle size fleet mix by creating incentives for manufacturers to use vehicle downsizing as a compliance strategy. Under a footprint-based standard, manufacturers are required to invest in technologies that improve the fuel economy of the vehicles they sell rather than shifting the product mix, because reducing the size of the vehicle is generally a less viable compliance strategy given that smaller vehicles have more stringent regulatory targets.

As in the MYs 2012-2016 CAFE rules, and as NHTSA did in the MY 2011 CAFE rule, NHTSA is setting CAFE standards that are based on vehicle footprint, which has an observable correlation to fuel economy and emissions. There are several policy and technical reasons why NHTSA believes that footprint is the most appropriate attribute on which to base the standards, even though some other vehicle attributes (notably curb weight) are better correlated to fuel economy and emissions.

First, in the agency's judgment, from the standpoint of vehicle safety, it is important that the CAFE and CO_2 standards be set in a way that does not encourage manufacturers to respond by selling vehicles that are in any way less safe. While NHTSA's research of historical crash data also indicates that reductions in vehicle mass that are accompanied by reductions in vehicle footprint tend to compromise vehicle safety, footprint-based standards provide an incentive to use advanced lightweight materials and structures that would be discouraged by weight-based standards, because manufacturers can use them to improve a vehicle's fuel economy and CO_2 emissions without their use necessarily resulting in a change in the vehicle's fuel economy and emissions targets.

Further, although we recognize that weight is better correlated with fuel economy than is footprint, we continue to believe that there is less risk of "gaming" (changing the attribute(s) to achieve a more favorable target) by increasing footprint under footprint-based standards than by increasing vehicle mass under weight-based standards—it is relatively easy for a manufacturer to add enough weight to a vehicle to decrease its applicable fuel economy target a significant amount, as compared to increasing vehicle footprint. We also continue to agree with concerns

[79] *Id*. at 4-5, finding 10.

raised in 2008 by some commenters on the MY 2011 CAFE rulemaking that there would be greater potential for gaming under multi-attribute standards, such as those that also depend on weight, torque, power, towing capability, and/or off-road capability. As presented in NHTSA's MY 2011 CAFE final rule,[80] we anticipate that the possibility of gaming is lowest with footprint-based standards, as opposed to weight-based or multi-attribute-based standards. Specifically, standards that incorporate weight, torque, power, towing capability, and/or off-road capability in addition to footprint would not only be more complex, but by providing degrees of freedom with respect to more easily-adjusted attributes, they could make it less certain that the future fleet would actually achieve the average fuel economy levels projected by the agency.

NHTSA recognizes that based on economic and consumer demand factors that are external to this rule, the distribution of footprints in the future may be different (either smaller or larger) than what is projected in this rule. However, NHTSA continues to believe that there will not be significant shifts in this distribution as a direct consequence of this proposed rule. The agency also recognizes that some international attribute-based standards use attributes other than footprint and that there could be benefits for a number of manufacturers if there was greater international harmonization of fuel economy and GHG standards for light-duty vehicles, but this is largely a question of how stringent standards are and how they are tested and enforced. It is entirely possible that footprint-based and weight-based systems can coexist internationally and not present an undue burden for manufacturers if they are carefully crafted. Different countries or regions may find different attributes appropriate for basing standards, depending on the particular challenges they face—from fuel prices, to family size and land use, to safety concerns, to fleet composition and consumer preference, to other environmental challenges besides climate change. NHTSA anticipates working more closely with other countries and regions in the future to consider how to address these issues in a way that least burdens manufacturers while respecting each country's need to meet its own particular challenges.

NHTSA continues to find that footprint is the most appropriate attribute upon which to base the proposed standards, but recognizing strong public interest in this issue, for the proposal we sought comment on whether the agency should consider setting standards for the final rule based on another attribute or another combination of attributes. If commenters suggested that the agency should consider another attribute or another combination of attributes, we specifically requested that commenters address the concerns raised in the paragraphs above regarding the use of other attributes, and explain how standards should be developed using the other attribute(s) in a way that contributes more to fuel savings and CO_2 reductions than the footprint-based standards, without compromising safety Comments on the choice of attribute (or attributes) are summarized and discussed below and in Section IV of the preamble to today's rule.

[80] *See* 74 FR at 14359 (Mar. 30, 2009).

For the MY 2011 CAFE rule, NHTSA estimated fuel economy levels after normalization for differences in technology.[81] Starting with the technology adjusted passenger car and light truck fleets, NHTSA used minimum absolute deviation (MAD) regression without sales weighting to fit a logistic form as a starting point to develop mathematical functions defining the standards. NHTSA then identified footprints at which to apply minimum and maximum values (rather than letting the standards extend without limit) and transposed these functions vertically (*i.e.*, on a gpm basis, uniformly downward) to produce the promulgated standards. In the preceding rule, for MYs 2008-2011 light truck standards, NHTSA examined a range of potential functional forms, and concluded that, compared to other considered forms, the constrained logistic form provided the expected and appropriate trend (decreasing fuel economy as footprint increases), but avoided creating "kinks" the agency was concerned would provide distortional incentives for vehicles with neighboring footprints.[82]

For the MYs 2012-2016 rules, NHTSA and EPA re-evaluated potential methods for specifying mathematical functions to define fuel economy and GHG standards. The agencies concluded that the constrained logistic form, if applied to post-MY 2011 standards, would likely contain a steep mid-section that would provide undue incentive to increase the footprint of midsize passenger cars.[83] The agencies judged that a range of methods to fit the curves would be reasonable, and used a minimum absolute deviation (MAD) regression without sales weighting on a technology-adjusted car and light truck fleet to fit a linear equation. This equation was used as a starting point to develop mathematical functions defining the standards as discussed above. The agencies then identified footprints at which to apply minimum and maximum values (rather than letting the standards extend without limit) and transposed these constrained/piecewise linear functions vertically (*i.e.*, on a gpm or CO_2 basis, uniformly downward) to produce the fleet-wide fuel economy and CO_2 emission levels for cars and light trucks described in the final rule.[84]

By requiring NHTSA to set CAFE standards that are attribute-based and defined by a mathematical function, Congress appears to have wanted the post-EISA standards to be data-driven – a mathematical function defining the standards, in order to be "attribute-based," should reflect the observed relationship in the data between the attribute chosen and fuel economy.[85] The relationship between fuel economy and footprint, though directionally clear (*i.e.*, fuel

[81] *See* 74 FR 14196, 14363-14370 (Mar. 30, 2009) for NHTSA discussion of curve fitting in the MY 2011 CAFE final rule.
[82] *See* 71 FR 17556, 17609-17613 (Apr. 6, 2006) for NHTSA discussion of "kinks" in the MYs 2008-2011 light truck CAFE final rule (there described as "edge effects"). A "kink," as used here, is a portion of the curve where a small change in footprint results in a disproportionally large change in stringency.
[83] 75 FR at 25362
[84] *See generally* 74 FR at 49491-96; 75 FR at 25357-62.
[85] A mathematical function can be defined, of course, that has nothing to do with the relationship between fuel economy and the chosen attribute – the most basic example is an industry-wide standard defined as the mathematical function *average required fuel economy* $= X$, where X is the single mpg level set by the agency. Yet a standard that is simply defined as a mathematical function that is not tied to the attribute(s) would not meet the requirement of EISA.

economy tends to decrease with increasing footprint), is theoretically vague and quantitatively uncertain; in other words, not so precise as to *a priori* yield only a single possible curve.[86] There is thus a range of legitimate options open to NHTSA in developing curve shapes. The agency may of course consider statutory objectives in choosing among the many reasonable alternatives. For example, curve shapes that might have some theoretical basis could lead to perverse outcomes contrary to the intent of the statute to conserve energy.[87] Thus, the decision of how to set the target curves cannot always be just about most "clearly" using a mathematical function to define the relationship between fuel economy and the attribute; it often has to have a normative aspect, where the agency adjusts the function that would define the relationship in order to avoid perverse results, improve equity of burden across manufacturers, preserve consumer choice, etc. This is true both for the decisions that guide the mathematical function defining the sloped portion of the target curves, and for the separate decisions that guide our choice of "cut-points" (if any) that define the fuel economy and footprints at each end of the curves where the curves become flat. Data informs these decisions, but how the agency defines and interprets the relevant data, and then the choice of methodology for fitting a curve to the data, must include a consideration of both technical concerns and policy goals.

Each of the CAFE standards that NHTSA is setting today for passenger cars and light trucks is expressed as a mathematical function that defines a fuel economy target applicable to each vehicle model and, for each fleet, establishes a required CAFE level determined by computing the sales-weighted harmonic average of those targets. We emphasize that whenever NHTSA shows required CAFE mpg levels, they are estimated required levels based on NHTSA's current projection of manufacturers' vehicle fleets in MYs 2017–2025. Actual required levels are not determined until the end of each model year, when all of the vehicles produced by a manufacturer in that model year are known and their compliance obligation can be determined with certainty. The target curves, as defined by the constrained linear function, and as embedded in the function for the sales-weighted harmonic average, are the real "standards."

NHTSA has determined passenger car fuel economy targets using a constrained linear function defined according to the following formula:

[86] In fact, numerous manufacturers have confidentially shared with the agencies what they described as "physics based" curves, with each OEM showing significantly different shapes, and footprint relationships. The sheer variety of curves shown to the agencies further confirm the lack of an underlying principle of "fundamental physics" driving the relationship between CO_2 emission or fuel consumption and footprint, and the lack of an underlying principle to dictate any outcome of the agencies' establishment of footprint-based standards.

[87] For example, if the agencies set weight-based standards defined by a steep function, the standards might encourage manufacturers to keep adding weight to their vehicles to obtain less stringent targets.

$$TARGET = \frac{1}{MIN\left[MAX\left(c \times FOOTPRINT + d, \frac{1}{a}\right), \frac{1}{b}\right]}$$

Here, *TARGET* is the fuel economy target (in mpg) applicable to vehicles of a given footprint (*FOOTPRINT*, in square feet), *b* and *a* are the function's lower and upper asymptotes (also in mpg), respectively, *c* is the slope (in gallons per mile per square foot) of the sloped portion of the function, and *d* is the intercept (in gallons per mile) of the sloped portion of the function (that is, the value the sloped portion would take if extended to a footprint of 0 square feet. The *MIN* and *MAX* functions take the minimum and maximum, respectively of the included values.

NHTSA is finalizing for this rule, consistent with the proposal and the standards for MYs 2011-2016, that the CAFE level required of any given manufacturer be determined by calculating the production-weighted harmonic average of the fuel economy targets applicable to each vehicle model:

$$CAFE_{required} = \frac{\sum_i PRODUCTION_i}{\sum_i \frac{PRODUCTION_i}{TARGET_i}}$$

$PRODUCTION_i$ is the number of units produced for sale in the United States of each i^{th} unique footprint within each model type, produced for sale in the United States, and $TARGET_i$ is the corresponding fuel economy target (according to the equation shown above and based on the corresponding footprint), and the summations in the numerator and denominator are both performed over all unique footprint and model type combinations in the fleet in question.

The proposed standards for passenger cars are, therefore, specified by the four coefficients defining fuel economy targets:

a = upper limit (mpg)
b = lower limit (mpg)
c = slope (gallon per mile per square foot)
d = intercept (gallon per mile)

For light trucks, NHTSA is proposing to define fuel economy targets in terms of a mathematical function under which the target is the maximum of values determined under each of two constrained linear functions. The second of these establishes a "floor" reflecting the MY 2016 standard, after accounting for estimated adjustments reflecting increased air conditioner efficiency. This prevents the target at any footprint from declining between model years. The resultant mathematical function is as follows:

$$TARGET = MAX\left(\frac{1}{MIN\left[MAX\left(c \times FOOTPRINT + d, \frac{1}{a}\right), \frac{1}{b}\right]}, \frac{1}{MIN\left[MAX\left(g \times FOOTPRINT + h, \frac{1}{e}\right), \frac{1}{f}\right]}\right)$$

The proposed standards for light trucks are, therefore, specified by the eight coefficients defining fuel economy targets:

a = upper limit (mpg)
b = lower limit (mpg)
c = slope (gallon per mile per square foot)
d = intercept (gallon per mile)
e = upper limit (mpg) of "floor"
f = lower limit (mpg) of "floor"
g = slope (gallon per mile per square foot) of "floor"
h = intercept (gallon per mile) of "floor"

Why are standards attribute-based and defined by a mathematical function?

As in the MYs 2012-2016 CAFE/GHG rules, and as NHTSA did in the MY 2011 CAFE rule, NHTSA is promulgating attribute-based CAFE standards that are defined by a mathematical function. EPCA, as amended by EISA, expressly requires that CAFE standards for passenger cars and light trucks be based on one or more vehicle attributes related to fuel economy, and be expressed in the form of a mathematical function.[88] Public comments on the MYs 2012-2016 rulemaking widely supported attribute-based standards for NHTSA's standards. Comments received on the MY 2017 and later proposal also generally supported an attribute-based standard, as further discussed in sections II.C and IV of the preamble to today's final rule.

Under an attribute-based standard, every vehicle model has a performance target (fuel economy and CO_2 emissions for CAFE standards, respectively), the level of which depends on the vehicle's attribute (for this rule, footprint, as discussed below). The manufacturers' fleet average

[88] 49 U.S.C. 32902(a)(3)(A).

performance is determined by the production-weighted[89] average (for CAFE, harmonic average) of those targets.

NHTSA believes that an attribute-based standard is preferable to a single-industry-wide average standard in the context of CAFE standards for several reasons. First, if the shape is chosen properly, every manufacturer is more likely to be required to continue adding more fuel efficient technology each year across their fleet, because the stringency of the compliance obligation will depend on the particular product mix of each manufacturer. Therefore a maximum feasible attribute-based standard will tend to require greater fuel savings and CO_2 emissions reductions overall than would a maximum feasible flat standard (that is, a single mpg or CO_2 level applicable to every manufacturer).

Second, depending on the attribute, attribute-based standards reduce the incentive for manufacturers to respond to CAFE standards in ways harmful to safety.[90] Because each vehicle model has its own target (based on the attribute chosen), properly fitted attribute-based standards provide little, if any, incentive to build smaller vehicles simply to meet a fleet-wide average, because the smaller vehicles will be subject to more stringent compliance targets.[91]

Third, attribute-based standards provide a more equitable regulatory framework for different vehicle manufacturers.[92] A single industry-wide average standard imposes disproportionate cost burdens and compliance difficulties on the manufacturers that need to change their product plans to meet the standards, and puts no obligation on those manufacturers that have no need to change their plans. As discussed above, attribute-based standards help to spread the regulatory cost burden for fuel economy more broadly across all of the vehicle manufacturers within the industry.

Fourth, attribute-based standards better respect economic conditions and consumer choice, as compared to single-value standards. A flat, or single value, standard encourages a certain vehicle size fleet mix by creating incentives for manufacturers to use vehicle downsizing as a compliance strategy. Under a footprint-based standard, manufacturers have greater incentive (compared to under a flat standard) to invest in technologies that improve the fuel economy of the vehicles they sell rather than shifting product mix, because reducing the size of the vehicle is generally a less viable compliance strategy given that smaller vehicles have more stringent regulatory targets.

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[89] Production for sale in the United States.
[90] The 2002 NAS Report described at length and quantified the potential safety problem with average fuel economy standards that specify a single numerical requirement for the entire industry. *See* 2002 NAS Report at 5, finding 12. Ensuing analyses, including by NHTSA, support the fundamental conclusion that standards structured to minimize incentives to downsize all but the largest vehicles will tend to produce better safety outcomes than flat standards.
[91] Assuming that the attribute is related to vehicle size.
[92] *Id*. at 4-5, finding 10.

What attribute is NHTSA adopting, and why?

As in the MYs 2012-2016 CAFE/GHG rules, and as NHTSA did in the MY 2011 CAFE rule, NHTSA is promulgating CAFE standards that are based on vehicle footprint, which has an observable correlation to fuel economy and emissions. There are several policy and technical reasons why NHTSA believes that footprint is the most appropriate attribute on which to base the standards for the vehicles covered by this rulemaking, even though some other light-duty vehicle attributes (notably curb weight) are better correlated to fuel economy and emissions.

First, in NHTSA's judgment, from the standpoint of vehicle safety, it is important that the CAFE standards be set in a way that does not encourage manufacturers to respond by selling vehicles that are less safe. NHTSA's research of historical crash data has found that reductions in vehicle size and reductions in the mass of lighter vehicles tend to compromise overall highway safety, while reductions in the mass of heavier vehicles tend to improve overall highway safety. If footprint-based standards are defined in a way that creates relatively uniform burden for compliance for vehicles of all sizes, then footprint-based standards will not incentivize manufacturers to downsize their fleets as a strategy for compliance, which could compromise societal safety, or to upsize their fleets which might reduce the program's fuel savings and GHG emission reduction benefits. Footprint-based standards also enable manufacturers to apply weight-efficient materials and designs to their vehicles while maintaining footprint, as an effective means to improve fuel economy and reduce GHG emissions. On the other hand, depending on their design, weight-based standards can create disincentives for manufacturers to apply weight-efficient materials and designs. This is because weight-based standards would become more stringent as vehicle mass is reduced. NHTSA discusses mass reduction and its relation to safety in more detail in Preamble section II.G.

Further, although we recognize that weight is better correlated with fuel economy and CO_2 emissions than is footprint, we continue to believe that there is less risk of "gaming" (changing the attribute(s) to achieve a more favorable target) by increasing footprint under footprint-based standards than by increasing vehicle mass under weight-based standards—it is relatively easy for a manufacturer to add enough weight to a vehicle to decrease its applicable fuel economy target a significant amount, as compared to increasing vehicle footprint. We also continue to agree with concerns raised in 2008 by some commenters on the MY 2011 CAFE rulemaking that there would be greater potential for gaming under multi-attribute standards, such as those that also depend on weight, torque, power, towing capability, and/or off-road capability. NHTSA agrees with the assessment first presented in NHTSA's MY 2011 CAFE final rule[93] that the possibility

[93] *See* 74 FR at 14359 (Mar. 30, 2009).

of gaming an attribute-based standard is lowest with footprint-based standards, as opposed to weight-based or multi-attribute-based standards. Specifically, standards that incorporate weight, torque, power, towing capability, and/or off-road capability in addition to footprint would not only be more complex, but by providing degrees of freedom with respect to more easily-adjusted attributes, they could make it less certain that the future fleet would actually achieve the average fuel economy and CO_2 reduction levels projected by NHTSA.[94] This is not to say that a footprint-based system will eliminate gaming, or that a footprint-based system will eliminate the possibility that manufacturers will change vehicles in ways that compromise occupant protection. In NHTSA's judgment, footprint-based standards achieved the best balance among affected considerations.

NHTSA recognizes that based on economic and consumer demand factors that are external to this rule, the distribution of footprints in the future may be different (either smaller or larger) than what is projected in this rule. However, NHTSA continues to believe that there will not be significant shifts in this distribution as a direct consequence of this rule. We note that comments by CBD, ACEEE, and NACAA referenced a 2011 study by Whitefoot and Skerlos, "Design incentives to increase vehicle size created from the U.S. footprint-based fuel economy standards."[95] This study concluded that the proposed MY 2014 standards "create an incentive to increase vehicle size except when consumer preference for vehicle size is near its lower bound and preference for acceleration is near its upper bound."[96] The commenters who cited this study generally did so as part of arguments in favor of flatter standards (*i.e.*, curves that are flatter across the range of footprints) for MYs 2017-2025. While NHTSA considers the concept of the Whitefoot and Skerlos analysis to have some potential merits, it is also important to note that, among other things, the authors assumed different inputs than NHTSA actually used in the MYs 2012-2016 rules regarding the baseline fleet, the cost and efficacy of potential future technologies, and the relationship between vehicle footprint and fuel economy. Were NHTSA to use the Whitefoot and Skerlos methodology (*e.g.*, methods to simulate manufacturers' potential decisions to increase vehicle footprint) with the actual inputs to the MYs 2012-2016 rules, NHTSA would likely obtain different findings. Underlining the potential uncertainty, considering a range of scenarios, the authors obtained a wide range of results in their analyses. NHTSA discusses this study more fully in the Section II of the preamble and in this RIA.

NHTSA also recognizes that some international attribute-based standards use attributes other than footprint and that there could be benefits for a number of manufacturers if there was greater

[94]However, for heavy-duty pickups and vans not covered by today's standards, the agencies determined that use of footprint and work factor as attributes for heavy duty pickup and van GHG and fuel consumption standards could reasonably avoid excessive risk of gaming. See 76 FR 57106, 57161-62 (Sept. 15, 2011)

[95] Whitefoot, K.S. and Skerlos, S.J., "Design Incentives to Increase Vehicle Size Created from the U.S. Footprint-based Fuel Economy Standards," *Energy Policy,* Vol. 41, Issue 1, 2012, DOI: 10.1016/j.enpol.2011.10.062. *Prepublication version available at:* http://designscience.umich.edu/alumni/katie/Whitefoot_Skerlos_Footprint.pdf

[96] *Id.*, *see* Abstract, p. 1.

international harmonization of fuel economy and GHG standards for light-duty vehicles, but this is largely a question of how stringent standards are and how they are tested and enforced. It is entirely possible that footprint-based and weight-based systems can coexist internationally and not present an undue burden for manufacturers if they are carefully crafted. Different countries or regions may find different attributes appropriate for basing standards, depending on the particular challenges they face—from fuel prices, to family size and land use, to safety concerns, to fleet composition and consumer preference, to other environmental challenges besides climate change. NHTSA anticipates working more closely with other countries and regions in the future to consider how to address these issues in a way that least burdens manufacturers while respecting each country's need to meet its own particular challenges.

In the proposal, NHTSA found that footprint was the most appropriate attribute upon which to base the proposed standards. Recognizing strong public interest in this issue, NHTSA sought comment on whether a different attribute or combination of attributes should be considered in setting standards for the final rule. NHTSA specifically requested that the commenters address the concerns raised in the proposal regarding the use of other attributes, and explain how standards should be developed using the other attribute(s) in a way that contributes more to fuel savings and CO_2 reductions than the footprint-based standards, without compromising safety.

NHTSA received several comments regarding the attribute(s) upon which new CAFE standards should be based. NADA[97] and the Consumer Federation of America (CFA)[98] expressed support for attribute-based standards, generally, indicating that such standards accommodate consumer preferences, level the playing field between manufacturers, and remove the incentive to push consumers into smaller vehicles. Many commenters, including automobile manufacturers, NGOs, trade associations and parts suppliers (e.g., General Motors,[99] Ford,[100] American Chemistry Council,[101] Alliance of Automobile Manufacturers,[102] International Council on Clean Transportation,[103] Insurance Institute for Highway Safety,[104] Society of the Plastics Industry,[105] Aluminum Association,[106] Motor and Equipment Manufacturers Association,[107] and others) expressed support for the continued use of vehicle footprint as the attribute upon which to base CAFE standards, citing advantages similar to those mentioned by NADA and CFA. Conversely, the Institute for Policy Integrity (IPI) at the New York University School of Law questioned

[97] NADA, Docket No. NHTSA-2010-0131-0261, at 11.
[98] CFA, Docket No. EPA-HQ-OAR-2010-0799-9419, at 8, 44.
[99] GM, Docket No. NHTSA-2010-0131-0236, at 2.
[100] Ford, Docket No. NHTSA-2010-0131-0235, at 8.
[101] ACC, Docket No. NHTSA-2010-0131-0095, at 2.
[102] Alliance, Docket No. NHTSA-2010-0131-0262, at 85.
[103] ICCT, Docket No. NHTSA-2010-0131-0258, at 48.
[104] IIHS, Docket No. NHTSA-2010-0131-0222, at 1.
[105] SPI, Docket No. EPA-HQ-OAR-2010-0799-9492, at 4.
[106] Aluminum Association, Docket No. NHTSA-2010-0131-0226, at 1.
[107] MEMA, Docket No. EPA-HQ-OAR-2010-0799-9478, at 1.

whether non-attribute-based (flat) or an alternative attribute basis would be preferable to footprint-based standards as a means to increase benefits, improve safety, reduce "gaming," and/or equitably distribute compliance obligations.[108] IPI argued that, even under flat standards, credit trading provisions would serve to level the playing field between manufacturers. IPI acknowledged that NHTSA, unlike EPA, is required to promulgate attribute-based standards, and agreed that a footprint-based system could have much less risk of gaming than a weight-based system. IPI suggested that NHTSA consider a range of options, including a fuel-based system, and select the approach that maximizes net benefits. Ferrari and BMW suggested that NHTSA consider weight-based standards, citing the closer correlation between fuel economy and footprint, and BMW further suggested that weight-based standards might facilitate international harmonization (*i.e.,* between U.S. standards and related standards in other countries).[109] Porsche commented that the footprint attribute is not well suited for manufacturers of high performance vehicles with small footprints.[110]

Regarding the comments from IPI, as IPI appears to acknowledge, EPCA/EISA expressly requires that CAFE standards be attribute-based and defined in terms of mathematical functions. Also, NHTSA has, in fact, considered and reconsidered options other than footprint, over the course of multiple CAFE rulemakings conducted throughout the past decade. When first contemplating attribute-based systems, NHTSA considered attributes such as weight, "shadow" (overall area), footprint, power, torque, and towing capacity. NHTSA also considered approaches that would combine two or potentially more than two such attributes. To date, every time NHTSA has reconsidered options, the agency has concluded that a properly designed footprint-based approach provides the best means of achieving the basic policy goals (i.e., better balancing compliance burdens among full-line and limited-line manufacturers and reducing incentives for manufacturers to respond to standards by reducing vehicle size in ways that could compromise overall highway safety) involved in applying an attribute-based standards, and at the same time structuring footprint-based standards in a way that furthers the energy and environmental policy goals of EPCA and the CAA by controlling incentives to increase vehicle size in ways that could increase fuel consumption and GHG emissions.[111] In response to IPI's suggestion to use fuel-based standards as a type of attribute, although NHTSA has not presented quantitative analysis of standards that differentiate between fuel type for light-duty vehicles, such standards would effectively use fuel type to identify different subclasses of vehicles, thus requiring mathematical functions—not addressed by IPI's comments—to recombine these fuel types into regulated classes.[112] Insofar as EPCA/EISA already specifies how different fuel types

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[108] IPI, Docket No. EPA-HQ-OAR-2010-0799-9480, at 13-15.
[109] BMW, Docket No. NHTSA-2010-0131-0250, at 3.
[110] Porsche, Docket No. NHTSA-2010-0131-0224, at 7.
[111] *See* 71 FR 17566, at17595-17596 (April 6, 2006); 74 FR 14196, at14359 (March 30, 2009); 75 FR 25324 at 25333 (May 7, 2010).
[112] The agencies did adopt separate standards for gasoline and diesel heavy-duty pickups and vans based on technological differences between gasoline and diesel engines. See 76 FR at 57163-65. However, the agencies

are to be treated for purposes of calculating fuel economy and CAFE levels, and moreover, insofar as the EISA revisions to EPCA removed NHTSA's previously-clear authority to set separate CAFE standards for different classes of light trucks, using fuel type to further differentiate subclasses of vehicles could conflict with the intent, and possibly the letter, of NHTSA's governing statute. Finally, in NHTSA's judgment, while regarding IPI's suggestion that NHTSA select the attribute-based approach that maximizes net benefits may have merit, net benefits are but one of many considerations which lead to the setting of the standard. Also, such an undertaking would be impracticable at this time, considering that the mathematical forms applied under each attribute-based approach would also need to be specified, and that NHTSA lacks methods to reliably quantify the relative potential for induced changes in vehicle attributes.

Regarding Ferrari's and BMW's comments, as stated previously, in NHTSA's judgment, footprint-based standards (a) discourage vehicle downsizing that might compromise occupant protection, (b) encourage the application of technology, including weight-efficient materials (*e.g.*, high-strength steel, aluminum, magnesium, composites, *etc.*), and (c) are less susceptible than standards based on other attributes to "gaming" that could lead to less-than-projected energy and environmental benefits. It is also important to note that there are many differences between both the standards and the on-road light-duty vehicle fleets in Europe and the United States. The stringency of standards, independent of the attribute used, is another factor that influences harmonization. While NHTSA agrees that international harmonization of test procedures, calculation methods, and/or standards could be a laudable goal, again, harmonization is not simply a function of the attribute upon which the standards are based. Given the differences in the on-road fleet (including vehicle classification and use), in fuel composition and availability, in regional consumer preferences for different vehicle characteristics, in other vehicle regulations besides for fuel economy/CO_2 emissions, it would not necessarily be expected that the CAFE and GHG emission standards would align with standards of other countries. Thus, NHTSA continues to judge vehicle footprint to be a preferable attribute for the same reasons enumerated in the proposal and reiterated above.

What mathematical functions has NHTSA previously used, and why?

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stated that "standards that do not distinguish between fuel types are generally preferable where technological and market-based reasons do not strongly argue otherwise. These technological differences exist presently between gasoline and diesel engines for GHGs … The agencies emphasize, however, that they are not committed to perpetuating separate GHG standards for gasoline and diesel heavy-duty vehicles and engines, and expect to reexamine the need for separate gasoline/diesel standards in the next rulemaking." 76 FR at 57165. IPI did not suggest that there were any such technological distinctions justifying separate fuel-based attributes for light duty vehicles, and the agencies note that EPCA/EISA already specifies how different fuels are to be treated for pruposes of CAFE

NHTSA in MY 2008 and MY 2011 CAFE (constrained logistic)

For the MY 2011 CAFE rule, NHTSA estimated fuel economy levels after normalization for differences in technology, but did not make adjustments to reflect other vehicle attributes (*e.g.*, power-to-weight ratios).[113] Starting with the technology adjusted passenger car and light truck fleets, NHTSA used minimum absolute deviation (MAD) regression without sales weighting to fit a logistic form as a starting point to develop mathematical functions defining the standards. NHTSA then identified footprints at which to apply minimum and maximum values (rather than letting the standards extend without limit) and transposed these functions vertically (*i.e.*, on a gallons-per-mile basis, uniformly downward) to produce the promulgated standards. In the preceding rule, for MYs 2008-2011 light truck standards, NHTSA examined a range of potential functional forms, and concluded that, compared to other considered forms, the constrained logistic form provided the expected and appropriate trend (decreasing fuel economy as footprint increases), but avoided creating “kinks” the agency was concerned would provide distortionary incentives for vehicles with neighboring footprints.[114]

MYs 2012-2016 Light Duty GHG/CAFE (constrained/piecewise linear)

For the MYs 2012-2016 rules, NHTSA reevaluated potential methods for specifying mathematical functions to define fuel economy and GHG standards. NHTSA concluded that the constrained logistic form, if applied to post-MY 2011 standards, would likely contain a steep mid-section that would provide undue incentive to increase the footprint of midsize passenger cars.[115] NHTSA judged that a range of methods to fit the curves would be reasonable, and used a minimum absolute deviation (MAD) regression without sales weighting on a technology-adjusted car and light truck fleet to fit a linear equation. This equation was used as a starting point to develop mathematical functions defining the standards as discussed above. NHTSA then identified footprints at which to apply minimum and maximum values (rather than letting the standards extend without limit) and transposed these constrained/piecewise linear functions vertically (*i.e.*, on a gpm or CO_2 basis, uniformly downward) to produce the fleet wide fuel economy and CO_2 emission levels for cars and light trucks described in the final rule.[116]

[113] *See* 74 FR 14196, 14363-14370 (Mar. 30, 2009) for NHTSA discussion of curve fitting in the MY 2011 CAFE final rule.
[114] *See* 71 FR 17556, 17609-17613 (Apr. 6, 2006) for NHTSA discussion of “kinks” in the MYs 2008-2011 light truck CAFE final rule (there described as “edge effects”). A “kink,” as used here, is a portion of the curve where a small change in footprint results in a disproportionally large change in stringency.
[115] 75 FR at 25362.
[116] *See generally* 74 FR at 49491-96; 75 FR at 25357-62.

How has NHTSA defined the mathematical functions for the MYs 2017-2025 standards, and why?

By requiring NHTSA to set CAFE standards that are attribute-based and defined by a mathematical function, NHTSA interprets Congress as intending that the post-EISA standards to be data-driven – a mathematical function defining the standards, in order to be "attribute-based," should reflect the observed relationship in the data between the attribute chosen and fuel economy.[117]

The relationship between fuel economy (and GHG emissions) and footprint, though directionally clear (*i.e.*, fuel economy tends to decrease and CO_2 emissions tend to increase with increasing footprint), is theoretically vague and quantitatively uncertain; in other words, not so precise as to *a priori* yield only a single possible curve.[118] There is thus a range of legitimate options open to NHTSA in developing curve shapes. NHTSA may of course consider statutory objectives in choosing among the many reasonable alternatives since the statutes do not dictate a particular mathematical function for curve shape. For example, curve shapes that might have some theoretical basis could lead to perverse outcomes contrary to the intent of the statutes to conserve energy and reduce GHG emissions.[119] Thus, the decision of how to set the target curves cannot always be just about most "clearly" using a mathematical function to define the relationship between fuel economy and the attribute; it often has to have reflect legitimate policy judgments, where NHTSA adjusts the function that would define the relationship in order to achieve environmental goals, reduce petroleum consumption, encourage application of fuel-saving technologies, not adversely affect highway safety, reduce disparities of manufacturers' compliance burdens (thereby increasing the likelihood of improved fuel economy and reduced GHG emissions across the entire spectrum of footprint targets), preserve consumer choice, etc. This is true both for the decisions that guide the mathematical function defining the sloped portion of the target curves, and for the separate decisions that guide NHTSA's choice of "cutpoints" (if any) that define the fuel economy/CO_2 levels and footprints at each end of the curves where the curves become flat. Data informs these decisions, but how NHTSA defines

[117] A mathematical function can be defined, of course, that has nothing to do with the relationship between fuel economy and the chosen attribute – the most basic example is an industry-wide standard defined as the mathematical function *average required fuel economy* = *X*, where *X* is the single mpg level set by the agency. Yet a standard that is simply defined as a mathematical function that is not tied to the attribute(s) would not meet the requirement of EISA.

[118] In fact, numerous manufacturers have confidentially shared with the agencies what they describe as "physics based" curves, with each OEM showing significantly different shapes, and footprint relationships. The sheer variety of curves shown to the agencies further confirm the lack of an underlying principle of "fundamental physics" driving the relationship between CO_2 emission or fuel consumption and footprint, and the lack of an underlying principle to dictate any outcome of the agencies' establishment of footprint-based standards.

[119] For example, if the agencies set weight-based standards defined by a steep function, the standards might encourage manufacturers to keep adding weight to their vehicles to obtain less stringent targets.

and interprets the relevant data, and then the choice of methodology for fitting a curve to the data, must include a consideration of both technical data and policy goals. Supporting the consideration and selection of mathematical functions upon which to base new CAFE standards, NHTSA conducted a broad-ranging analysis spanning different techniques for adjusting data and fitting linear functions. The next sections examine the policy concerns that NHTSA considered in developing the target curves that define the MYs 2017-2025 CAFE standards, technical work (expanding on similar analyses performed by NHTSA when the agency proposed MY 2011-2015 standards, and by both agencies during consideration of options for MY 2012-2016 CAFE standards) that was completed in the process of reexamining potential mathematical functions for this rulemaking, how NHTSA has defined the data, and how NHTSA explored statistical curve-fitting methodologies in order to arrive at proposed and final curves. Because NHTSA is finalizing the target curves for MYs 2017-2025 as proposed, the following discussion largely mirrors the discussion in the version of the TSD that accompanied the proposal; it is repeated here for the reader's convenience.

What did NHTSA propose for the MYs 2017-2025 curves?

The mathematical functions for the proposed MYs 2017-2025 standards were somewhat changed from the functions for the MYs 2012-2016 standards, in response to comments received from stakeholders both pre-proposal and during the public comment period and in order to address technical concerns and policy goals that NHTSA judged more significant in this nine-model year rulemaking than in the prior one, which only included five model years.[120] This section discusses the methodology NHTSA selected as best addressing those technical concerns and policy goals for this rulemaking, given the various technical inputs to NHTSA's current analyses. The section titled "Once NHTSA determined the appropriate slope for the sloped part, how did NHTSA determine the rest of the mathematical function?", below, discusses how NHTSA determined the cutpoints and the flat portions of the MYs 2017-2025 target curves. We note that both of these sections address only how the target curves were fit to fuel consumption and CO_2 emission values determined using the city and highway test procedures, and that in determining respective regulatory alternatives, NHTSA made further adjustments to the resultant curves in order to account for adjustments for improvements to mobile air conditioners.

[120] We note that although, due to statutory constraints, NHTSA is finalizing standards for only MYs 2017-2021 and presenting augural standards for MYs 2022-2025, NHTSA's analysis was conducted with respect to shapes of target curves for all nine model years because NHTSA's augural standards for MYs 2022-2025 represent the agency's best estimate, based on the information currently before it, of the standards that the agency would finalize had it the authority to do so. NHTSA will fully revisit all aspects of the MYs 2022-2025 standards as part of the later rulemaking concurrent with the planned mid-term evaluation.

Thus, recognizing that there are many reasonable statistical methods for fitting curves to data points that define vehicles in terms of footprint and fuel economy, NHTSA chose for the proposed rule to fit curves using an ordinary least-squares formulation, on sales-weighted data, using a fleet that has had technology applied, and after adjusting the data for the effects of weight-to-footprint, as described below. This represents a departure from the statistical approach for fitting the curves in the MYs 2012-2016 rules, as explained in the next section. NHTSA considered a wide variety of reasonable statistical methods in order to better understand the range of uncertainty regarding the relationship between fuel consumption (the inverse of fuel economy), CO_2 emission rates, and footprint, thereby providing a range within which decisions about standards would be potentially supportable.

What concerns were NHTSA looking to address that led them to change from the approach used for the MYs 2012-2016 curves?

Before the MY 2017 and later proposal was issued, NHTSA received a number of comments from stakeholders on how curves should be fitted to the passenger car and light truck fleets.[121] Some limited-line manufacturers argued that curves should generally be flatter in order to avoid discouraging production of small vehicles, because steeper curves tend to result in more stringent targets for smaller vehicles. Most full-line manufacturers argued that a passenger car curve similar in slope to the MY 2016 passenger car curve would be appropriate for future model years, but that the light truck curve should be revised to be less stringent for manufacturers selling the largest full-size pickup trucks. These manufacturers argued that the MY 2016 light truck curve was not "physics-based," and that in order for future tightening of standards to be feasible for full-line manufacturers, the truck curve for later model years should be steeper and extended further (i.e., made less stringent) into the larger footprints. As stated in the TSD accompanying the proposal, NHTSA does not agree that the MY 2016 light truck curve was somehow deficient in lacking a "physics basis," or that it was somehow overly stringent for manufacturers selling large pickups—manufacturers making these arguments presented no "physics-based" model to explain how fuel economy should depend on footprint.[122] The same manufacturers indicated that they believed that the light truck standard should be somewhat steeper after MY 2016, primarily because, after more than ten years of progressive increases in the stringency of applicable CAFE standards, large pickups would be less capable of achieving further improvements without compromising load carrying and towing capacity.

In developing the curve shapes for the proposed rule, NHTSA was aware of the current and prior technical concerns raised by OEMs concerning the effects of the stringency on individual manufacturers and their ability to meet the standards with available technologies, while

[121] See 75 FR at 76341 for a general summary.
[122] See footnote 85.

producing vehicles at a cost that allowed them to recover the additional costs of the technologies being applied. Although we continue to believe that the methodology for fitting curves for the MYs 2012-2016 standards was technically sound, we recognize manufacturers' technical concerns regarding their abilities to comply with a similarly shallow curve after MY 2016 given the anticipated mix of light trucks in MYs 2017-2025. As in the MYs 2012-2016 rules, NHTSA considered these concerns in the analysis of potential curve shapes for the MYs 2017-2025 proposal. NHTSA also considered safety concerns which could be raised by curve shapes creating an incentive for vehicle downsizing, as well as the potential loss to consumer welfare should vehicle upsizing be unduly disincentivized. In addition, NHTSA sought to improve the balance of compliance burdens among manufacturers, and thereby increase the likelihood of improved fuel economy and reduced GHG emissions across the entire spectrum of footprint targets. Among the technical concerns and resultant policy trade-offs NHTSA considered were the following:

- Flatter standards (*i.e.*, curves) increase the risk that both the weight and size of vehicles will be reduced, potentially compromising highway safety.
- Flatter standards potentially impact the utility of vehicles by providing an incentive for vehicle downsizing.
- Steeper footprint-based standards may create incentives to upsize vehicles, thus increasing the possibility that fuel economy and greenhouse gas reduction benefits will be less than expected.
- Given the same industry-wide average required fuel economy or CO_2 standard, flatter standards tend to place greater compliance burdens on full-line manufacturers
- Given the same industry-wide average required fuel economy or CO_2 standard, steeper standards tend to place greater compliance burdens on limited-line manufacturers (depending of course, on which vehicles are being produced).
- If cutpoints are adopted, given the same industry-wide average required fuel economy, moving small-vehicle cutpoints to the left (*i.e.*, up in terms of fuel economy, down in terms of CO_2 emissions) discourages the introduction of small vehicles, and reduces the incentive to downsize small vehicles in ways that could compromise overall highway safety.
- If cutpoints are adopted, given the same industry-wide average required fuel economy, moving large-vehicle cutpoints to the right (*i.e.*, down in terms of fuel economy, up in terms of CO_2 emissions) better accommodates the design requirements of larger vehicles—especially large pickups—and extends the size range over which downsizing is discouraged.

All of these were policy goals that required weighing and consideration. Ultimately, NHTSA rejected the argument that the MY 2017 target curves for the proposal, on a relative basis, should be made significantly flatter than the MY 2016 curve,[123] as we believed that this would undo

[123] While "significantly" flatter is subjective qualitative description, the year over year change in curve shapes is discussed in greater detail in Section 0.

some of the safety-related incentives and balancing of compliance burdens among manufacturers—effects that attribute-based standards are intended to provide.

Nonetheless, NHTSA recognized full-line OEM concerns and tentatively concluded that further increases in the stringency of the light truck standards would be more feasible if the light truck curve is made steeper than the MY 2016 truck curve and the right (large footprint) cut-point is extended over time to larger footprints. This conclusion was supported by NHTSA's technical analyses of regulatory alternatives defined using the curves developed in the manner described below.

What methodologies and data did NHTSA consider in developing the 2017-2025 curves presented in the proposal?

In considering how to address the various policy concerns discussed in the previous sections, NHTSA revisited the data and performed a number of analyses using different combinations of the various statistical methods, weighting schemes, adjustments to the data and the addition of technologies to make the fleets less technologically heterogeneous. As discussed below, in NHTSA's judgment, there is no single "correct" way to estimate the relationship between CO_2 or fuel consumption and footprint – rather, each statistical result is based on the underlying assumptions about the particular functional form, weightings and error structures embodied in the representational approach. These assumptions are the subject of the following discussion.

This process of performing many analyses using combinations of statistical methods generated many possible outcomes, each embodying different potentially reasonable combinations of assumptions and each thus reflective of the data as viewed through a particular lens. The choice of a standard developed by a given combination of these statistical methods was consequently a decision based upon NHTSA's determination of how, given the policy objectives for this rulemaking and NHTSA's MY 2008-based forecast of the market through MY 2025, to appropriately reflect the current understanding of the evolution of automotive technology and costs, the future prospects for the vehicle market, and thereby establish curves (i.e., standards) for cars and light trucks.

For the MYs 2017-2025 standards, what information did NHTSA use to estimate a relationship between fuel economy, CO_2 and footprint?

For each fleet, NHTSA began with the MY 2008-based market forecast developed to support the proposal (*i.e.*, the baseline fleet), with vehicles' fuel economy levels and technological characteristics at MY 2008 levels.[124] The development, scope, and content of this market forecast are discussed in detail in Chapter 1 of the joint Technical Support Document supporting the proposed rulemaking.

Figure V-1 shows the MY 2008 CO_2 by car and truck class as it existed in the NHTSA CAFE NPRM model data files (for a gasoline-only fleet, fuel consumption—the inverse of fuel economy—is directly proportional to CO_2). This fleet was the starting point for all analysis in the proposal.

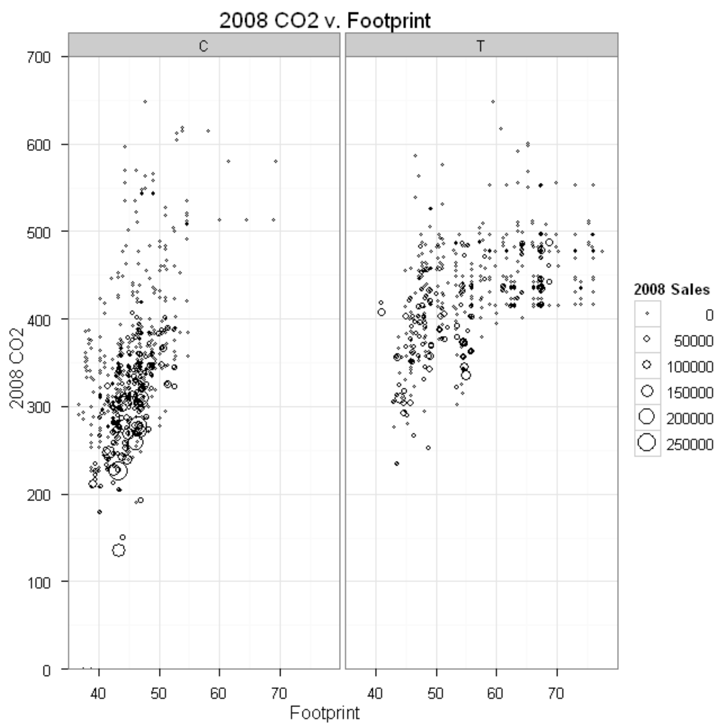

Figure V-1 2008 CO_2 vs. Footprint by Car and Truck

Although NHTSA is finalizing the target curves as proposed, NHTSA has also revisited and updated their analyses for this final rule, and found that the proposed curves are well within the ranges spanned by the final rule analyses. As discussed above, NHTSA has used two different market forecasts to conduct additional analyses supporting this final rule. The first, referred to here as the "MY 2008-Based Fleet Projection," is largely identical to that used for analysis supporting the NPRM, but includes some corrections to the footprint of some vehicle models discussed in section III of this RIA, as well as other minor changes. The second, referred to here as the "MY 2010-Based Fleet Projection," is a post-proposal market forecast based on the MY

[124] While the agencies jointly conducted this analysis, the coefficients ultimately used in the slope setting analysis are from the CAFE model.

2010 fleet of vehicles. Using both of these projected fleets, NHTSA repeated the analyses described below, and obtained broadly similar results, details of which are presented in a memorandum available in NHTSA's docket.[125] Because NHTSA is promulgating target curve standards identical to those proposed in the NPRM, the remainder of this chapter reviews results supporting the development of those proposed standards. This chapter concludes with a summary of results of NHTSA's updated analysis, and discussion of the consideration that analysis was given in selecting mathematical functions upon which to base the standards in the final rules.

What adjustments did NHTSA evaluate?

As indicated in the joint TSD supporting the NPRM, one possible approach is to fit curves to the minimally adjusted data shown above (the approach still includes sales mix adjustments, which influence results of sales-weighted regressions), much as DOT did when it first began evaluating potential attribute-based standards in 2003.[126] However, NHTSA found, as in prior rulemakings, that the data are so widely spread (*i.e.*, when graphed, they fall in a loose "cloud" rather than tightly around an obvious line) that they indicate a relationship between footprint and CO_2 and fuel consumption that is real but not particularly strong (Figure V-1). Therefore, as discussed below, NHTSA also explored possible adjustments that could help to explain and/or reduce the ambiguity of this relationship, or could help to produce policy outcomes NHTSA judged to be more desirable.

Adjustment to reflect differences in technology

As in prior rulemakings, NHTSA considered technology differences between vehicle models to be a significant factor producing uncertainty regarding the relationship between CO_2/fuel consumption and footprint. Noting that attribute-based standards are intended to encourage the application of additional technology to improve fuel efficiency and reduce CO_2 emissions, NHTSA, in addition to considering approaches based on the unadjusted engineering characteristics of MY 2008 vehicle models, therefore also considered approaches in which, as for previous rulemakings, technology is added to vehicles for purposes of the curve fitting analysis in order to produce fleets that are less varied in technology content. This approach helps to reduce "noise" (*i.e.*, dispersion) in the plot of vehicle footprints and fuel consumption levels and to identify a more technology-neutral relationship between footprint and fuel economy / CO_2 emissions.

[125] Docket No. NHTSA-2010-0131.
[126] 68 FR 74920-74926.

For the analysis supporting the NPRM, NHTSA adjusted the NPRM baseline fleet for technology by adding all technologies considered, except for, diesel engines, integrated starter generators, strong HEVs, PHEVs, EVs, FCVs, and the most advanced high-BMEP (brake mean effective pressure) gasoline engines.[127] NHTSA included 15 percent mass reduction on all vehicles. Figure V-2 shows the same fleet, with technology adjustment and 2021 sales applied, and the baseline diesel fueled vehicles, HEV and EVs removed from the fleet. Of note, the fleet is now more closely clustered[128] (and lower in emissions), but the same basic pattern emerges; in both figures, the CO_2 emission rate (which, as mentioned above, is directly proportional to fuel consumption for a gasoline-only fleet) increases with increasing footprint, although the relationship is less pronounced for larger light trucks.

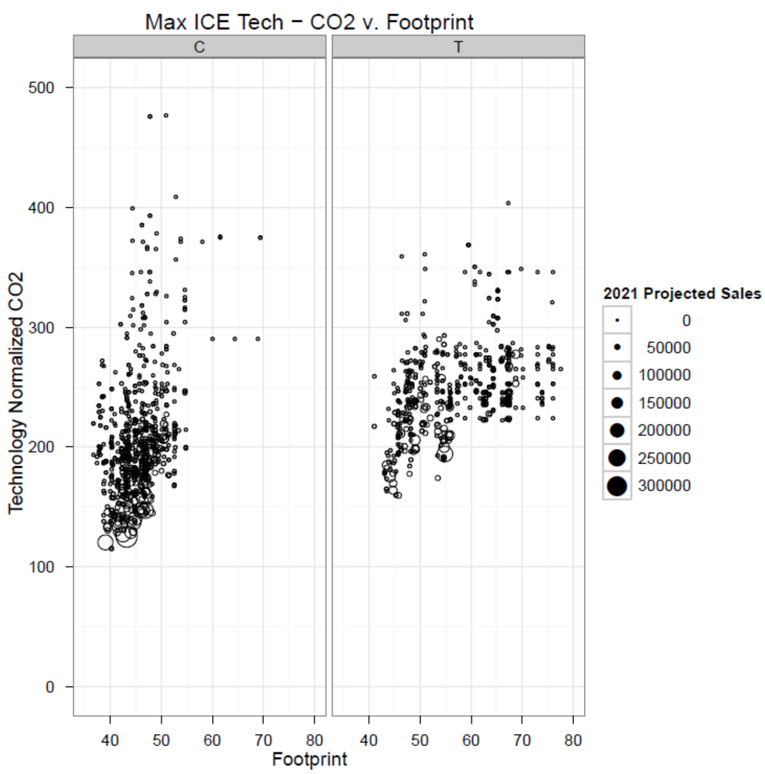

Figure V-2 2008 CO_2 vs. Footprint by Car and Truck, after Adjustment Reflecting Technology Differences, and removing diesel fueled vehicles, HEVs and EVs

[127] As described in the preceding paragraph, applying technology in this manner serves to reduce the effect of technology differences across the vehicle fleet. The particular technologies used for the normalization were chosen as a reasonable selection of technologies which could potentially be used by manufacturer over this time period.
[128] For cars, the standard deviation of the CO_2 data is reduced from 81 to 54 through the technology normalization. For trucks, the standard deviation is reduced from 62 to 36.

Updating this analysis using the current MY2008- and MY2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[129]

Adjustments reflecting differences in performance and "density"

As discussed previously, during stakeholder meetings NHTSA held while developing the NPRM,[130] some manufacturers indicated that they believed that the light truck standard should be somewhat steeper after MY 2016. As a means to produce a steeper light truck curve, NHTSA considered adjustments for other differences between vehicle models (*i.e.*, inflating or deflating the fuel economy of each vehicle model based on the extent to which one of the vehicle's attributes, such as power, is higher or lower than average). Previously, NHTSA had rejected such adjustments because they imply that a multi-attribute standard may be necessary, and as explained above, NHTSA judged most multi-attribute standards to be more subject to gaming than a footprint-only standard.[131,132] Having considered this issue again for purposes of this rulemaking, NHTSA concluded the need to accommodate in the target curves the challenges faced by manufacturers of large pickups currently outweighs these prior concerns (comments on this topic are discussed in Chapter 2 of the joint TSD and in Section II.C of the preamble). Therefore, NHTSA also evaluated curve fitting approaches through which fuel consumption and CO_2 levels were adjusted with respect to weight-to-footprint alone, and in combination with power-to-weight. While NHTSA examined these adjustments for purposes of fitting curves, NHTSA did not propose a multi-attribute standard; the proposed fuel economy and CO_2 targets for each vehicle were still functions of footprint alone. NHTSA is not promulgating a multi-attribute standard, and no adjustment will be used in the compliance process.

NHTSA also examined some differences between the technology-adjusted car and truck fleets in order to better understand the relationship between footprint and CO_2/fuel consumption in NHTSA's MY 2008 based forecast. More direct measures (such as coefficients of drag and rolling resistance), while useful for vehicle simulation, were not practical or readily available at the fleet level. Given this issue, and based on analysis published in the MYs 2012-2016 rule,[133]

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[129] Docket No. NHTSA-2010-0131.

[130] See Preamble I.A.2 for a discussion of the stakeholder meetings before the NPRM.

[131] For example, in comments on NHTSA's 2008 NPRM regarding MY 2011-2015 CAFE standards, Porsche recommended that standards be defined in terms of a "Summed Weighted Attribute", wherein the fuel economy target would calculated as follows: $target = f(SWA)$, where *target* is the fuel economy target applicable to a given vehicle model and $SWA = footprint + torque^{1/1.5} + weight^{1/2.5}$. (NHTSA-2008-0089-0174). While the standards the agencies proposed for MY 2017-2025 are not multi-attribute standards-- that is, the target is only a function of footprint--we proposed curve shapes that were developed considering more than one attribute.

[132] 74 FR 14359.

[133] See 75 FR at 25458

NHTSA investigated a sales-weighted (*i.e.*, treating every vehicle unit sold as a separate observation) regression equation involving power to weight ratio and vehicle weight (Equation V-1).[134] This equation provides for a strong correlation between HP/WT, weight and CO_2 emissions (R^2=0.78, Table V-1) after accounting for technology adjustments.[135]

Equation V-1 – Relationship between vehicle attributes and emissions or fuel consumption

$$\mathrm{CO2i\ or\ GPMi} = \beta_{\mathrm{hp/wt}}\left(\frac{\mathrm{Horsepower}}{\mathrm{Weight}}\right)_{\mathrm{i}} + \beta_{\mathrm{weight}}\mathrm{Weight}_{\mathrm{i}} + \mathrm{C}$$

Where:

HP/Weight= the rated horsepower of the vehicle divided by the curb weight
Weight = the curb weight of the vehicle in pounds
C = a constant.

Table V-1 – Physical Regression Coefficients against Technology Adjusted CO_2*

	Cars	Light Trucks
R^2	0.78	0.78
F-test p	<0.01	<0.01
$\beta_{hp/wt}$	$1.09*10^3$	$1.13*10^3$
β_{weight}	$3.29*10^{-2}$	$3.45*10^{-2}$
C	-3.29	2.73

*In this gasoline only fleet, these coefficients can be divided by 8887 (the amount of CO_2 produced by the combustion of a gallon of the fuel used to certify the fuel economy and emissions of gasoline vehicles) to yield the corresponding fuel consumption coefficients.

Updating this analysis using the MY 2008- and MY 2010-based fleet projections yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented a memorandum titled “Curve Fitting Analysis: Regression Results,” available in NHTSA’s docket.[136]

The coefficients above show, for NHTSA’s MY 2008-based market forecast as developed for the NPRM, strong correlation between these vehicle attributes and the fuel consumption and emissions of the vehicle, as well as strong similarity between car and truck coefficients. (As explained in below, our analysis using the corrected version of the MY 2008 based market forecast used for the final rule, as well as the alternative 2010 based market forecast, is

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[134] These parameters directly relate to the amount of energy required to move the vehicle. As compared to a lighter vehicle, more energy is required to move a heavier vehicle the same distance. Similarly, a more powerful engine, when technology adjusted, is less efficient than a less powerful engine.
[135] As R^2 does not equal 1, there are remaining unaccounted for differences beyond technology, power and weight. These may include gear ratios, axle ratios, aerodynamics, and other vehicle features not captured in this equation.
[136] Docket No. NHTSA-2010-0131.

consistent with these results.) Given these very similar parameters, similar distributions of power and weight would be expected to produce similarly arrayed plots of CO_2 (or equivalently, fuel consumption) by footprint, regardless of car or truck class. Based on the differences seen in the technology-adjusted plot (Figure V-2), NHTSA further investigated these particular attributes and their relationship to footprint in NHTSA's MY 2008-based market forecast developed for the NPRM, to examine the differences across the footprint distribution.

Figure V-3 shows vehicle curb weight charted against footprint, with sales weighted ordinary least squares sales fit (blue) and sales-weighted LOESS fit (red) imposed. For cars, the LOESS fit, which weights nearby points more heavily, [137] is nearly identical to the linear fit in the data filled region between about 40 and 56 square feet (with the gray bar showing standard error on the LOESS fit). For this market forecast, average car curb weight is linearly proportional to car footprint between 40 and 56 square feet, or in other words, cars progress in weight in a regular fashion as they get larger (
Figure V-3). By contrast, a linear fit does not overlap with the LOESS fit on the truck side, which indicates that for this market forecast, truck curb weight does not linearly increase with footprint, at least not across the entire truck fleet. The LOESS fit shows that larger trucks (those on the right side of the data bend in Figure V-2) have a different trend than smaller trucks, and after about 55 square feet, no longer proportionally increases in weight. The same pattern is seen in Figure V-1 and Figure V-2 above.

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[137]: In a LOESS regression, "fitting is done locally. That is, for the fit at point *x*, the fit is made using points in a neighborhood of *x*, weighted by their distance from *x* (with differences in 'parametric' variables being ignored when computing the distance). The size of the neighborhood is controlled by *α* For *α < 1*, the neighborhood includes proportion *α* of the points, and these have tricubic weighting (proportional to *(1 - (dist/maxdist)^3)^3*. For *α > 1*, all points are used, with the 'maximum distance' assumed to be *α^1/p* times the actual maximum distance for *p* explanatory variables."
A span of 1 was used in these images. http://cran.r-project.org/doc/manuals/fullrefman.pdf, p. 1406.

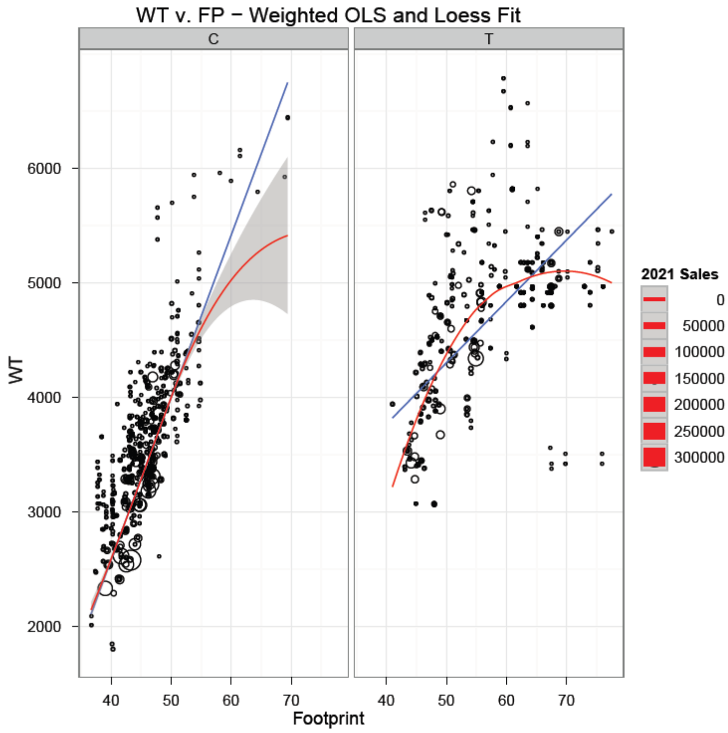

Figure V-3 Relationship between Weight and Footprint in Agencies' MY2008-Based Market Forecast

Updating this analysis using the revised MY 2008- and the MY 2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[138]

To further pursue this topic, weight divided by footprint (WT/FP) can be thought of as a "density" of a vehicle (although dimensionally it has units of pressure). As seen in Figure V-4, the trend in WT/FP in NHTSA's MY2008-based market forecast is different in trucks than in cars. The linear trend on cars is an increase in WT/FP as footprint increases (Figure V-4). In contrast, light trucks do not consistently increase in WT/FP ratio as the vehicles grow larger, but WT/FP actually decreases (Figure V-4).

[138] Docket No. NHTSA-2010-0131.

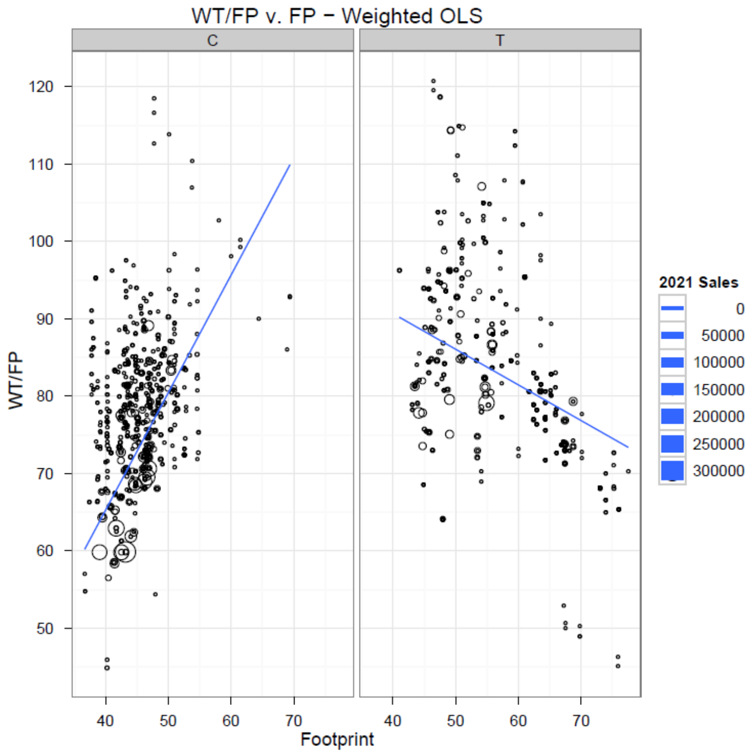

Figure V-4 Relationship between Weight/FP and Footprint in Agencies' MY2008-Based Market Forecast

Updating this analysis using the current MY 2008- and MY 2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[139]

The heterogeneity of the truck fleet explains part of the WT/FP trend, where the pickup truck fleet is largest in footprint, but is also relatively light for its size due to the flat bed (Figure V-5). Note that the two light truck classes with the smallest WT/FP ratios are small and large pickups. Further, as the only vehicle class with a sales-weighted average footprint above 60 square feet, the large pickup trucks have a strong influence on the slope of the truck curve. As the correlation between weight and CO_2 is strong (Table V-1), having proportionally lighter vehicles at one extreme of the footprint distribution can bias a curve fit to these vehicles. If no adjustment is made to the curve fitted to the truck fleet, and no other compensating flexibilities or adjustments are made available, manufacturers selling significant numbers of vehicles at the large end of the truck distribution will face compliance burdens that are comparatively more challenging that those faced by manufacturers not serving this part of the light truck market. As

[139] Docket No. NHTSA-2010-0131.

noted further below, this consideration provided the basis for NHTSA's proposal to change the cutpoint for larger light trucks from 66 feet to 74 feet, and to steepen the slope of the light truck curve for larger light trucks.

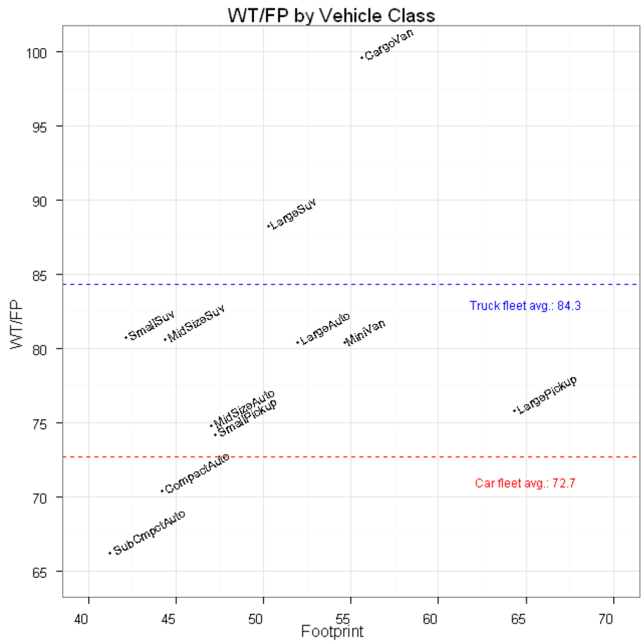

Figure V-5 Class and the WT/FP distribution

Updating this analysis using the revised MY 2008- and the MY 2010-based market forecasts yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[140]

NHTSA also investigated the relationship between HP/WT and footprint in NHTSA's MY 2008-based market forecast developed for the NPRM (Figure V-6). On a sales weighted basis, cars tend to become proportionally more powerful as they get larger. In contrast, there is a minimally positive relationship between HP/WT and footprint for light trucks, indicating that light trucks become only slightly more powerful as they get larger, but that the trend is not especially pronounced.

[140] Docket No. NHTSA-2010-0131.

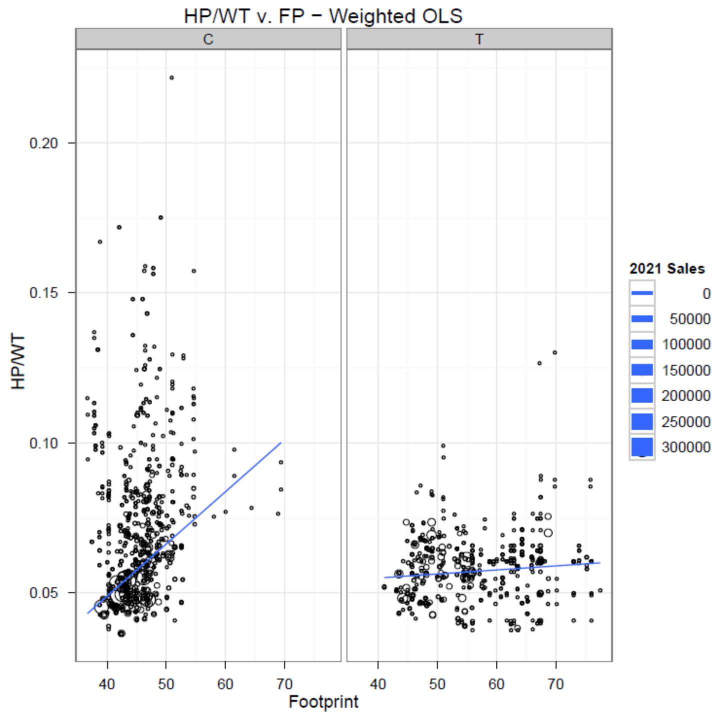

Figure V-6 HP/WT v. FP

Updating this analysis using the revised MY 2008- and the MY 2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[141]

One factor influencing results of this analysis is the non-homogenous nature of the truck fleet; some vehicles at the smaller end of the footprint curve are different in design and utility from others at the larger end (leading to the observed bend in the LOESS fit, Figure V-6). There are many high volume four-wheel drive vehicles with smaller footprint in the truck fleet (such as the Chevrolet Equinox, Dodge Nitro, Ford Escape, Honda CR-V, Hyundai Santa Fe, Jeep Liberty, Nissan Rogue, Toyota RAV4, and others) exhibit only select truck characteristics.[142] By contrast, the largest pickup trucks in the light truck fleet have unique aerodynamic and power characteristics that tend to increase CO_2 emissions and fuel consumption. These disparities contribute to the slopes of lines fitted to the light truck fleet.

[141] Docket No. NHTSA-2010-0131.

[142] In most cases, these vehicles have four-wheel drive, but no significant towing capability, and no open-bed. Many of these vehicles are also offered without four-wheel drive, and these two-wheel drive versions are classified as passenger cars, not light trucks.

Several comments, such as those by CBD and ACEEE, were submitted with regard to the non-homogenous nature of the truck fleet, and the "unique" attributes of pickup trucks. Ford Motor Company described the attributes of these vehicles, noting that "towing capability generally requires increased aerodynamic drag caused by a modified frontal area, increased rolling resistance, and a heavier frame and suspension to support this additional capability."[143] Ford further noted that these vehicles further require auxiliary transmission oil coolers, upgraded radiators, trailer hitch connectors and wiring harness equipment, different steering ratios, upgraded rear bumpers and different springs for heavier tongue load (for upgraded towing packages), body-on-frame (vs. unibody) construction (also known as ladder frame construction) to support this capability and an aggressive duty cycle, and lower axle ratios for better pulling power/capability. In NHTSA's judgment, the curves and cutpoints defining the light truck standards appropriately account for engineering differences between different types of vehicles. For example, NHTSA's estimates of the applicability, cost, and efficacy of different fuel-saving technologies differentiate between small, medium, and large light trucks. Further discussion on this topic is contained in Section II.C of the preamble to this final rule.

NHTSA's technical analyses of regulatory alternatives developed using curves fitted as described below supported OEM comments that there would be significant compliance challenges for the manufacturers of large pickup trucks, and led toward NHTSA's policy goal of a steeper slope for the light truck curve relative to MY 2016. Three primary drivers were as follows: (a) the largest trucks have unique equipment and design, as described in the Ford comment referenced above; (b) NHTSA agree with those large truck manufacturers who indicated in discussions prior to the proposal that they believed that the light truck standard should be somewhat steeper after MY 2016, primarily because, after more than ten recent years of progressive increases in the stringency of applicable CAFE standards (after nearly ten years during which Congress did not allow NHTSA to increase light truck CAFE standards), manufacturers of large pickups would have limited options to comply with more stringent standards without resorting to compromising large truck load carrying and towing capacity; and (c) given the relatively few platforms which comprise the majority of the sales at the largest truck footprints, NHTSA was concerned about requiring levels of average light truck performance that might lead to overly aggressive advanced technology penetration rates in this important segment of the work fleet. Specifically, NHTSA was concerned at proposal, and remain concerned, about issues of lead time and cost with regard to manufacturers of these work vehicles. As noted later in this chapter, while the largest trucks are a small segment of the overall truck fleet, and an even smaller segment of the overall fleet, [144] these changes to the truck

[143] Ford comments, Docket No. NHTSA-2010-0131-0235, at 6.

[144] The agencies' market forecast used at proposal includes about 24 vehicle configurations above 74 square feet with a total volume of about 50,000 vehicles or less during any MY in the 2017-2025 time frame, In the MY2010 based market forecast, there are 14 vehicle configurations with a total volume of 130,000 vehicles or less during any

slope have been made in order to provide a clearer path toward compliance for manufacturers of these vehicles, and reduce the potential that new standards would lead these manufacturers to choose to downpower, modify the structure, or otherwise reduce the utility of these work vehicles.

Some commenters disagreed with these policy goals concerning the largest light trucks and argued that higher fuel economy for the largest light trucks is fully compatible with maintaining towing and hauling capacity. These comments, which largely deal with stringency, are addressed Section IV.F of the preamble to today's final rule, as well as in Section II.C, which addresses the shapes of the target curves. Consequently, NHTSA considered options including fitting curves developed using results of the analysis described above. Specifically, NHTSA notes that the WT/FP ratio of the light duty fleet potentially has a large impact on a sales-weighted regression.[145] The increasing trend in WT/FP versus footprint for cars in the 2008 MY baseline would steepen the slope of the car curve, while the decreasing trend in WT/FP would flatten the truck slope, as compared to a WT/FP adjusted fleet. This result was reflected in the MYs 2012-2016 final rulemaking,[146] where NHTSA noted the steep car curves resulting from a weighted least-squares analysis.

Based on the above analysis, NHTSA also considered adjustments for other differences between vehicle models. Therefore, utilizing the coefficients derived in Equation V-1, NHTSA also evaluated curve fitting approaches through which fuel consumption and CO_2 levels were adjusted with respect to weight-to-footprint alone, and in combination with power-to-weight. This adjustment procedure inflates or deflates the fuel economy or CO_2 emissions of each vehicle model based on the extent to which one of the vehicle's attributes, such as power, is higher or lower than average. As mentioned above, while NHTSA considered this technique for purposes of fitting curves, NHTSA did not propose a multi-attribute standard, as the proposed fuel economy and CO_2 targets for each vehicle were still functions of footprint alone. NHTSA is not promulgating a multi-attribute standard, and no adjustment would be used in the compliance process.

The basis for the gallon-per-mile (GPM) adjustments is the sales-weighted linear regression discussed previously (Equation V-1, Table V-1). The coefficients to this equation give the impact of the various car attributes on CO_2 emissions and fuel consumption in NHTSA's MY 2008-based market forecast used in the NPRM. For example, β_{weight} gives the impact of weight while holding the ratio horsepower to weight constant. Importantly, this means that as weight

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MY in the 2017-2025 time frame. This is a similarly small portion of the overall number of vehicle models or vehicle sales.

[145] As mentioned above, the agencies also performed the same analysis without sales-weighting, and found that the WT/FP ratio also had a directionally similar effect on the fitted car and truck curves.

[146] 75 FR at 25363

changes, horsepower must change as well to keep the power/weight ratio constant. Similarly, $\beta_{hp/wt}$ gives the CO_2 impact of changing the performance of the vehicle while keeping the weight constant. These coefficients were used to perform an adjustment of the gallons per mile measure for each vehicle to the respective car or truck—*i.e.,* in the case of a HP/WT adjustment, to deflate or inflate the fuel consumption of each vehicle model based on the extent to which the vehicle's power-to-weight ratio is above or below the regression-based value at that footprint.

NHTSA performed this normalization to adjust for differences in vehicle weight per square foot observations in the data discussed in Section 2.4 of the Joint TSD. This adjustment process requires two pieces of information: the weight coefficient from Equation V-1 and the average weight per footprint (*i.e.*, pounds per square foot) for that vehicle's group. Two groups, passenger cars and light trucks, were used. For each group, the average weight per footprint was calculated as a weighted average with the weight being the same as in the above regression (projected sales by vehicle in 2021). The equation below indicates how this adjustment was carried out.

Equation V-2 WT/FP adjustment

$$\text{Weight per Footprint Adjusted GPM}_i \text{ or CO2i} = \text{GPM}_i - \left(\text{Weight}_i - \overline{\frac{\text{Weight}}{\text{Footprint}}} \times \text{Footprint}_i\right) \times \beta_{\text{weight}}$$

The term in parentheses represents the vehicle's deviation from an "expected weight." That is, multiplying the average weight per footprint for a group of vehicles (cars or trucks) by a specific vehicle's footprint gives an estimate of the weight of that specific vehicle if its density were "average," based on the analyzed fleet. Put another way, this factor represents what the weight is "expected" to be, given the vehicle's footprint, and based on the analyzed fleet. This "expected weight" is then subtracted from the vehicle's actual weight. Vehicles that are heavier than their "expected weight" will receive a positive value (*i.e.*, a deflated fuel economy value) here, while vehicles that are lighter than their "expected weight" will receive a negative number (*i.e.*, an inflated fuel economy value).

This deviation from "expected weight" is then converted to a gallon value by the regression coefficient. The units on this coefficient are gallons per mile per pound, as can be deduced from Equation V-1. This value is then subtracted from the vehicle's actual gallons per mile measure. Note that the adjusted truck data no longer exhibits the bend seen in Figure V-1 and Figure V-2.

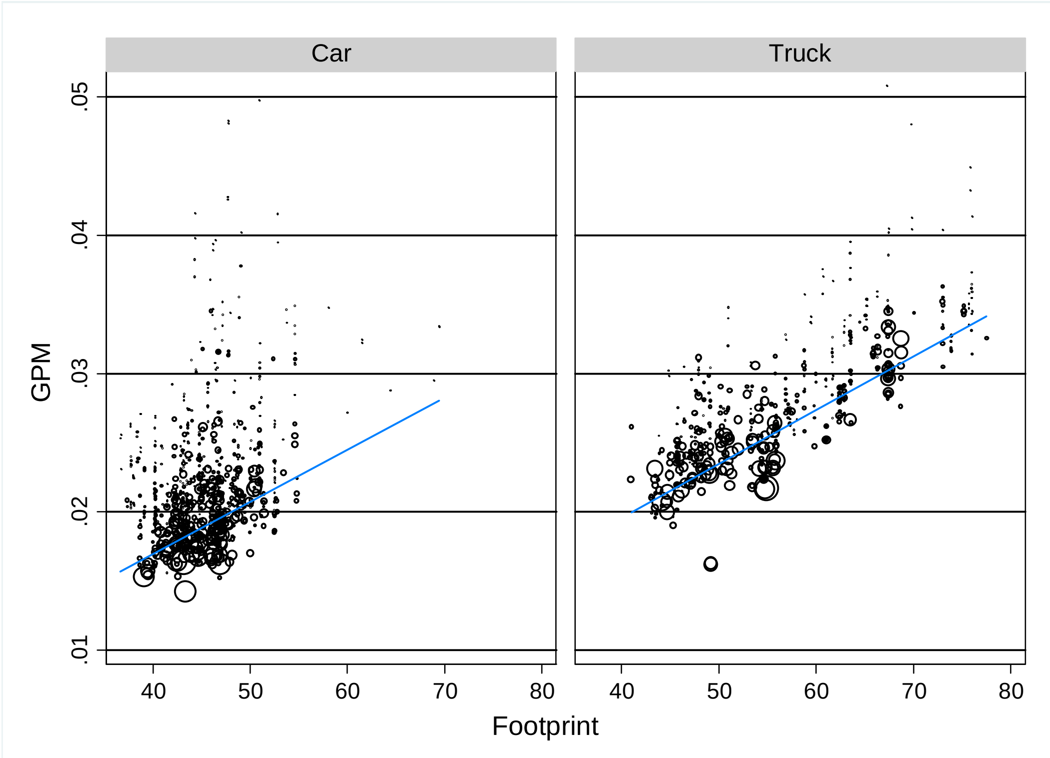

Figure V-7 WT/FP Adjusted Fuel Consumption vs. Footprint

Updating this analysis using the revised MY 2008- and the MY 2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[147]

This adjustment serves to reduce the variation in gallons per mile measures caused by variation in weight in NHTSA's MY 2008-based market forecast used in the NPRM. Importantly, this adjustment serves to reduce the fuel consumption (*i.e.*, inflate fuel economy) for those vehicles which are heavier than their footprint would suggest while increasing the gallons per mile measure (*i.e.*, deflating fuel economy) for those vehicles which are lighter. For trucks, a linear trend is more evident in the data cloud. The following table shows the degree of adjustment for several vehicle models:

Table V-2 - Sample Adjustments for Weight to Footprint, Cars

[147] Docket No. NHTSA-2010-0131.

Manufacturer	Model	Name Plate	Weight / Footprint	Footprint	GPM	MPG	Adjusted GPM	Adjusted MPG	GPM % Adjustment
HONDA	HONDA FIT	FIT	64.4	39.5	0.01	69.40	0.0157	63.73	8.9%
TOYOTA	TOYOTA COROLLA	COROLLA	61.3	42.5	0.01	69.94	0.0164	60.80	15.0%
FORD	FORD FOCUS	FOCUS FWD	62.9	41.7	0.02	61.94	0.0177	56.34	9.9%
GENERAL MOTORS	CHEVROLET MALIBU	MALIBU	73.5	46.9	0.02	53.70	0.0185	54.08	-0.7%
HONDA	HONDA ACCORD	ACCORD 4DR SEDAN	69.6	46.6	0.02	57.57	0.0179	55.73	3.3%
NISSAN	INFINITI G37	G37 COUPE	76.7	47.6	0.02	47.83	0.0200	50.08	-4.5%
GENERAL MOTORS	CHEVROLET CORVETTE	CORVETTE	69.3	46.3	0.02	40.84	0.0251	39.83	2.5%
FORD	FORD MUSTANG	MUSTANG	74.7	46.7	0.03	31.32	0.0316	31.67	-1.1%
TOYOTA	TOYOTA CAMRY	CAMRY SOLARA CONVERTIB LE	75.6	46.9	0.02	50.87	0.0191	52.27	-2.7%
VOLKSWAG EN	VOLKSWAG EN JETTA	JETTA	78.0	42.4	0.02	46.77	0.0211	47.47	-1.5%
FORD	FORD FUSION	FUSION FWD	72.2	46.1	0.02	59.96	0.0168	59.61	0.6%
HONDA	HONDA ACCORD	ACCORD 2DR COUPE	71.6	46.6	0.02	56.92	0.0178	56.26	1.2%
HYUNDAI	HYUNDAI SONATA	SONATA	70.7	46.0	0.02	61.72	0.0166	60.34	2.3%
HONDA	HONDA CIVIC	CIVIC	59.9	43.2	0.02	64.25	0.0177	56.38	14.0%

Table V-3 – Sample Adjustments for Weight to Footprint, Trucks

Manufacturer	Model	Name Plate	Weight / Footprint	Footprint	GPM	MPG	Adjusted GPM	Adjusted MPG	GPM % Adjustment
FORD	FORD ESCAPE	ESCAPE FWD	80.1	65.2	0.02	51.00	0.0181	55.11	-7.5%
GENERAL MOTORS	CHEVROLET C15	C15 SILVERADO 2WD 119WB	85.9	55.9	0.03	39.76	0.0248	40.29	-1.3%
FIAT	JEEP GRAND CHEROKEE	GRAND CHEROKEE 4WD	103.7	47.1	0.02	41.45	0.0222	44.98	-7.9%
HONDA	HONDA PILOT	PILOT 4WD	85.2	51.3	0.02	40.95	0.0243	41.22	-0.6%
TOYOTA	TOYOTA HIGHLANDER	HIGHLANDER 4WD	79.6	49.0	0.02	45.90	0.0227	44.05	4.2%
FORD	FORD F150	F150 FFV 4WD 145 WB	73.8	67.4	0.03	32.70	0.0334	29.97	9.1%
FIAT	DODGE RAM	RAM 1500 PICKUP 4WD 140 WB	78.1	66.3	0.03	33.75	0.0316	31.65	6.6%
TOYOTA	TUNDRA	TOYOTA TUNDRA 4WD 145 WB	79.3	68.7	0.03	32.07	0.0325	30.73	4.3%
TATA	LAND ROVER RANGE ROVER SPORT	RANGE ROVER SPORT	118.6	47.5	0.03	33.17	0.0239	41.92	-20.9%
GENERAL MOTORS	CHEVROLET UPLANDER	UPLANDER FWD	114.4	49.2	0.02	45.46	0.0163	61.34	-25.9%
GENERAL MOTORS	HUMMER H3	H3 4WD	99.9	50.7	0.03	36.71	0.0242	41.30	-11.1%
GENERAL MOTORS	PONTIAC TORRENT	TORRENT FWD	84.2	48.2	0.02	46.64	0.0215	46.56	0.2%
TOYOTA	TACOMA	TOYOTA TACOMA 4WD	74.8	53.4	0.02	43.01	0.0252	39.63	8.5%

Updating this analysis using the revised MY 2008- and the MY 2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[148]

Based on Equation V-1, NHTSA also evaluated an adjustment of GPM and CO_2 based on HP/WT.

Equation V-3 –Adjustment based on HP/WT

$$\frac{\mathrm{HP}}{\mathrm{WT}}\text{adjusted } \mathrm{GPM_i} \text{ or } \mathrm{CO2_i} = \mathrm{GPM_i} - \left(\frac{\mathrm{HP_i}}{\mathrm{WT_i}} - \frac{\overline{\mathrm{HP}}}{\overline{\mathrm{WT}}}\right) \times \beta_{\mathrm{HP/WT}}$$

[148] Docket No. NHTSA-2010-0131.

Figure V-8 shows the adjusted data and the estimated relationship between the adjusted GPM values and footprint.

Table V-4 shows the degree of adjustment for several vehicle models. Those vehicles which have more power than average for their actual curb weight are adjusted downward (i.e., fuel economy ratings are inflated), while those that have less power than average are adjusted upward (i.e., fuel economy ratings are deflated).

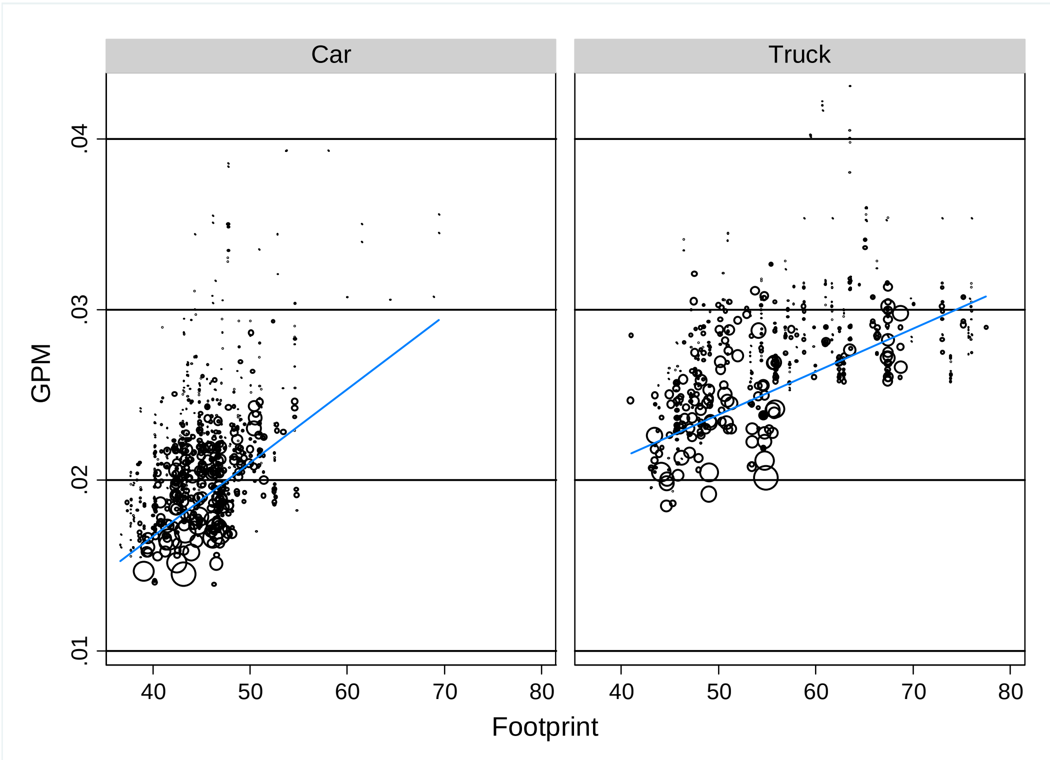

Figure V-8 HP/WT Adjusted Fuel Consumption v. Footprint

Table V-4 - Sample Adjustments for Horsepower to Weight, Cars

Manufacturer	Model	Name Plate	Horsepower	Footprint	GPM	MPG	Adjusted GPM	Adjusted MPG	GPM % Adjustment
HONDA	HONDA FIT	FIT	109	39.5	0.01	69.40	0.0157	63.73	8.9%
TOYOTA	TOYOTA COROLLA	COROLLA	126	42.5	0.01	69.94	0.0164	60.80	15.0%
FORD	FORD FOCUS	FOCUS FWD	140	41.7	0.02	61.94	0.0177	56.34	9.9%
GENERAL MOTORS	CHEVROLET MALIBU	MALIBU	169	46.9	0.02	53.70	0.0185	54.08	-0.7%
HONDA	HONDA ACCORD	ACCORD 4DR SEDAN	190	46.6	0.02	57.57	0.0179	55.73	3.3%
NISSAN	INFINITI G37	G37 COUPE	330	47.6	0.02	47.83	0.0200	50.08	-4.5%
GENERAL MOTORS	CHEVROLET CORVETTE	CORVETTE	400	46.3	0.02	40.84	0.0251	39.83	2.5%
FORD	FORD MUSTANG	MUSTANG	500	46.7	0.03	31.32	0.0316	31.67	-1.1%
TOYOTA	TOYOTA CAMRY	CAMRY SOLARA CONVERTIBL E	225	46.9	0.02	50.87	0.0191	52.27	-2.7%
VOLKSWAG EN	VOLKSWAG EN JETTA	JETTA	170	42.4	0.02	46.77	0.0211	47.47	-1.5%
FORD	FORD FUSION	FUSION FWD	160	46.1	0.02	59.96	0.0168	59.61	0.6%
HONDA	HONDA ACCORD	ACCORD 2DR COUPE	190	46.6	0.02	56.92	0.0178	56.26	1.2%
HYUNDAI	HYUNDAI SONATA	SONATA	162	46.0	0.02	61.72	0.0166	60.34	2.3%
HONDA	HONDA CIVIC	CIVIC	140	43.2	0.02	64.25	0.0177	56.38	14.0%

Table V-5 - Sample Adjustments for Horsepower to Weight, Trucks

Manufacturer	Model	Name Plate	Horsepower	Footprint	GPM	MPG	Adjuste d GPM	Adjusted MPG	GPM % Adjustmen t
FORD	FORD ESCAPE	ESCAPE FWD	153	65.2	0.02	51.00	0.0181	55.11	-7.5%
GENERAL MOTORS	CHEVROLET C15	C15 SILVERADO 2WD 119WB	195	55.9	0.03	39.76	0.0248	40.29	-1.3%
FIAT	JEEP GRAND CHEROKEE	GRAND CHEROKEE 4WD	210	47.1	0.02	41.45	0.0222	44.98	-7.9%
HONDA	HONDA PILOT	PILOT 4WD	244	51.3	0.02	40.95	0.0243	41.22	-0.6%
TOYOTA	TOYOTA HIGHLANDE R	HIGHLANDER 4WD	270	49.0	0.02	45.90	0.0227	44.05	4.2%
FORD	FORD F150	F150 FFV 4WD 145 WB	300	67.4	0.03	32.70	0.0334	29.97	9.1%
FIAT	DODGE RAM	RAM 1500 PICKUP 4WD 140 WB	345	66.3	0.03	33.75	0.0316	31.65	6.6%
TOYOTA	TUNDRA	TOYOTA TUNDRA 4WD 145 WB	381	68.7	0.03	32.07	0.0325	30.73	4.3%
TATA	LAND ROVER RANGE ROVER SPORT	RANGE ROVER SPORT	300	47.5	0.03	33.17	0.0239	41.92	-20.9%
GENERAL MOTORS	CHEVROLET UPLANDER	UPLANDER FWD	240	49.2	0.02	45.46	0.0163	61.34	-25.9%

GENERAL MOTORS	HUMMER H3	H3 4WD	242	50.7	0.03	36.71	0.0242	41.30	-11.1%
GENERAL MOTORS	PONTIAC TORRENT	TORRENT FWD	185	48.2	0.02	46.64	0.0215	46.56	0.2%
TOYOTA	TACOMA	TOYOTA TACOMA 4WD	236	53.4	0.02	43.01	0.0252	39.63	8.5%

Updating this analysis using the revised MY 2008- and the MY 2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analyses are with the final rulemaking fleet projections presented in a memorandum available in NHTSA's docket.[149]

The above approaches resulted in three data sets each for (a) vehicles without added technology and (b) vehicles with technology added to reduce technology differences, any of which may provide a reasonable basis for fitting mathematical functions upon which to base the slope of the standard curves: (1) vehicles without any further adjustments; (2) vehicles with adjustments reflecting differences in "density" (weight/footprint); and (3) vehicles with adjustments reflecting differences in "density," and adjustments reflecting differences in performance (power/weight). Further, these sets were developed for both the revised MY 2008-based fleet projection and the post-proposal MY 2010-based fleet projection. Detailed results using these market forecasts are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[150]

What statistical methods did NHTSA evaluate?

Using these data sets, NHTSA tested a range of regression methodologies, each judged to be possibly reasonable for application to at least some of these data sets.

Regression Approach

In the MYs 2012-2016 final rules, NHTSA employed a robust regression approach (minimum absolute deviation, or MAD), rather than an ordinary least squares (OLS) regression.[151] MAD is generally applied to mitigate the effect of outliers in a dataset, and thus was employed in that rulemaking as part of our interest in attempting to best represent the underlying technology. NHTSA had used OLS in early development of attribute-based CAFE standards, but NHTSA subsequently chose MAD instead of OLS for both the MY 2011 and the MYs 2012-2016 rulemakings. These decisions on regression technique were made both because OLS gives

[149] Docket No. NHTSA-2010-0131.
[150] Docket No. NHTSA-2010-0131.
[151] *See* 75 FR at 25359.

additional emphasis to outliers[152] and because the MAD approach helped achieve NHTSA's policy goals with regard to curve slope in those rulemakings.[153] In the interest of taking a fresh look at appropriate regression methodologies as promised in the 2012-2016 light duty rulemaking, in developing this proposal, NHTSA gave full consideration to both OLS and MAD. The OLS representation, as described, uses squared errors, while MAD employs absolute errors and thus weights outliers less.

As noted, one of the reasons stated for choosing MAD over least square regression in the MYs 2012-2016 rulemaking was that MAD reduced the weight placed on outliers in the data. As seen in Figure 2-1, there clearly are some outliers in the data, mostly to the high CO_2 and fuel consumption side. However, NHTSA has further considered whether it is appropriate to classify these vehicles as outliers. Unlike in traditional datasets, these vehicles' performance is not mischaracterized due to errors in their measurement, a common reason for outlier classification. Being certification data, the chances of large measurement errors should be near zero, particularly towards high CO_2 or fuel consumption. Thus, they can only be outliers in the sense that the vehicle designs are unlike those of other vehicles. These outlier vehicles may include performance vehicles, vehicles with high ground clearance, 4WD, or boxy designs. Given that these are equally legitimate on-road vehicle designs, NHTSA concluded that it would appropriate to reconsider the treatment of these vehicles in the regression techniques.

Based on these considerations as well as on the adjustments discussed above, NHTSA concluded it was not meaningful to run MAD regressions on gpm data that had already been adjusted in the manner described above. Normalizing already reduced the variation in the data, and brought outliers towards average values. This was the intended effect, so NHTSA deemed it unnecessary to apply an additional remedy to resolve an issue that had already been addressed, but we sought comment on the use of robust regression techniques under such circumstances. One commenter, ACEEE, addressed this question in this rulemaking, indicating (consistent with NHTSA's views) that MAD and OLS are both technically sound methods for fitting functions.

Sales Weighting

Likewise, in the proposal, NHTSA reconsidered the application of sales-weighting to represent the data. As explained below, the decision to sales weight or not is ultimately based upon a choice about how to represent the data, and not by an underlying statistical concern. Sales weighting is used if the decision is made to treat each (mass produced) unit sold as a unique physical observation. Doing so thereby changes the extent to which different vehicle model types are emphasized as compared to a non-sales weighted regression. For example, while total

[152] Id. at 25362-63.
[153] Id. at 25363.

General Motors Silverado (332,000) and Ford F-150 (322,000) sales differed by less than 10,000 in MY 2021 market forecast used for the NPRM, 62 F-150s models and 38 Silverado models were reported in NHTSA baselines. Without sales-weighting, the F-150 models, because there were more of them, were given 63 percent more weight in the regression despite comprising a similar portion of the marketplace and a relatively homogenous set of vehicle technologies.

NHTSA did not use sales weighting in the MYs 2012-2016 rulemaking analysis of the curve shapes. A decision to not perform sales weighting reflects judgment that each vehicle model provides an equal amount of information concerning the underlying relationship between footprint and fuel economy. Sales-weighted regression gives the highest sales vehicle model types vastly more emphasis than the lowest-sales vehicle model types thus driving the regression toward the sales-weighted fleet norm. For unweighted regression, vehicle sales do not matter. NHTSA notes that the light truck market forecast shows MY 2025 sales of 218,000 units for Toyota's 2WD Sienna, and shows 66 model configurations with MY 2025 sales of fewer than 100 units. Similarly, NHTSA's market forecast shows MY 2025 sales of 267,000 for the Toyota Prius, and shows 40 model configurations with MY2025 sales of fewer than 100 units. Sales-weighted analysis would give the Toyota Sienna and Prius more than a thousand times the consideration of many vehicle model configurations. Sales-weighted analysis would, therefore, cause a large number of vehicle model configurations to be virtually ignored in the regressions.[154]

However, NHTSA did note in the MYs 2012-2016 final rules that, "sales weighted regression would allow the difference between other vehicle attributes to be reflected in the analysis, and also would reflect consumer demand." [155] In reexamining the sales-weighting for this analysis, NHTSA notes that there are low-volume model types that account for many of the passenger car model types (50 percent of passenger car model types account for 3.3 percent of sales), and it is unclear whether the engineering characteristics of these model types should equally determine the standard for the remainder of the market.

In the interest of taking a fresh look at appropriate methodologies as promised in the last final rule, in developing proposed and final standards for MYs 2017-2025, NHTSA gave full consideration to both sales-weighted and unweighted regressions.

Analyses Performed

We performed regressions describing the relationship between a vehicle's CO_2/fuel consumption and its footprint, in terms of various combinations of factors: initial (raw) fleets with no

[154] 75 FR at 25362 and n. 64
[155] 75 FR at 25632/3.

technology, versus after technology is applied; sales-weighted versus non-sales weighted; and with and without two sets of normalizing factors applied to the observations. NHTSA excluded diesels and dedicated AFVs because NHTSA anticipates that advanced gasoline-fueled vehicles are likely to be dominant through MY2025. Results supporting development of the proposed and finalized standards are depicted graphically in Figure V-9 through Figure V-16, below.

Thus, the basic OLS regression on the initial data (with no technology applied) and no sales-weighting represents one perspective on the relation between footprint and fuel economy. Adding sales weighting changes the interpretation to include the influence of sales volumes, and thus steps away from representing vehicle technology alone. Likewise, MAD is an attempt to reduce the impact of outliers, but reducing the impact of outliers might perhaps be less representative of technical relationships between the variables, although that relationship may change over time in reality. Each combination of methods and data reflects a perspective, and the regression results reflect that perspective in a simple quantifiable manner, expressed as the coefficients determining the line through the average (for OLS) or the median (for MAD) of the data. It is left to policy makers to determine an appropriate perspective and to interpret the consequences of the various alternatives.

NHTSA sought comment on the application of the weights as described above, and the implications for interpreting the relationship between fuel efficiency and footprint. ACEEE questioned adjustment of the light truck data based on differences in weight/footprint, indicating that, in their view, the adjustment produces too steep a slope and potentially implies overstatement of the efficacy of some technologies as applied to pickup trucks. ACEEE also suggested that adjustment based on differences in power/weight would yield flatter curves and be more consistent with how the EU constructed related CO_2 targets. The Alliance, in contrast, supported the weightings applied by NHTSA, and the resultant relationships between fuel efficiency and footprint. Both ACEEE and the Alliance commented that NHTSA should revisit the application of weights—and broader aspects of analysis to develop mathematical functions—in the future. Moreover, although ACEEE expressed concern regarding the outcomes of the application of the weight/footprint adjustment, NHTSA maintains that the adjustments (including no adjustments) considered in the NPRM are all potentially reasonable to apply for purposes of developing fuel economy and GHG target curves. This issue is discussed in greater detail in Section II.C of the preamble, and related issues–the slope and stringency of the light truck standards—are addressed further in Sections III and IV of the preamble.

What results did NHTSA obtain?

Both agencies employed the same statistical approaches. For regressions against data including technology normalization, NHTSA used the CAFE modeling system.

For illustrative purposes, the set of figures below show the range of curves determined by the possible combinations of regression techniques, with and without sales weighting, with and without the application of technology, and with various adjustments to the gpm variable prior to running a regression. Again, from a statistical perspective, each of these regressions simply represents the assumptions employed. Since they are all univariate linear regressions, they describe the line that will result from minimizing the sum of the residuals (for MAD) or sum of squared residuals (for OLS). Figures show the results for passenger cars, then light trucks, for ordinary least squares (OLS) then similar results for MAD regressions for cars and light trucks, respectively. The various equations are represented by the string of attributes used to define the regression. See the table, Regression Descriptors, below, for the legend. Thus, for example, the line representing "ols_LT_wt_ft_adj_init_w" should be read as follows: an OLS regression, for light trucks, using data adjusted according to weight to footprint, no technology added, and weighted by sales.

Table V-6 Regression Descriptors

Notation	Description
ols or mad	Ordinary least squares or mean absolute deviation
PC or LT	Passenger car or light truck
hp_wt_adj	Adjustment for horsepower to weight
wt_ft_adj	Adjustment for weight to footprint
wt_ft_hp_wt_adj	Adjustment for both horsepower to weight and weight to footprint
init or final	Vehicles with no technology (initial) or with technology added (final)
u or w	Unweighted or weighted by sales

Thus, the next figures, for example, represent a family of curves (lines) fit using ordinary least squares on data for passenger cars, not modified for technology, and which therefore permits comparisons of results in terms of the factors that change in each regression. These factors are whether the data are sales-weighted (denoted "w") or unweighted (denoted "u"), as well as the adjustments described above. Each of these adjustments has an influence on the regressions results, depicted in the figures below.

Updating this analysis using the revised MY 2008- and the MY 2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analysis with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[156]

[156] Docket No. NHTSA-2010-0131.

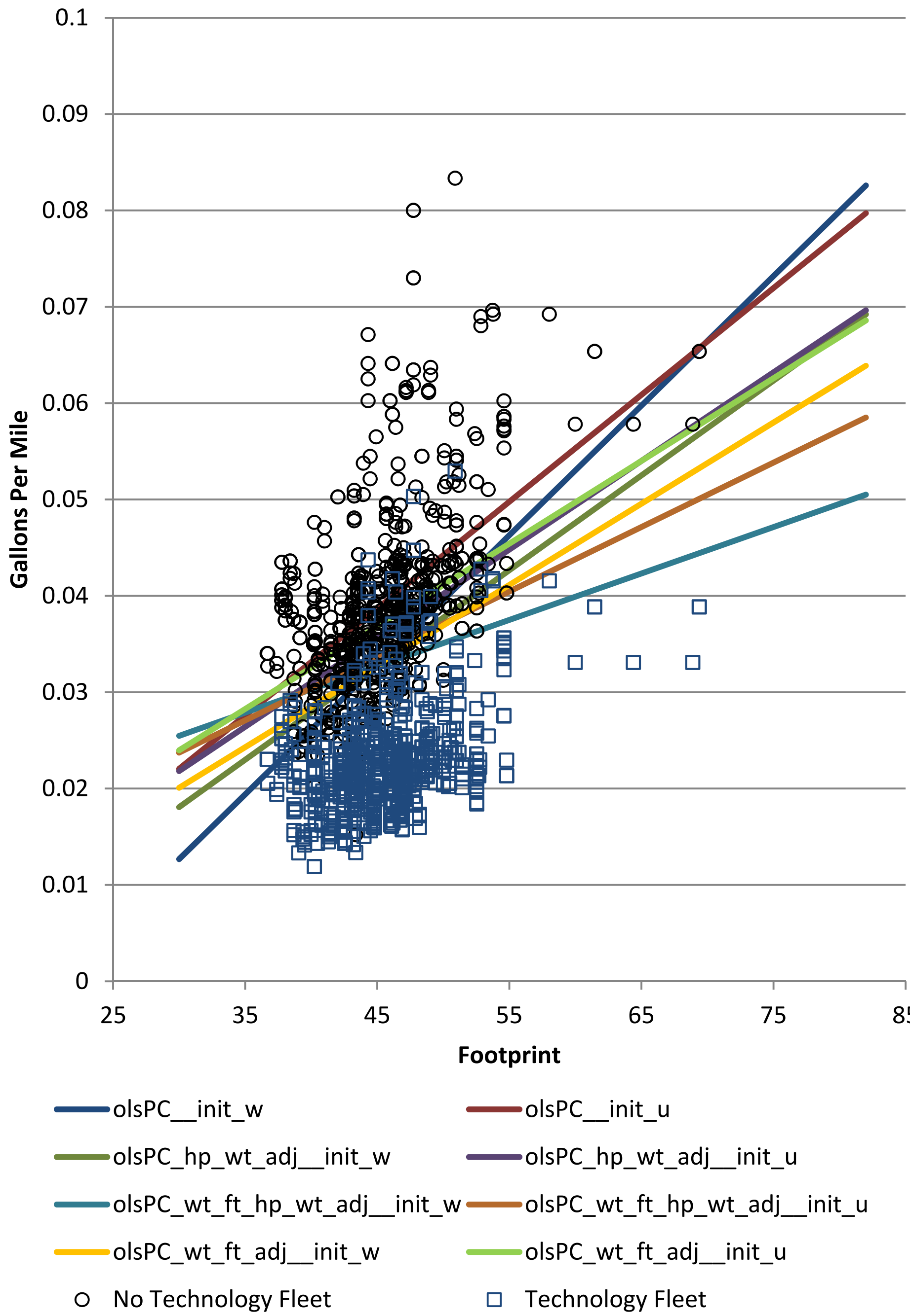

Figure V-9 Best Fit Results for Various Regressions: Cars, No Added Technology, OLS

Figure V-10, below, shows comparable results, this time with data representing the additional technology that has been added to reduce technological heterogeneity. Note that the data now pass through the relevant data "cloud" for the fleet with the technology adjustment applied. The slopes of the lines are somewhat more clustered (less divergent) in the chart depicting added technology (as discussed in footnote 128).

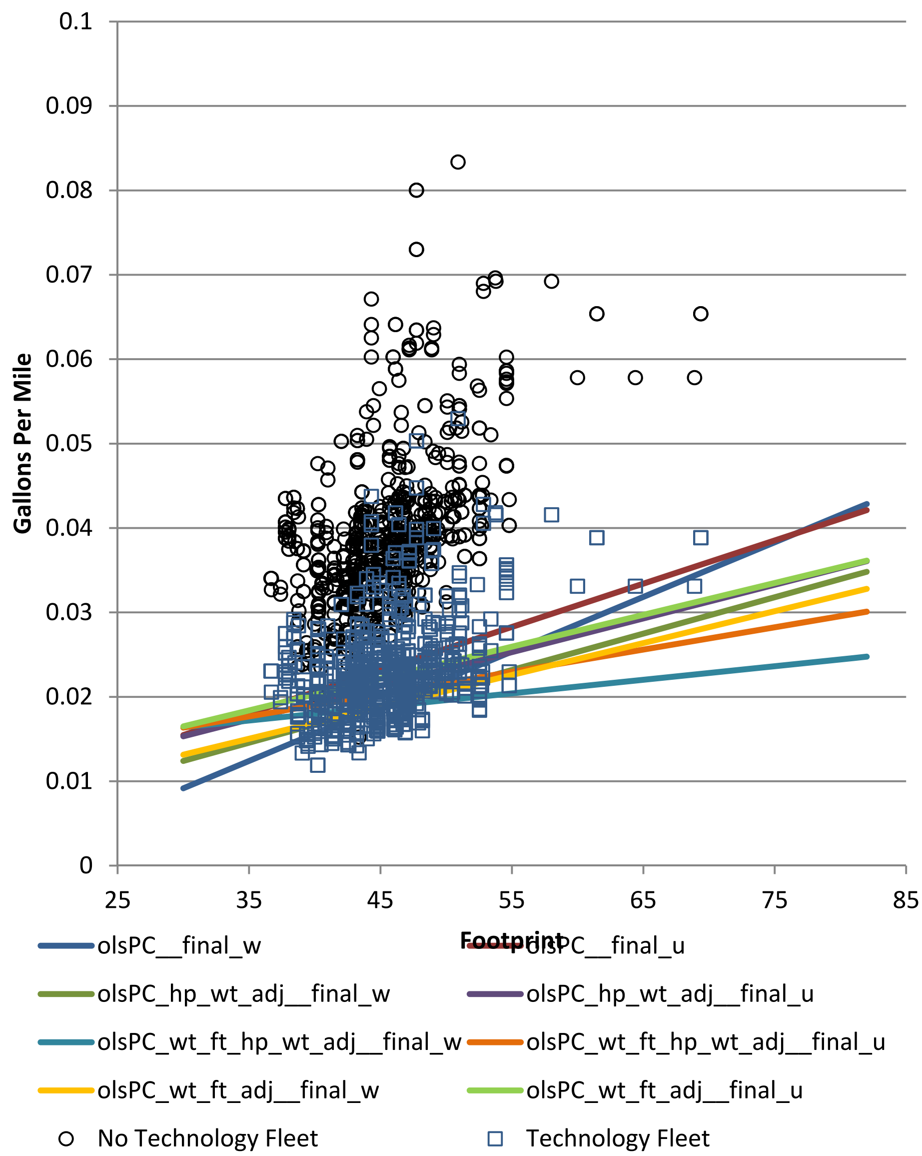

Figure V-10 Best Fit Results for Various Regressions: Cars, with Added Technology, OLS

Similar to the figures displaying the results for passenger cars, the figures below display regression lines for trucks, first with no technology added, then subsequently, for the case where technology has been added. Slopes appear more similar to each other here than of passenger cars.

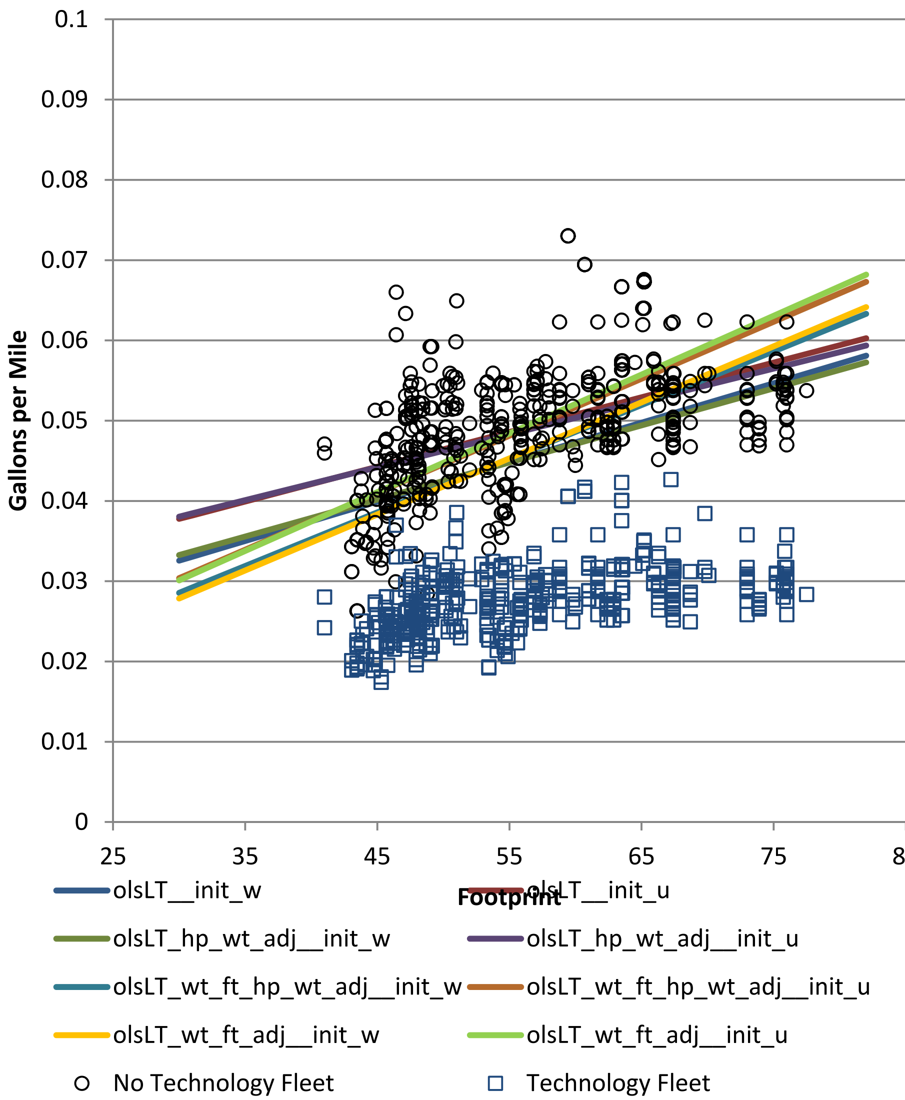

Figure V-11 Best Fit Results for Various Regressions: Trucks, No Added Technology, OLS

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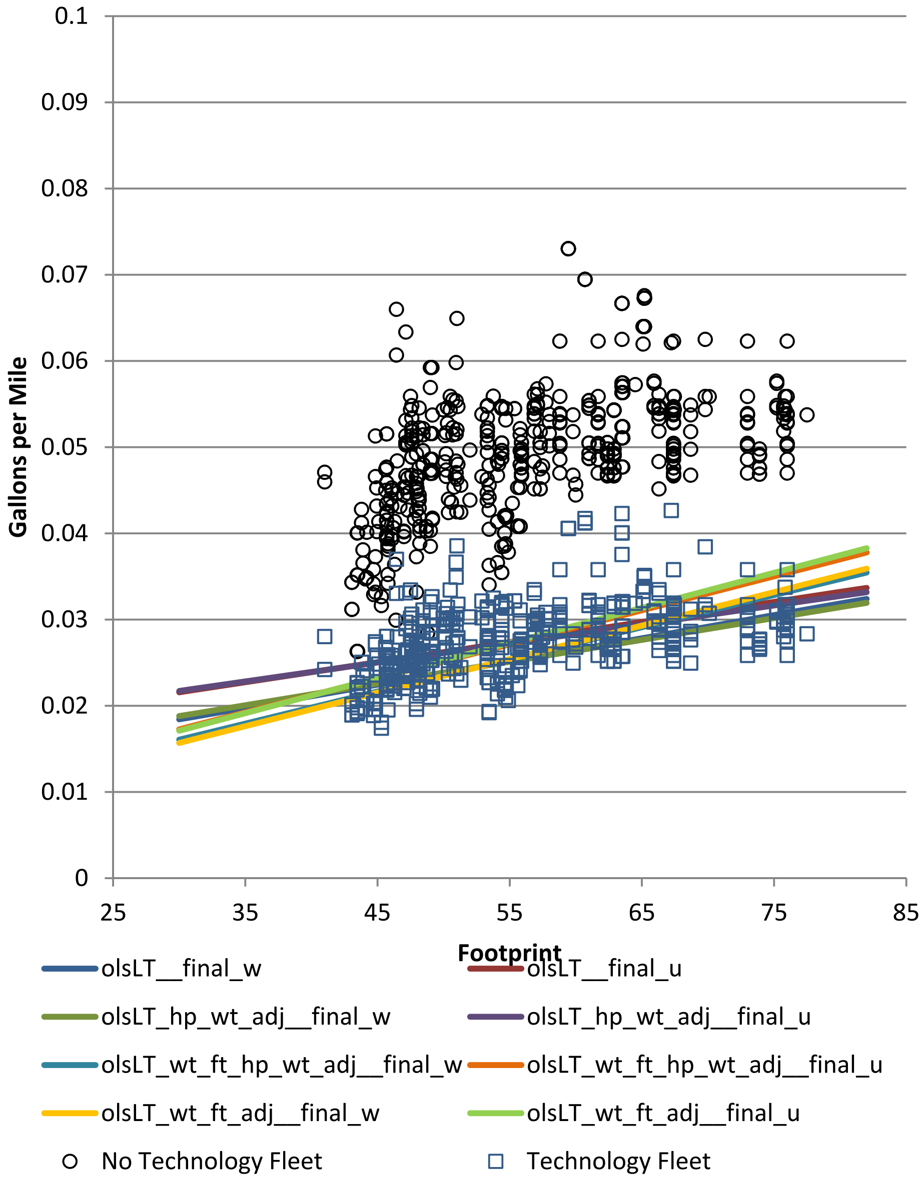

Figure V-12 Best Fit Results for Various Regressions: Trucks, With Added Technology, OLS

Figure V-13, below, displays regression results for the passenger car MAD fitted curves. The technology adjustment does not have, however, the same degree of impact in reducing the difference in the attained slopes (between those with and without the addition of technology) evidenced in the OLS regressions.

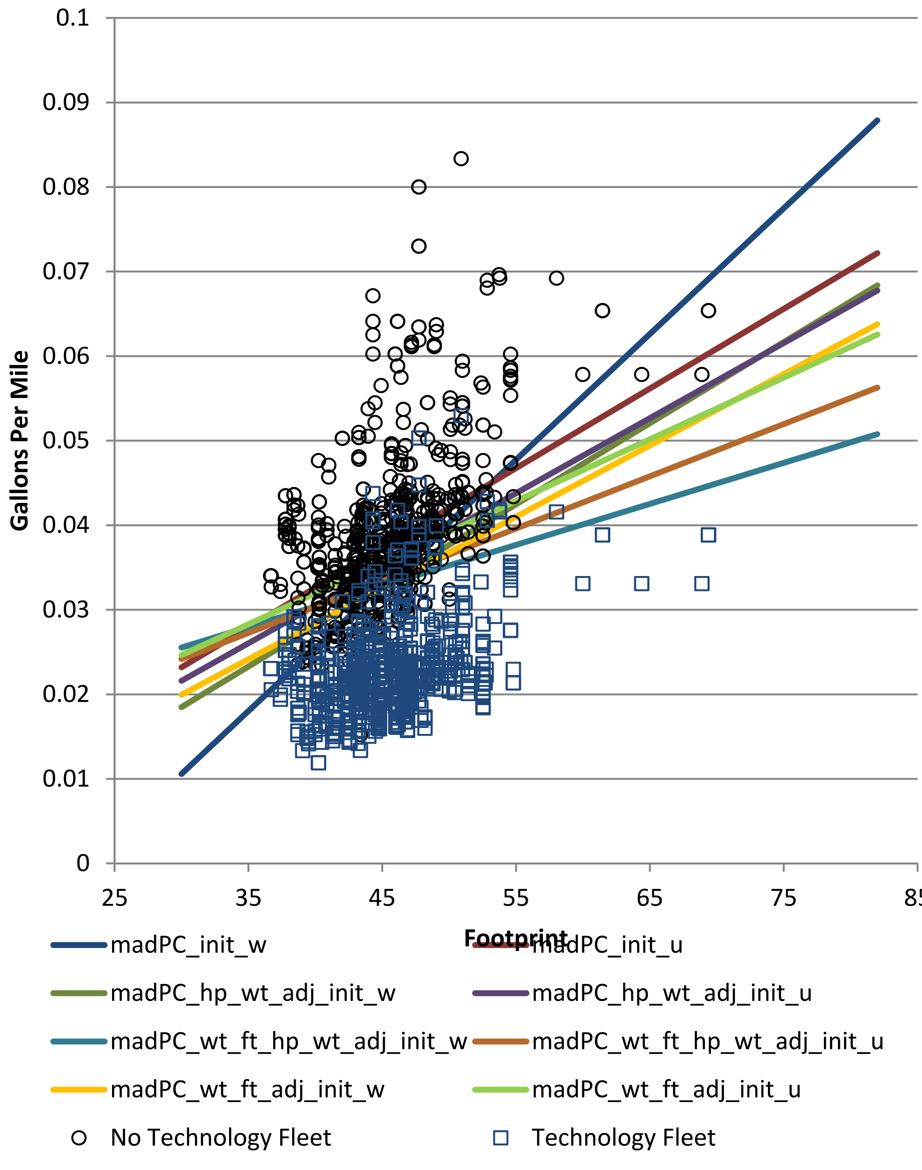

Figure V-13 Best Fit Results for Various Regressions: Cars, No Added Technology, MAD

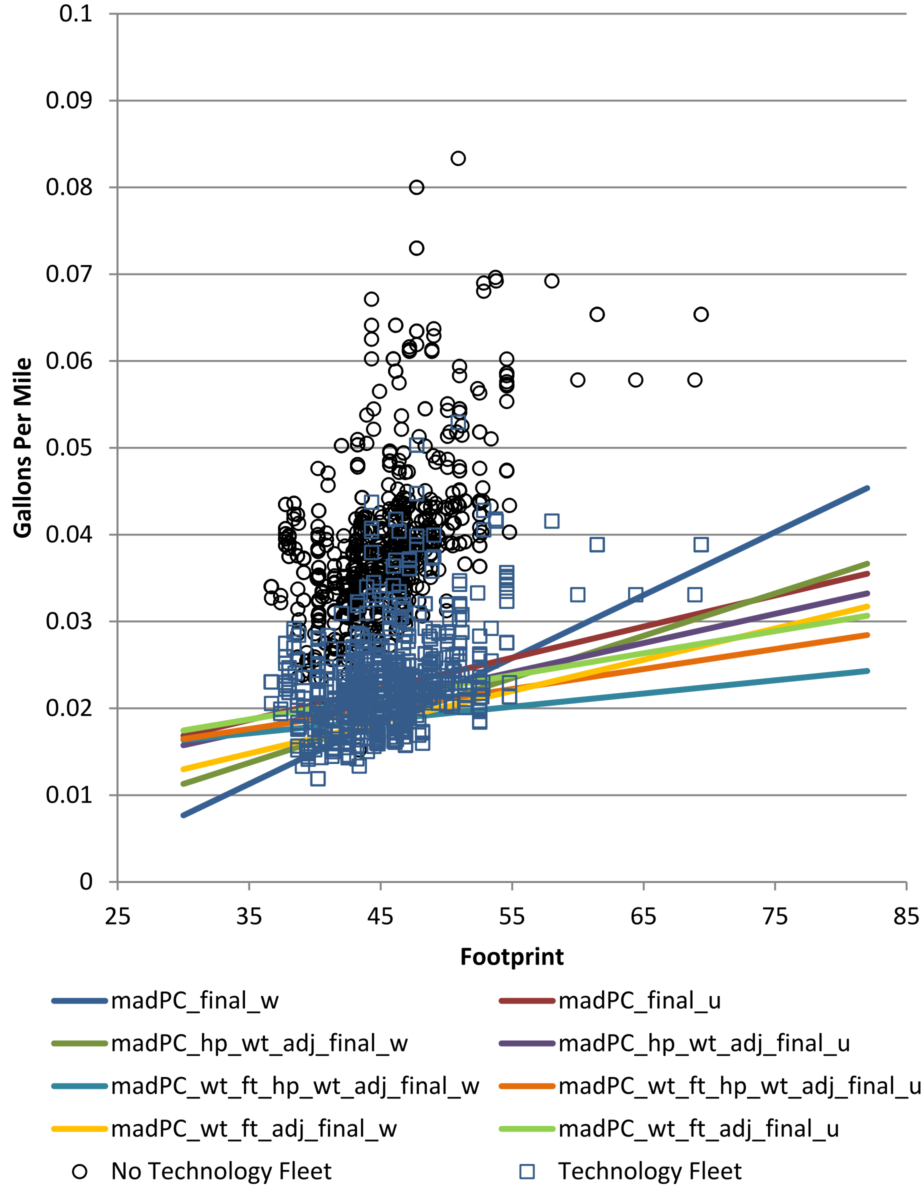

Figure V-14 Best Fit Results for Various Regressions: Cars, Added Technology, MAD

The MAD regression results below in Figure V-15 show a grouping of the fitted lines similar to that displayed in the OLS fits for trucks. As expected, an additional reduction in divergence is seen in the case where technology has been added, in Figure V-15, which can be ascribed to the reduction in heterogeneity of the fleet brought about by the addition of the technology.

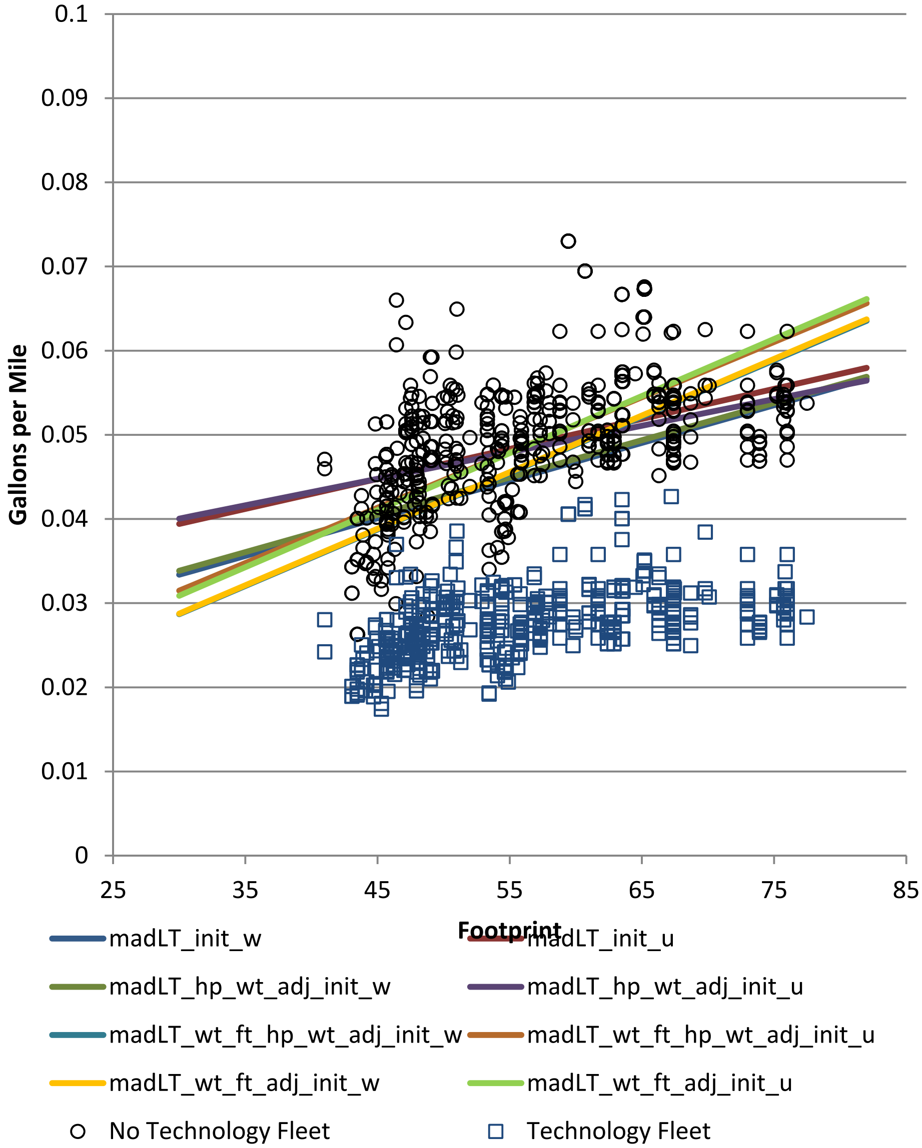

Figure V-15 Best Fit Results for Various Regressions: Trucks, No Added Technology, MAD

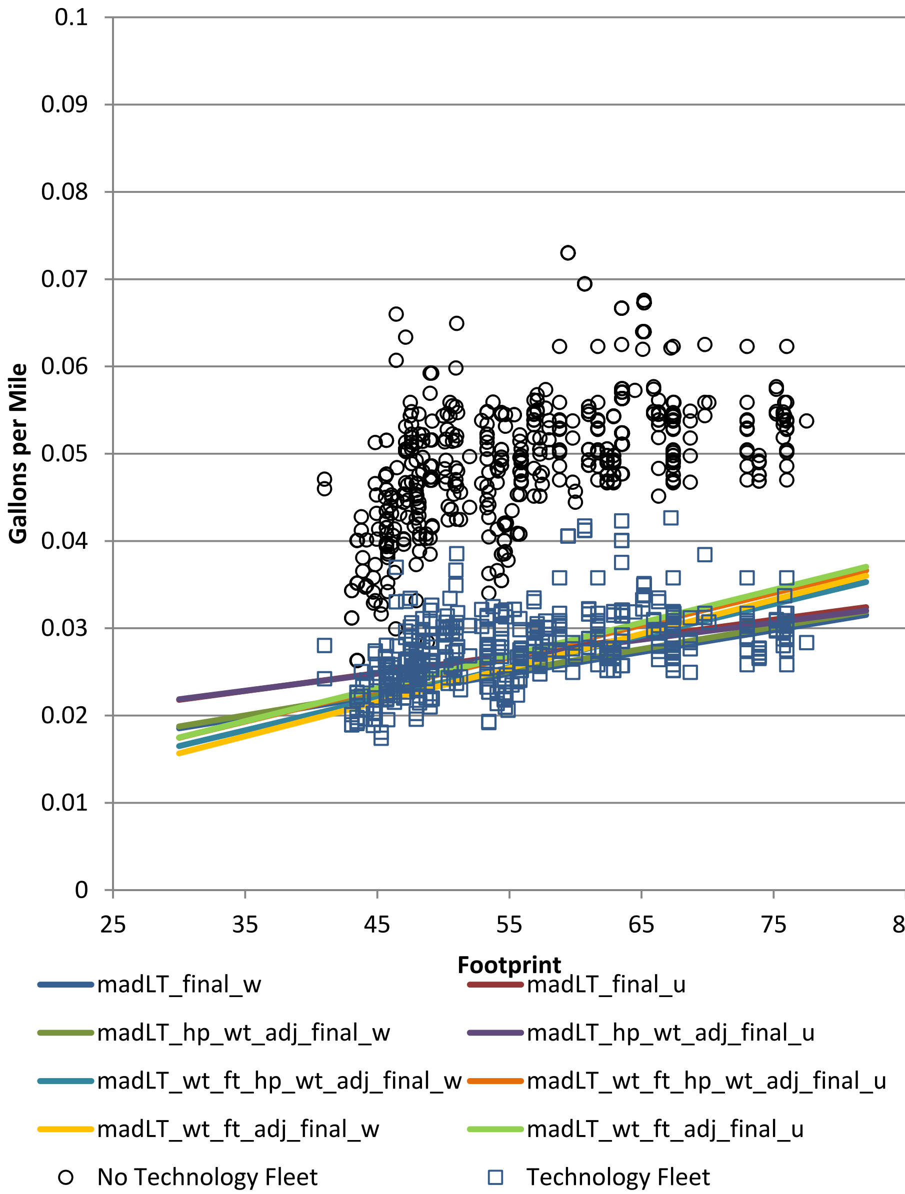

Figure V-16 Best Fit Results for Various Regressions: Trucks, with Added Technology, MAD

Updating this analysis using the revised MY 2008- and the MY 2010-based fleet projections yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[157]

[157] Docket No. NHTSA-2010-0131.

Which methodology did NHTSA choose for the proposal, and why was it reasonable?

For the proposal, the choice among the alternatives presented above was to use the OLS formulation, on sales-weighted data, using a fleet that has had technology applied, and after adjusting the data for the effect of weight-to-footprint, as described above. NHTSA believes that this represented a technically reasonable approach for purposes of developing target curves to define the proposed standards, and that it represents a reasonable trade-off among various considerations balancing statistical, technical, and policy matters, which include the statistical representativeness of the curves considered and the steepness of the curve chosen. NHTSA judged the application of technology prior to curve fitting to provide a reasonable means—one consistent with the rule's objective of encouraging manufacturers to add technology in order to increase fuel economy and reduce GHG emissions—of reducing variation in the data and thereby helping to estimate a relationship between fuel consumption/CO_2 and footprint.

Similarly, for NHTSA's NPRM MY 2008-based market-forecast and NHTSA's estimates of future technology effectiveness, the inclusion of the weight-to-footprint data adjustment prior to running the regression also helped to improve the fit of the curves by reducing the variation in the data, and NHTSA believed that the benefits of this adjustment for the proposed rule likely outweighed the potential that resultant curves might somehow encourage reduced load carrying capability or vehicle performance (note that we were not suggesting that we believed these adjustments would reduce load carrying capability or vehicle performance). In addition to reducing the variability, the truck curve was also steepened, and the car curve flattened compared to curves fitted to sales weighted data that do not include these normalizations. NHTSA agreed with manufacturers of full-size pick-up trucks that in order to maintain towing and hauling utility, the engines on pick-up trucks must be more powerful, than their low "density" nature statistically suggested based on NHTSA's NPRM MY 2008-based market forecast and NHTSA's estimates of the effectiveness of different fuel-saving technologies. Therefore, NHTSA judged that it may be more appropriate (*i.e.*, in terms of relative compliance challenges faced by different light truck manufacturers) to adjust the slope of the curves defining fuel economy and CO_2 targets.

The results of the normalized regressions are displayed in Table, below.[158]

Table V-7 Regression Results

[158] As presented in the draft TSD and PRIA supporting the NPRM, this table erroneously reported coefficients from the regression using normalization based on differences in horsepower to weight rather than differences in weight per footprint. The differences in this Table as presented in this final RIA reflect this correction.

Vehicle	Slope (gallons/mile)	Constant (gallons/mile)
Passenger cars	0.00037782	0.00181033
Light trucks	0.00038891	0.00401336

Updating this analysis using the corrected MY 2008- and the MY 2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[159]

As described above, however, other approaches are also technically reasonable, and also represent a way of expressing the underlying relationships. NHTSA revisited the analysis for the final rule, after correcting the underlying MY 2008 based market forecast, developing a MY 2010 based market forecast, updating estimates of technology effectiveness and cost, and after considering relevant public comments. As presented below, results of these updated analyses were generally similar to those supporting the NPRM analysis results, and NHTSA's balancing of considerations led NHTSA to select final curves unchanged from the NPRM curves.

As shown in the figures below, the line represents the sales-weighted OLS regression fit of gallons per mile regressed on footprint, with the proposal data first adjusted by weight to footprint, as described above. This introduces weight as an additional consideration into the slope of the footprint curve, although in a manner that adjusts the data as described above, and thus maintains a simple graphical interpretation of the curve in a two dimensional space (gallons per mile and footprint).

[159] Docket No. NHTSA-2010-0131.

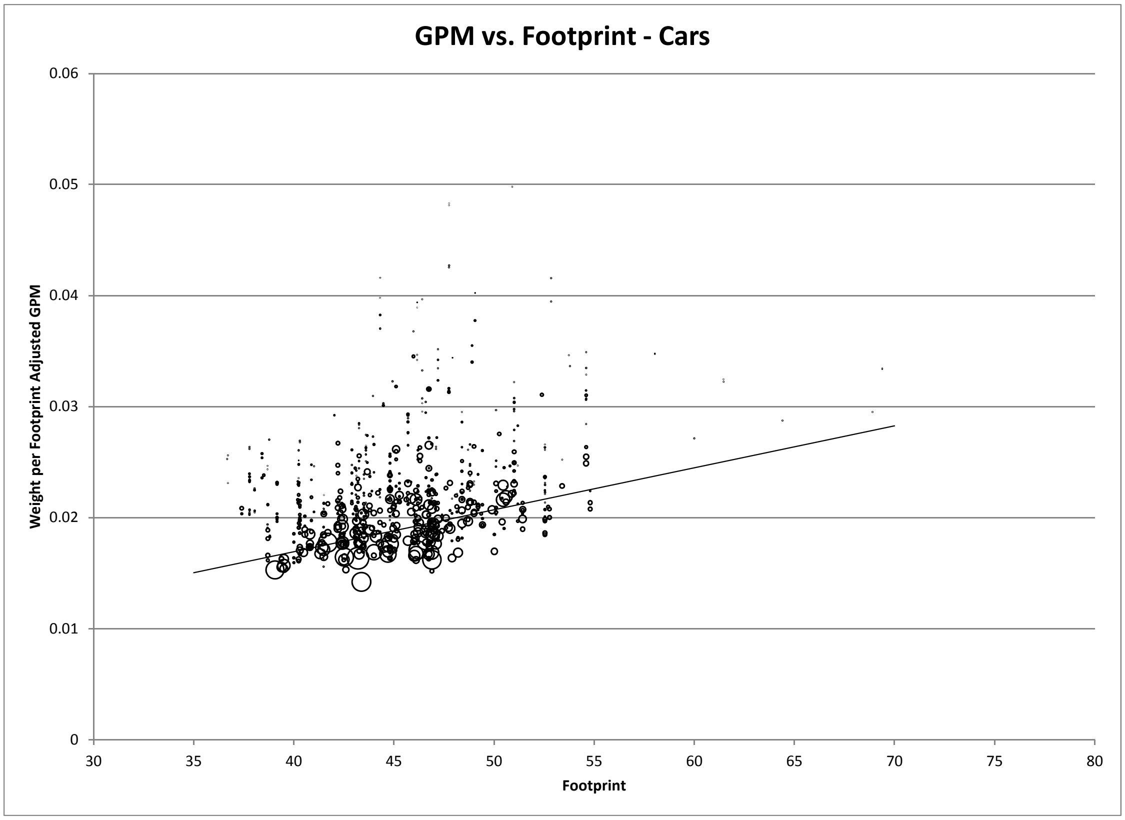

Figure V-17 Gallons per Mile versus Footprint, Cars (Data adjusted by weight to footprint).

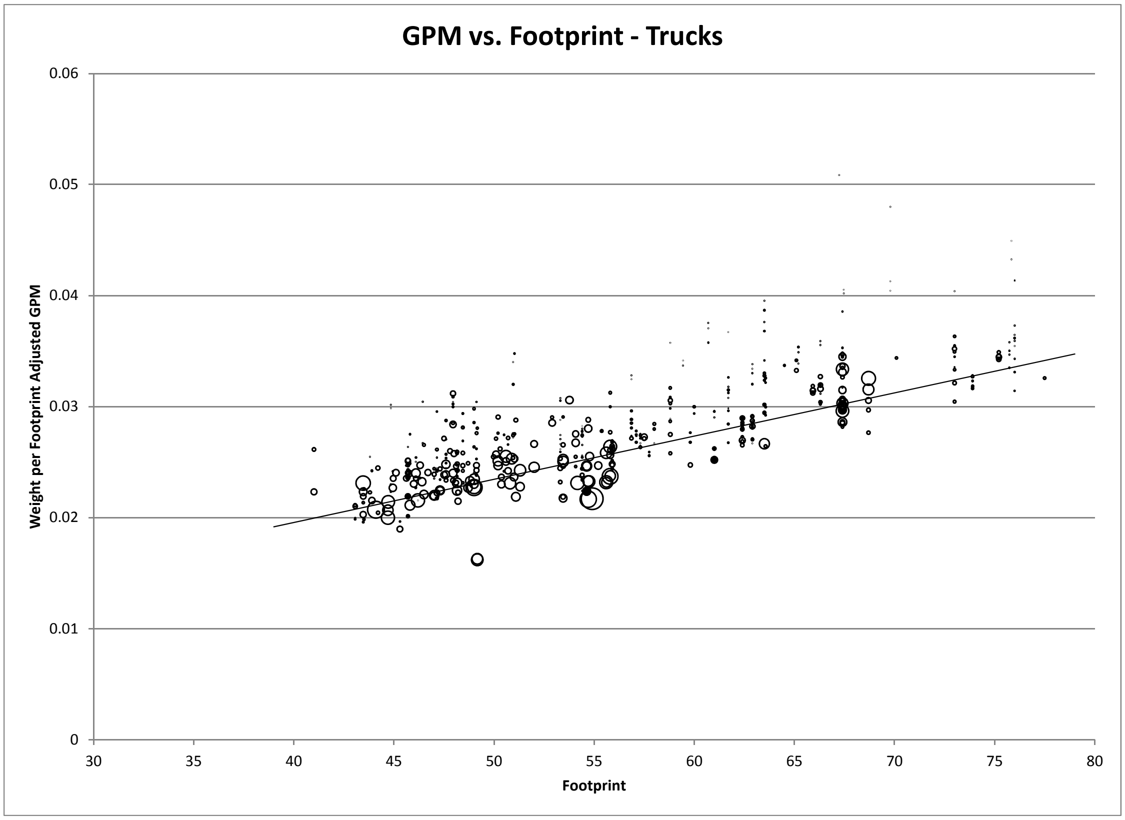

Figure V-18 Gallons per Mile versus Footprint, Trucks (data adjusted by weight to footprint).

Updating this analysis using the revised MY 2008- and the MY 2010-based fleet projection yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[160]

In the preceding two figures, passenger car and light truck data is represented for the specification chosen, with the size of the observation scaled to sales. NHTSA notes with regard to light trucks that for the MYs 2012-2016 analysis NPRM and final rule analyses, some models of pickups are aggregated, when, for example, the same pickup had been available in different cab configurations with different wheelbases.[161] For the analysis presented above, these models have been disaggregated and are represented individually, which leads to a slightly different outcome in the regression results than had they remained aggregated.

Implications of the adopted slopes compared to the slopes in MYs 2012-2016 Rules

[160] Docket No. NHTSA-2010-0131.
[161] *See* 75 FR at 25354

The slope first proposed, and now adopted by NHTSA has several implications relative to the MY 2016 curves, with the majority of changes affecting the truck curve. The selected car curve has a slope similar to that finalized in the MYs 2012-2016 rulemaking (4.7 g/mile in MY 2016, vs. 4.5 g/mile proposed in MY 2017). By contrast, the truck curve is steeper in MY 2017 than in MY 2016 (4.0 g/mile in MY 2016 vs. 4.9 g/mile in MY 2017). As discussed previously, a steeper slope relaxes the stringency of targets for larger vehicles relative to those for smaller vehicles, thereby shifting relative compliance burdens among manufacturers based on their respective product mix. Comments regarding the slope of NHTSA's proposed curves are discussed in Section II.C of the preamble to today's final rule.

Once NHTSA determined the appropriate slope for the sloped part, how did NHTSA determine the rest of the mathematical function?

NHTSA continues to believe that without a limit at the smallest footprints, the function—whether logistic or linear—can reach values that would be unfairly burdensome for a manufacturer that elects to focus on the market for small vehicles; depending on the underlying data, an unconstrained form could result in stringency levels that are technologically infeasible and/or economically impracticable for those manufacturers that may elect to focus on the smallest vehicles. On the other side of the function, without a limit at the largest footprints, the function may provide no floor on required fuel economy. Also, the safety considerations that support the provision of a disincentive for downsizing as a compliance strategy apply weakly, if at all, to the very largest vehicles. Limiting the function's value for the largest vehicles thus leads to a function with an inherent absolute minimum level of performance, while remaining consistent with safety considerations.

Just as for slope, in determining the appropriate footprint and fuel economy values for the "cutpoints," the places along the curve where the sloped portion becomes flat, NHTSA took a fresh look for purposes of this rulemaking, taking into account the updated market forecasts and new assumptions about the availability of technologies. The next two sections discuss NHTSA's approach to cutpoints for the passenger car and light truck curves separately, as the policy considerations for each vary somewhat.

Cutpoints for Passenger Car curve

The passenger car fleet upon which NHTSA based the proposed target curves for MYs 2017-2025 was derived from MY 2008 data, as discussed above. In MY 2008, passenger car footprints ranged from 36.7 square feet, the Lotus Exige 5, to 69.3 square feet, the Daimler Maybach 62. In that fleet, several manufacturers offer small, sporty coupes below 41 square feet, such as the BMW Z4 and Mini, Honda S2000, Mazda MX-5 Miata, Porsche Carrera and 911, and Volkswagen New Beetle. Because such vehicles represent a small portion (less than 10 percent) of the passenger car market, yet often have performance, utility, and/or structural characteristics that could make it technologically infeasible and/or economically impracticable for manufacturers focusing on such vehicles to achieve the very challenging average requirements that could apply in the absence of a constraint, NHTSA again proposed to cut off the sloped portion of the passenger car function at 41 square feet, consistent with the MYs 2012-2016 rulemaking. NHTSA recognized that for manufacturers who make small vehicles in this size range, putting the cutpoint at 41 square feet creates some incentive to downsize (*i.e.*, further reduce the size, and/or increase the production of models currently smaller than 41 square feet) to make it easier to meet the target. Putting the cutpoint here may also create the incentive for manufacturers who do not currently offer such models to do so in the future. However, at the same time, NHTSA believes that there is a limit to the market for cars smaller than 41 square feet -- most consumers likely have some minimum expectation about interior volume, among other things. NHTSA thus believes that the number of consumers who will want vehicles smaller than 41 square feet (regardless of how they are priced) is small, and that the incentive to downsize to less than 41 square feet in response to this proposal, if present, will be at best minimal. On the other hand, NHTSA notes that some manufacturers are introducing mini cars not reflected in NHTSA MY 2008-based market forecast, such as the Fiat 500, to the U.S. market, and that the footprint at which the curve is limited may affect the incentive for manufacturers to do so.

Above 56 square feet, the only passenger car models present in the MY 2008 fleet were four luxury vehicles with extremely low sales volumes—the Bentley Arnage and three versions of the Rolls Royce Phantom. As in the MYs 2012-2016 rulemaking, NHTSA therefore proposed again to cut off the sloped portion of the passenger car function at 56 square feet.[162]

While meeting with manufacturers prior to issuing the proposal, NHTSA received comments from some manufacturers that, combined with slope and overall stringency, using 41 square feet as the footprint at which to cap the target for small cars would result in unduly challenging targets for small cars. NHTSA does not agree. No specific vehicle need meet its target (because standards apply to fleet average performance), and maintaining a sloped function toward the smaller end of the passenger car market is important to discourage unsafe downsizing, NHTSA thus proposed to again "cut off" the passenger car curve at 41 square feet, notwithstanding these comments.

NHTSA discusses the comments that were received for the cutpoints on both passenger car and light truck curves in the next section.

[162] The MY 2010 based market forecast has a similarly small number of cars above a footprint of 56 sq ft. These nine vehicle models include 5 Rolls Royce models, a Maybach 57-S and three BMW vehicles, with fewer than 20,000 total projected sales in any model year during this timeframe.

Cutpoints for Light Truck curve

The light truck fleet upon which NHTSA based the proposed target curves for MYs 2017-2025, like the passenger car fleet, was derived from MY 2008 data, as discussed above. In MY 2008, light truck footprints ranged from 41.0 square feet, the Jeep Wrangler, to 77.5 square feet, the Toyota Tundra. For consistency with the curve for passenger cars, NHTSA proposed to cut off the sloped portion of the light truck function at the same footprint, 41 square feet, although we recognized that no light trucks are currently offered below 41 square feet. With regard to the upper cutpoint, NHTSA heard from a number of manufacturers during the discussions leading up to the proposal of the MYs 2017-2025 standards that the location of the cutpoint in the MYs 2012-2016 rules, 66 square feet, resulted in very challenging targets for the largest light trucks in the later years of that rulemaking (although, because CAFE standards are based on average performance, manufacturers to not need to ensure that every vehicle model meets its fuel economy and GHG targets). See 76 FR at 74864-65. Those manufacturers requested that NHTSA extend the cutpoint to a larger footprint, to reduce targets for the largest light trucks which represent a significant percentage of those manufacturers' light truck sales. At the same time, in re-examining the light truck fleet data, NHTSA concluded that aggregating pickup truck models in the MYs 2012-2016 rule had led NHTSA to underestimate the impact of the different pickup truck model configurations above 66 square feet on manufacturers' fleet average fuel economy and CO2 levels (as discussed immediately below). In disaggregating the pickup truck model data, the impact of setting the cutpoint at 66 square feet after model year 2016 became clearer to NHTSA.

In NHTSA's view, these comments have a legitimate basis. NHTSA's market forecast used at proposal includes about 24 vehicle configurations above 74 square feet with a total volume of about 50,000 vehicles or less during any MY in the 2017-2025 time frame.[163] While a relatively small portion of the overall truck fleet, for some manufacturers, these vehicles are a non-trivial portion of their sales. As noted above, the very largest light trucks have significant load-carrying and towing capabilities that make it particularly challenging for manufacturers to add fuel economy-improving/CO_2-reducing technologies in a way that maintains the full functionality of those capabilities.[164] Considering manufacturer CBI and our estimates of the impact of the 66 square foot cutpoint for future model years, NHTSA determined to adopt curves that transition to a different cut point. While noting that no specific vehicle need meet its target (because

[163] In the MY2010 based market forecast, there are 14 vehicle configurations with a total volume of 130,000 vehicles or less during any MY in the 2017-2025 time frame. This is a similarly small portion of the overall number of vehicle models or vehicle sales.

[164] Comments on this issue are discussed in previous section of this FRIA entitled "Adjustments reflecting differences in performance and 'density'."

standards apply to fleet average performance), we believe that the information provided to us by manufacturers (*i.e.*, information provided regarding the accumulated impacts, especially on manufacturers' credit balances, of CAFE standards since MY2005 and GHG standards since MY2012) and our own analysis supported the gradual extension of the cutpoint for large light trucks in the proposal from 66 square feet in MY 2016 out to a larger footprint square feet before MY 2025. NHTSA's analysis with regard to this topic, and how it relates to the stringency of the standards, are presented in preamble IV.F and summarized in preamble section II.C.

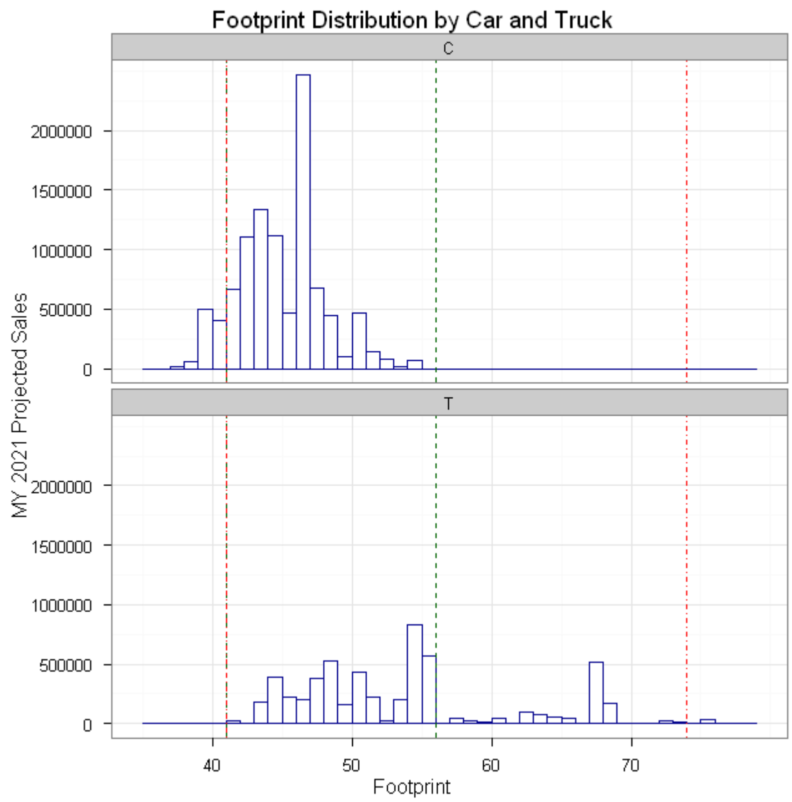

Figure V-19 Footprint Distribution by Car and Truck*

*Proposed truck cutpoints for MY 2025 shown in red, car cutpoints shown in green

Updating this analysis using the revised MY 2008- and the MY 2010-based market forecasts yielded results generally similar to those shown above. Detailed results of the analyses with the final rulemaking fleet projections are presented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[165], and noted in footnotes 162 and 163.

NHTSA proposed to phase in the higher cutpoint for the truck curve in order to avoid any backsliding from the MY 2016 standard. A target that is feasible in one model year should never

[165] Docket No. NHTSA-2010-0131.

become less feasible in a subsequent model year since manufacturers should have no reason to remove fuel economy-improving/CO_2-reducing technology from a vehicle once it has been applied. Put another way, NHTSA proposed to not allow "curve crossing" from one model year to the next. In proposing MYs 2011-2015 CAFE standards and promulgating MY 2011 standards, NHTSA proposed and requested comment on avoiding curve crossing, as an "anti-backsliding measure."[166] The MY 2016 2-cycle test curves are therefore a floor for the MYs 2017-2025 curves. For passenger cars, which have minimal change in slope from the MY 2012-2016 rulemakings and no change in cut points, there were no curve crossing issues in the proposed (or final) standards.

The minimum stringency determination was done using the two-cycle curves. Stringency adjustments for air conditioning and other credits were calculated after curves that did not cross were determined in two-cycle space. The year over year increase in these adjustments cause neither the GHG nor CAFE curves (with A/C) to contact the 2016 curves when charted.

NHTSA received some comments on the selection of these cutpoints. ACEEE commented that the extension of the light truck cutpoint upward from 66 square feet to 74 square feet would reduce stringency for large trucks even though there is no safety-related reason to discourage downsizing of these trucks. Sierra Club and Volkswagen commented that moving this cutpoint could encourage trucks to get larger and may be detrimental to societal fatalities. Global Automakers commented that the cutpoint for the smallest light trucks should be set at approximately ten percent of sales (as for passenger cars) rather than at 41 square feet. Conversely, IIHS commented that, for both passenger cars and light trucks, the 41 square feet cutpoint should be moved further to the left (*i.e.*, to even smaller footprints), to reduce the incentive for manufacturers to downsize the lightest vehicles.

NHTSA has considered these comments regarding the cutpoint applied to the high footprint end of the target function for light trucks, and we judge there to be minimal risk that manufacturers would respond to this upward extension of the cutpoint by deliberately increasing the size of light trucks that are already at the upper end of marketable vehicle sizes, particularly as gasoline prices may continue to increase in the future. Such vehicles have distinct size, maneuverability, fuel consumption, storage, and other characteristics which differ from vehicles between 43 and 48 square feet, and are likely not be suited for all consumers in all usage scenarios. Further, larger vehicles typically also have additional production costs that make it unlikely that the sales of these vehicles will increase in response to changes in the cutpoint. Therefore, we remain concerned that not to extend this cutpoint to 74 square feet would fail to take into adequate consideration the challenges to improving fuel economy and CO_2 emissions to the levels required by this final rule for vehicles with footprints larger than 66 square feet, given their increased utility. As noted above, while manufacturers are not required to ensure that every

[166] 74 Fed. Reg. at 14370 (Mar. 30, 2009).

vehicle model meets its target, NHTSA is concerned that standards with more stringent targets for large trucks would unduly burden full-line manufacturers active in the market for full-size pickups and other large light trucks, as discussed earlier, and evidenced by NHTSA's estimates of differences between compliance burdens faced by OEMs active and not active in the market for full-size pickups. While some manufacturers have recently indicated[167] that buyers are currently willing to pay a premium for fuel economy improvements, NHTSA is concerned that disparities in long-term regulatory requirements could lead to future market distortions undermining the economic practicability of the standards. Absent an upward extension of the cutpoint, such disparities would be even greater. For these reasons, NHTSA does not expect that gradually extending the cutpoint to 74 square feet will incentivize the upsizing of large trucks and, thus, believe there will be no adverse effects on societal safety. Therefore, we are promulgating standards that, as proposed, gradually extend the truck curve cutpoint to 74 square feet. We have also considered the above comments by Global Automakers and IIHS on the cutpoints for the smallest passenger cars and light trucks. In our judgment, placing these cutpoints at 41 square feet continues to strike an appropriate balance between (a) not discouraging manufacturers from introducing new small vehicle models in the U.S. and (b) not encouraging manufacturers to downsize small vehicles.

Once NHTSA determined the complete mathematical function shape, how did NHTSA adjust the curves to develop the proposed standards and regulatory alternatives?

The curves discussed above all reflect the addition of technology to individual vehicle models to reduce technology differences between vehicle models before fitting curves. This application of technology was conducted not to directly determine the proposed standards, but rather for purposes of technology adjustments, and set aside considerations regarding potential rates of application (*i.e.*, phase-in caps), and considerations regarding economic implications of applying specific technologies to specific vehicle models. The following sections describe further adjustments to the curves discussed above, that affect both the shape of the curve, and the location of the curve, that helped NHTSA determine curves that defined the proposed standards.

Adjusting for Year over Year Stringency

As in the MYs 2012-2016 rules, NHTSA developed curves defining regulatory alternatives for consideration by "shifting" these curves. For the MYs 2012-2016 rules, NHTSA did so on an

[167] For example, in its June 11, 2012 edition, *Automotive News* quoted a Ford sales official saying that "fuel efficiency continues to be a top purchaser driver." ("More MPG – ASAP", *Automotive News*, Jun 11, 2012.)

absolute basis, offsetting the fitted curve by the same value (in gpm or g/mi) at all footprints. In developing the proposal for MYs 2017-2025, NHTSA reconsidered the use of this approach, and concluded that after MY 2016, curves should be offset on a relative basis—that is, by adjusting the entire gpm-based curve (and, equivalently, the CO_2 curve) by the same percentage rather than the same absolute value. NHTSA's estimates—made jointly with EPA—of the effectiveness of these technologies are all expressed in relative terms—that is, each technology (with the exception of A/C) is estimated to reduce fuel consumption (the inverse of fuel economy) and CO_2 emissions by a specific percentage of fuel consumption without the technology. It is, therefore, more consistent with the agencies' estimates of technology effectiveness to develop standards and regulatory alternatives by applying a proportional offset to curves expressing fuel consumption or emissions as a function of footprint. In addition, extended indefinitely (and without other compensating adjustments), an absolute offset would eventually (*i.e.*, at very high average stringencies) produce negative (gpm or g/mi) targets. Relative offsets avoid this potential outcome. Relative offsets do cause curves to become, on a fuel consumption and CO_2 basis, flatter at greater average stringencies; however, as discussed above, this outcome remains consistent with the agencies' estimates of technology effectiveness. In other words, given a relative decrease in average required fuel consumption or CO_2 emissions, a curve that is flatter by the same relative amount should be equally challenging in terms of the potential to achieve compliance through the addition of fuel-saving technology.

On this basis, and considering that the "flattening" occurs gradually for the regulatory alternatives NHTSA has evaluated, NHTSA conclude that this approach to offsetting the curves to develop year-by-year regulatory alternatives neither re-creates a situation in which manufacturers are likely to respond to standards in ways that compromise highway safety, nor undoes the attribute-based standard's more equitable balancing of compliance burdens among disparate manufacturers. NHTSA sought comment on these conclusions, and on any other means that might avoid the potential negative outcomes discussed above. As indicated earlier, ACEEE and the Alliance both expressed support for the application of relative adjustments in order to develop year-over-year increases in the stringency of fuel consumption and CO_2 targets, although the Alliance also commented that this approach should be revisited as part of the planned mid-term evaluation.

Adjusting for anticipated improvements to mobile air conditioning systems

The fuel economy values in NHTSA's market forecasts are based on the 2-cycle (*i.e.*, city and highway) fuel economy test and calculation procedures that do not reflect potential improvements in air conditioning system efficiency, refrigerant leakage, or refrigerant Global Warming Potential (GWP). Recognizing that there are significant and cost effective potential air conditioning system improvements available in the rulemaking timeframe (discussed in detail in joint TSD Chapter 5), NHTSA is increasing the stringency of the target curves based on

NHTSA's assessment of the capability of manufacturers to implement these changes. For the proposed CAFE standards and alternatives, an offset was included based on air conditioning system efficiency improvements, as these improvements are the only improvements that effect vehicle fuel economy. For the proposed GHG standards and alternatives, a stringency increase was included based on air conditioning system efficiency, leakage and refrigerant improvements. As discussed in Chapter 5 of the joint TSD, the air conditioning system improvements affect a vehicle's fuel efficiency or CO_2 emissions performance as an additive stringency increase, as compared to other fuel efficiency improving technologies which are multiplicative. Therefore, in adjusting target curves for improvements in the air conditioning system performance, NHTSA adjusted the target curves by additive stringency increases (or vertical shifts) in the curves.

For the GHG target curves, the offset for air conditioning system performance is being handled in the same manner as for the MYs 2012-2016 rules. For the CAFE target curves, NHTSA for the first time is accounting for potential improvements in air conditioning system performance. Using this methodology, NHTSA first uses a multiplicative stringency adjustment for the sloped portion of the curves to reflect the effectiveness on technologies other that air conditioning system technologies, creating a series of curve shapes that are "fanned" based on two-cycle performance. Then the curves are offset vertically by the air conditioning improvement by an equal amount at every point.

What does NHTSA's updated analysis indicate?

As discussed above, NHTSA has used two different market forecasts to conduct analyses supporting today's final rule. The first, referred to here as the "MY 2008-Based Fleet Projection," is largely identical to that used for analysis supporting the NPRM, but includes some corrections (in particular, to the footprint of some vehicle models) discussed in Chapter 1 of the joint TSD. The second, referred to here as the "MY 2010-Based Fleet Projection," is a post-proposal market forecast based on the MY 2010 fleet of vehicles; the development of this 2010 based fleet projection is discussed in Chapter 1 of the joint TSD.

Having made these changes, NHTSA repeated the normalization and statistical analyses describe above, following the same approaches as used in the analysis supporting the NPRM. The tables and charts that follow compare the results of NHTSA's updated analysis—documented in a memorandum titled "Curve Fitting Analysis: Regression Results," available in NHTSA's docket.[168]—to those of NHTSA's prior analysis, and compare the resultant fitted lines to the lines (one each for passenger cars and light trucks) selected for purposes of developing the proposed attribute-based standards. The charts below present details of the results in graphical form.

[168] Docket No. NHTSA-2010-0131.

Table V-8 Fitted Coefficients (Slope in gpm/sf, Intercept in gpm), Passenger Cars

Normalized for Technology Differences	Normalized for Differences in Power/Weight	Normalized for Differences in Weight/Footprint	Sales-Weighted	Regression Technique	Slope - NPRM Analysis	Slope - MY2008-Based Market Forecast	Slope - MY2010-Based Market Forecast	Intercept - NPRM Analysis	Intercept - MY2008-Based Market Forecast	Intercept - MY2010-Based Market Forecast
Yes	No	No	Yes	OLS	0.000648	0.000510	0.000472	-0.01027	-0.00450	-0.00376
Yes	No	No	No	OLS	0.000513	0.000464	0.000502	0.00009	0.00184	-0.00076
Yes	No	No	Yes	MAD	0.000725	0.000560	0.000427	-0.01408	-0.00699	-0.00210
Yes	No	No	No	MAD	0.000359	0.000334	0.000445	0.00610	0.00650	0.00076
Yes	Yes	No	Yes	OLS	0.000431	0.000293	0.000248	-0.00052	0.00520	0.00643
Yes	Yes	No	No	OLS	0.000399	0.000351	0.000398	0.00336	0.00508	0.00221
Yes	Yes	Yes	Yes	OLS	0.000161	0.000131	0.000093	0.01155	0.01238	0.01349
Yes	Yes	Yes	No	OLS	0.000264	0.000250	0.000268	0.00844	0.00873	0.00736
No	No	No	Yes	MAD	0.001486	0.001220	0.001058	-0.03401	-0.02131	-0.01670
No	No	No	No	MAD	0.000942	0.000959	0.000995	-0.00507	-0.00572	-0.00944
No	No	No	Yes	OLS	0.001345	0.001175	0.001096	-0.02766	-0.01974	-0.01806
No	No	No	No	OLS	0.001109	0.001085	0.001099	-0.01122	-0.00983	-0.01259
No	Yes	No	Yes	OLS	0.000984	0.000800	0.000737	-0.01144	-0.00299	-0.00176
No	Yes	No	No	OLS	0.000920	0.000890	0.000933	-0.00579	-0.00425	-0.00785
No	Yes	Yes	Yes	OLS	0.000481	0.000452	0.000403	0.01103	0.01242	0.01336
No	Yes	Yes	No	OLS	0.000669	0.000673	0.000654	0.00367	0.00358	0.00319
Yes	No	Yes	Yes	OLS	<u>0.000378</u>	0.000348	0.000316	<u>0.00181</u>	0.00268	0.00330
Yes	No	Yes	No	OLS	0.000378	0.000362	0.000371	0.00517	0.00550	0.00440

Note 1: Coefficients selected for NPRM shown underlined.

Note 2: "MY2008-Based Fleet Projection" refers to market forecast developed using (a) MY2008 vehicle models and characteristics, (b) AEO2011-based overall passenger car and light truck volumes, and (c) manufacturer- and segment-level shares from forecast provided late 2009 by CSM (now owned by Global Insight).

Note 3: "MY2010-Based Fleet Projection" refers to market forecast developed using (a) MY2010 vehicle models and characteristics, (b) AEO2012-based overall passenger car and light truck volumes, and (c) manufacturer- and segment-level shares from forecast provided late 2011 by J.D. Power (automotive forecasting service now owned by LMC).

Table V-9 Fitted Coefficients (Slope in gpm/sf, Intercept in gpm), Light Trucks

Normalized for Technology Differences	Normalized for Differences in Power/Weight	Normalized for Differences in Weight/Footprint	Sales-Weighted	Regression Technique	Slope - NPRM Analysis	Slope - MY2008-Based Market Forecast	Slope - MY2010-Based Market Forecast	Intercept - NPRM Analysis	Intercept - MY2008-Based Market Forecast	Intercept - MY2010-Based Market Forecast
Yes	No	No	Yes	OLS	0.000269	0.000251	0.000256	0.01036	0.01012	0.00976
Yes	No	No	No	OLS	0.000233	0.000229	0.000198	0.01457	0.01376	0.01477
Yes	No	No	Yes	MAD	0.000250	0.000245	0.000278	0.01104	0.01060	0.00832
Yes	No	No	No	MAD	0.000204	0.000210	0.000231	0.01567	0.01438	0.01248
Yes	Yes	No	Yes	OLS	0.000253	0.000239	0.000237	0.01122	0.01078	0.01078
Yes	Yes	No	No	OLS	0.000221	0.000220	0.000201	0.01509	0.01414	0.01448
Yes	Yes	Yes	Yes	OLS	0.000373	0.000347	0.000340	0.00487	0.00507	0.00526
Yes	Yes	Yes	No	OLS	0.000395	0.000374	0.000303	0.00541	0.00558	0.00864
No	No	No	Yes	MAD	0.000448	0.000452	0.000481	0.01995	0.01984	0.01654
No	No	No	No	MAD	0.000356	0.000349	0.000440	0.02872	0.02914	0.02139
No	No	No	Yes	OLS	0.000491	0.000483	0.000470	0.01784	0.01825	0.01756
No	No	No	No	OLS	0.000433	0.000432	0.000423	0.02480	0.02486	0.02283
No	Yes	No	Yes	OLS	0.000462	0.000453	0.000446	0.01941	0.01988	0.01890
No	Yes	No	No	OLS	0.000410	0.000409	0.000426	0.02575	0.02579	0.02245
No	Yes	Yes	Yes	OLS	0.000669	0.000662	0.000629	0.00849	0.00881	0.00903
No	Yes	Yes	No	OLS	0.000710	0.000708	0.000609	0.00909	0.00919	0.01199
Yes	No	Yes	Yes	OLS	<u>0.000389</u>	0.000359	0.000358	<u>0.00401</u>	0.00441	0.00425
Yes	No	Yes	No	OLS	0.000407	0.000383	0.000301	0.00489	0.00520	0.00892

Note 1: Coefficients selected for NPRM shown underlined.

Note 2: "MY2008-Based Market Forecast" refers to market forecast developed using (a) MY2008 vehicle models and characteristics, (b) AEO2011-based overall passenger car and light truck volumes, and (c) manufacturer- and segment-level shares from forecast provided late 2009 by CSM (now owned by Global Insight).

Note 3: "MY2010-Based Fleet Projection" refers to market forecast developed using (a) MY2010 vehicle models and characteristics, (b) AEO2012-based overall passenger car and light truck volumes, and (c) manufacturer- and segment-level shares from forecast provided late 2011 by J.D. Power (automotive forecasting service now owned by LMC).

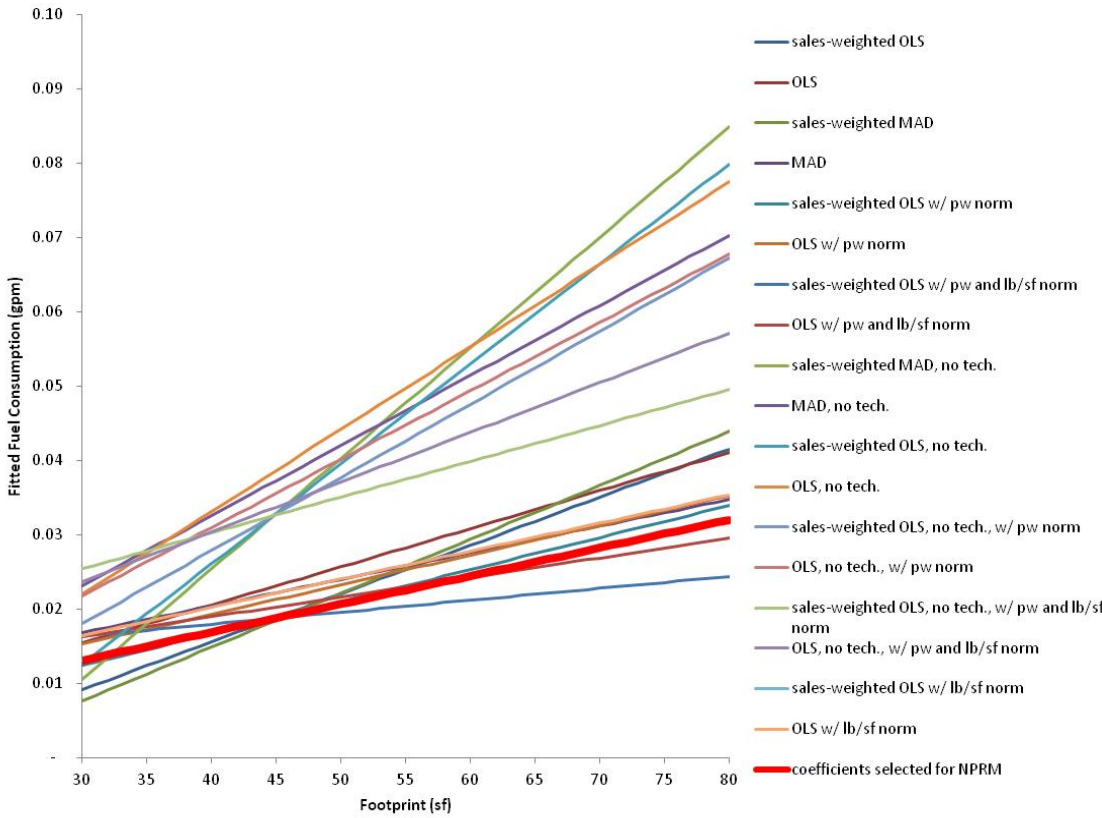

Figure V-20 Fitted Lines, Passenger Cars, NPRM Analysis

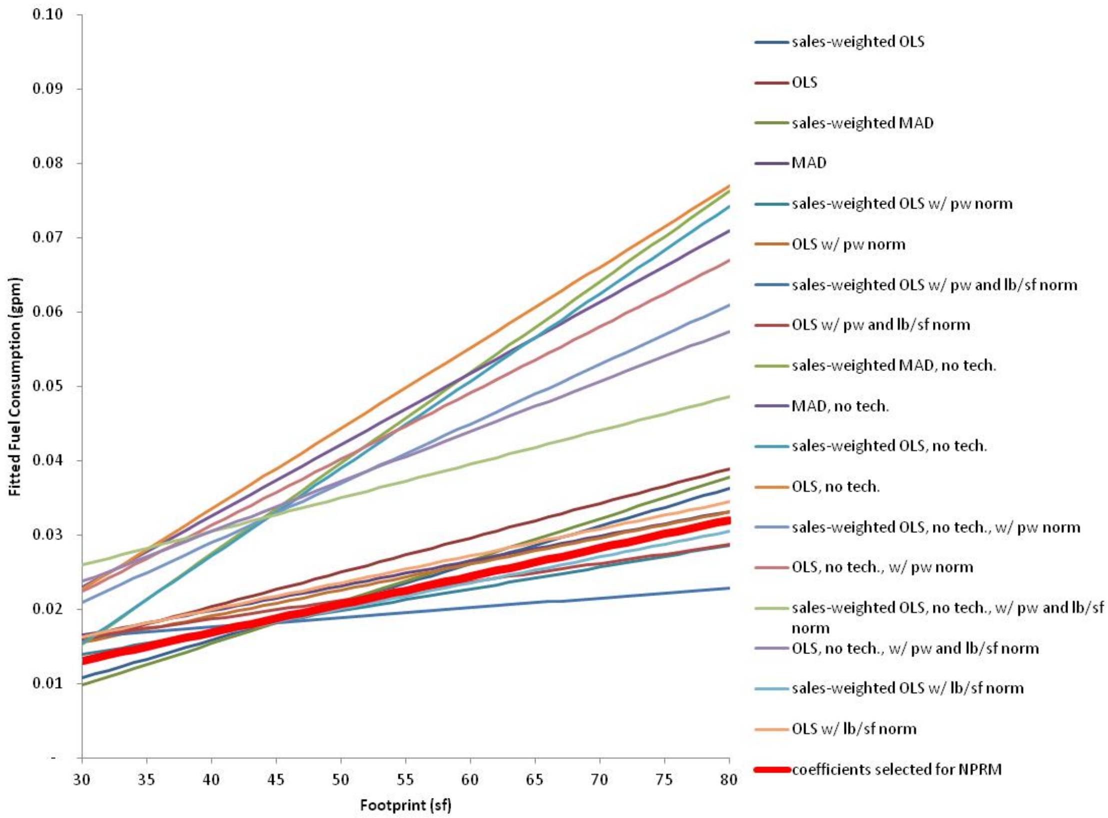

Figure V-21 Fitted Lines, Passenger Cars, Corrected MY2008-Based Market Forecast

Note 1: Line based on coefficients selected for NPRM shown for comparison.

Note 2: “MY2008-Based Fleet Projection” refers to market forecast developed using (a) MY2008 vehicle models and characteristics, (b) AEO2011-based overall passenger car and light truck volumes, and (c) manufacturer- and segment-level shares from forecast provided late 2009 by CSM (now owned by Global Insight).

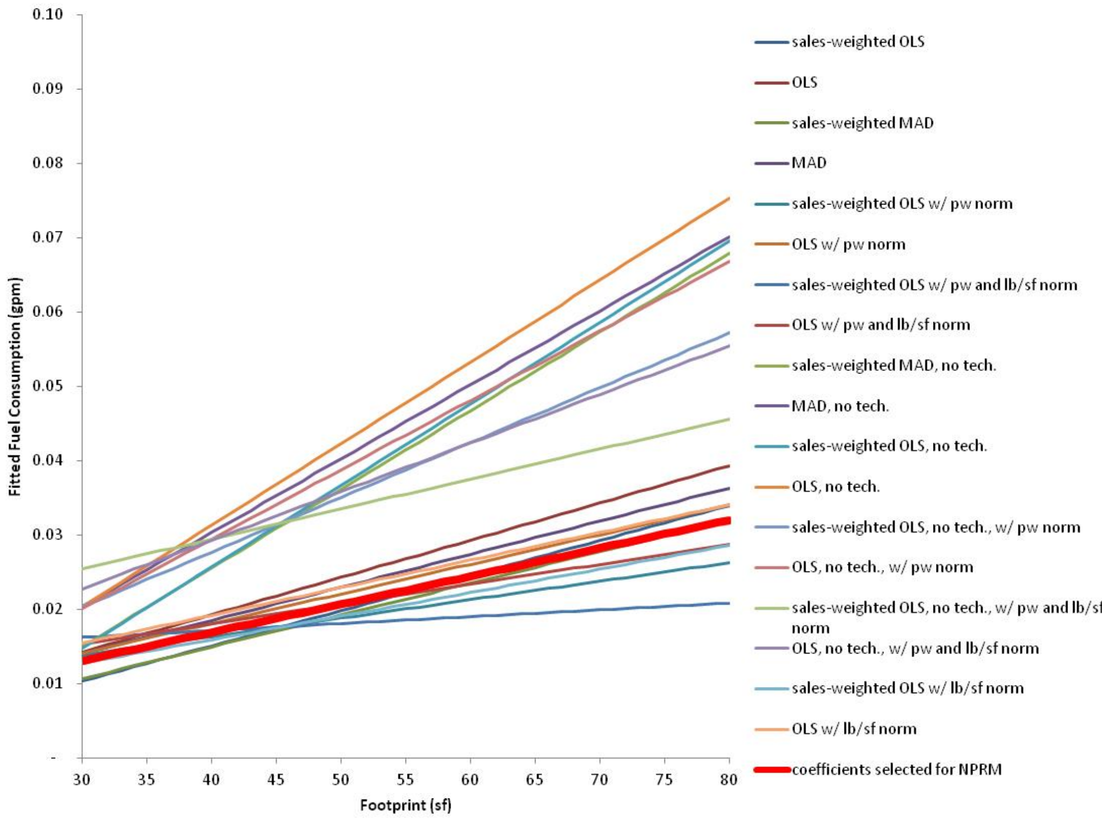

Figure V-22 Fitted Lines, Passenger Cars, MY2010-Based Market Forecast

Note 1: Line based on coefficients selected for NPRM shown for comparison.

Note 2: “MY2010-Based Fleet Projection” refers to market forecast developed using (a) MY2010 vehicle models and characteristics, (b) AEO2012-based overall passenger car and light truck volumes, and (c) manufacturer- and segment-level shares from forecast provided late 2011 by J.D. Power (automotive forecasting service now owned by LMC).

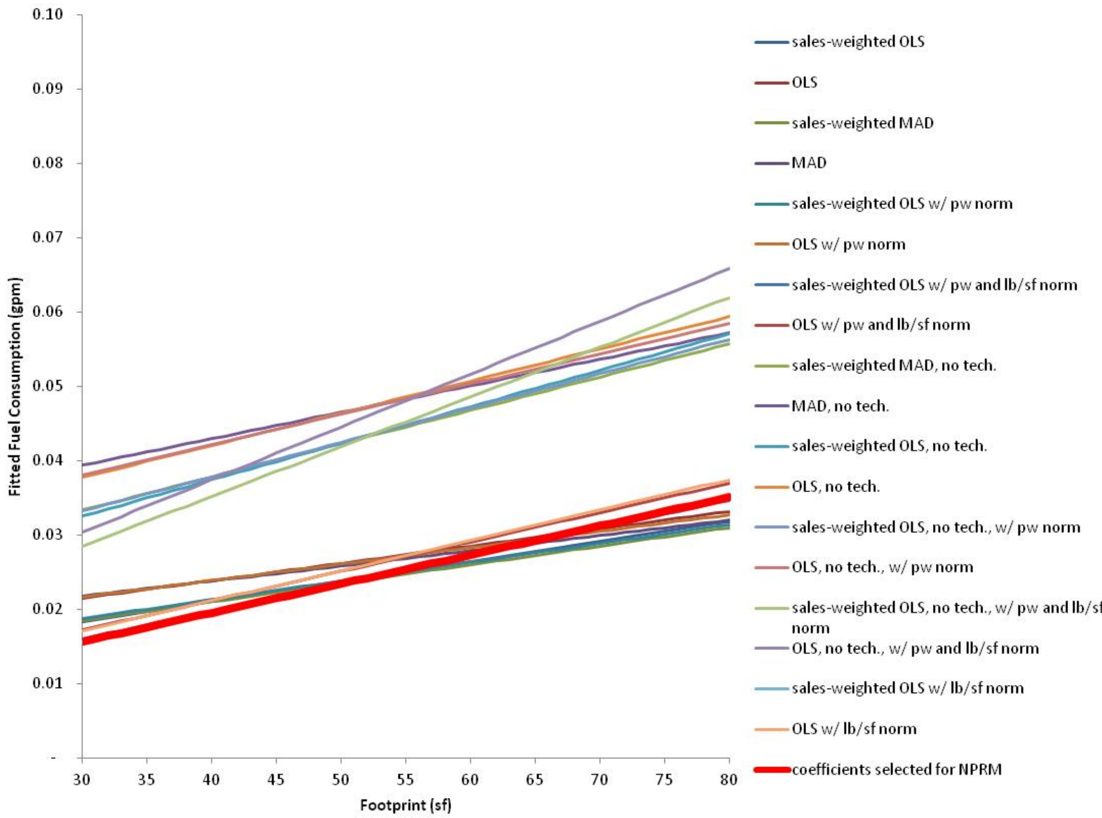

Figure V-23 Fitted Lines, Light Trucks, NPRM Analysis

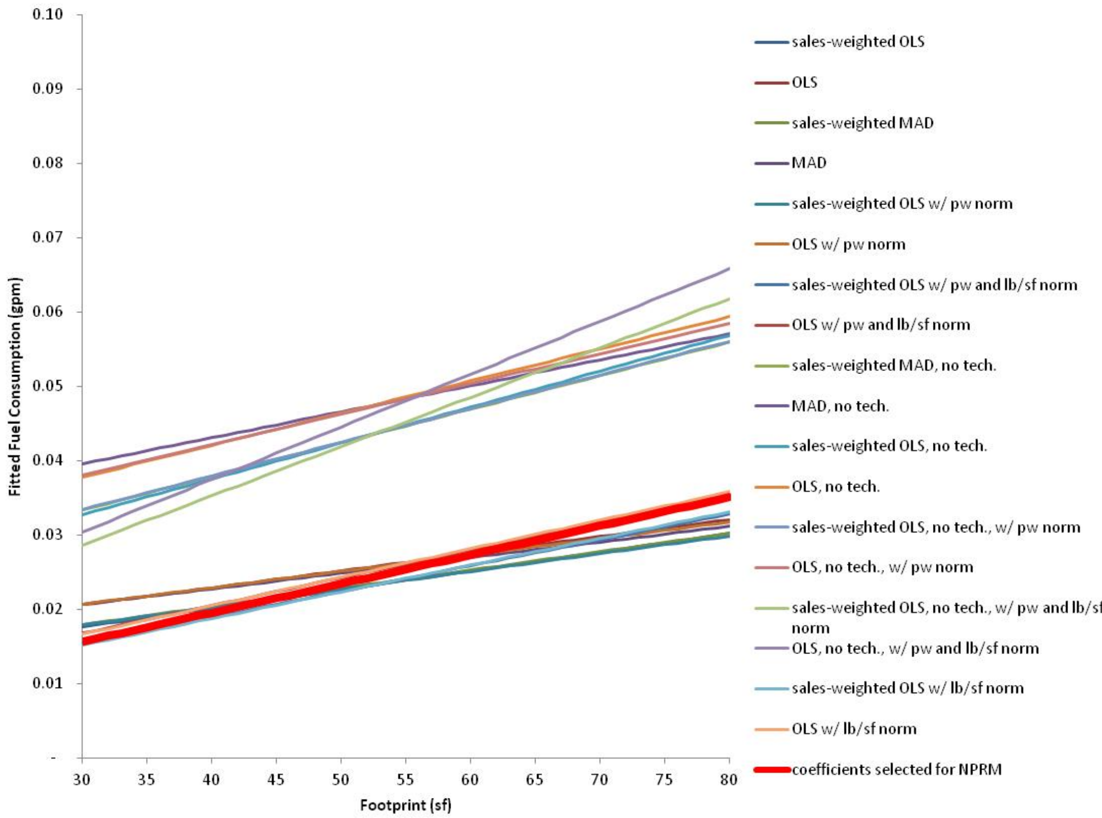

Figure V-24 Fitted Lines, Light Trucks, Corrected MY2008-Based Market Forecast

Note 1: Line based on coefficients selected for NPRM shown for comparison.

Note 2: "MY2008-Based Fleet Projection" refers to market forecast developed using (a) MY2008 vehicle models and characteristics, (b) AEO2011-based overall passenger car and light truck volumes, and (c) manufacturer- and segment-level shares from forecast provided late 2009 by CSM (now owned by Global Insight).

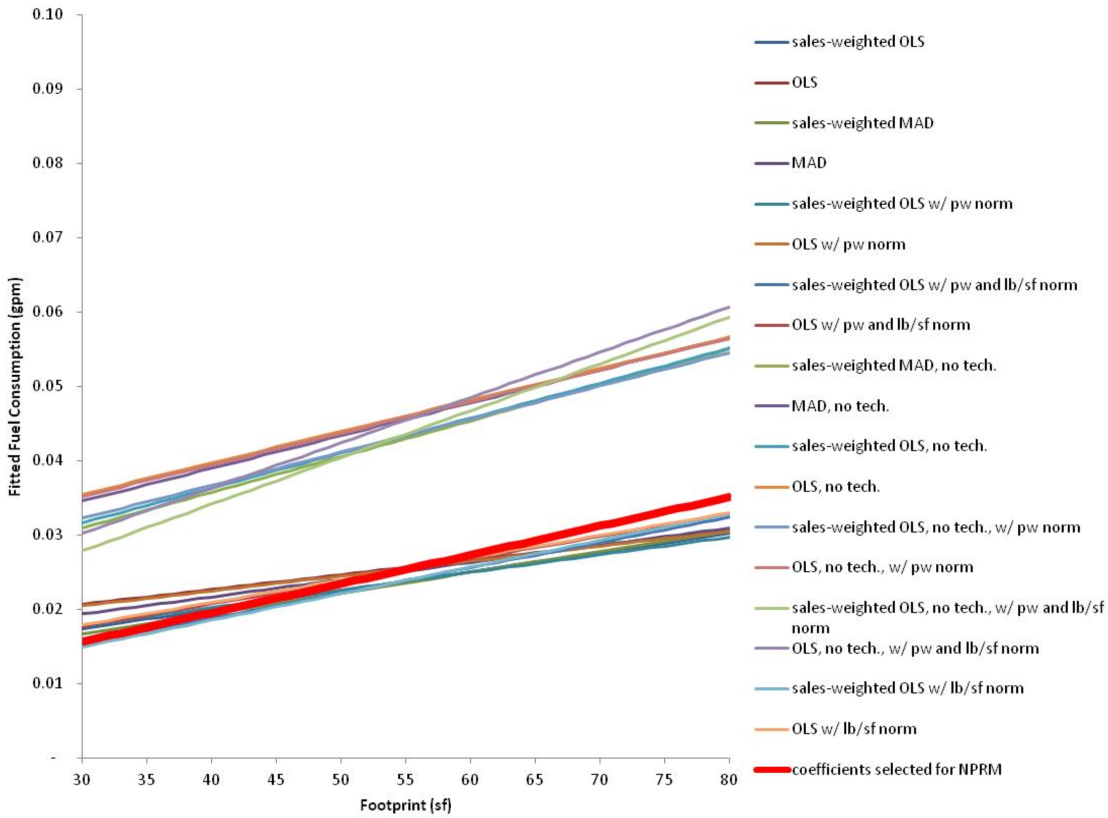

Figure V-25 Fitted Lines, Light Trucks, MY2010-Based Market Forecast

Note 1: Line based on coefficients selected for NPRM shown for comparison.

Note 2: “MY2010-Based Fleet Projection” refers to market forecast developed using (a) MY2010 vehicle models and characteristics, (b) AEO2012-based overall passenger car and light truck volumes, and (c) manufacturer- and segment-level shares from forecast provided late 2011 by J.D. Power (automotive forecasting service now owned by LMC).

As discussed above, the selection of a calibrated functional form—in this case, a specific line expressing a relationship between fuel consumption and footprint—upon which to base attribute-based fuel economy and related GHG standards involves considering not just the apparent range of the relevant technical relationship, but also the potential implications for affected policy issues. The approaches described above provide a range of reasonable means of estimating relationships between observed or adjusted fuel consumption and footprint.

Having made corrections to the MY 2008-based fleet projection, and having developed a new MY 2010-based fleet projection, NHTSA has obtained results generally similar, albeit not identical, to those obtained for the NPRM analysis. For any given method of estimating these lines, it is unlikely that NHTSA could have obtained identical results after changing inputs. Also, there is no reason to expect that the MY 2008- and MY 2010-based fleet projections should produce identical results. Still, these differences were mostly small. Using both the corrected MY 2008-based passenger car market forecast and the new MY 2010-based forecast, three techniques produced fitted passenger car lines very close—in terms of average squared differences within the range of footprints between the selected cutpoints discussed above—to those selected for the NPRM: sales-weighted OLS without normalizations for differences in power/weight or weight/footprint, sales-weighted OLS with normalization for differences weight/footprint, and unweighted OLS with normalizations for differences in both power/weight and weight/footprint. For light trucks, two techniques did so for both the corrected MY 2008-based passenger car market forecast and the post-proposal MY 2010-based forecast: unweighted OLS with normalizations for differences in both power/weight and weight/footprint, and unweighted OLS with normalization for differences weight/footprint. Without any normalizations applied to the set of footprint and fuel economy values, unweighted OLS produced fitted slopes within 2% of the values obtained through the corresponding unweighted OLS analysis conducted in support of the NPRM. Also, as the above charts show, the resultant ranges (*i.e.*, areas in fuel consumption – footprint space) spanned by these methods are similar across the NPRM analysis and the updated analyses using the MY 2008- and MY 2010-based fleet projections.

Considering that NHTSA has adopted an approach whereby regulatory alternatives are developed by shifting fitted curves on a multiplicative basis, results of several of the techniques evaluated here thus would produce regulatory alternatives virtually identical to those developed for the NPRM. For the method that produced results selected for development of the NPRM, relative adjustment of lines fitted to the corrected MY 2008-based market forecast and the MY 2010-based market forecast produces lines that are, between the footprint cutpoints discussed above (41-56 ft^2 and 41-74 ft^2 for passenger cars and light trucks, respectively), very close to the lines fitted for the NPRM (Figure V-26 and Figure V-27):

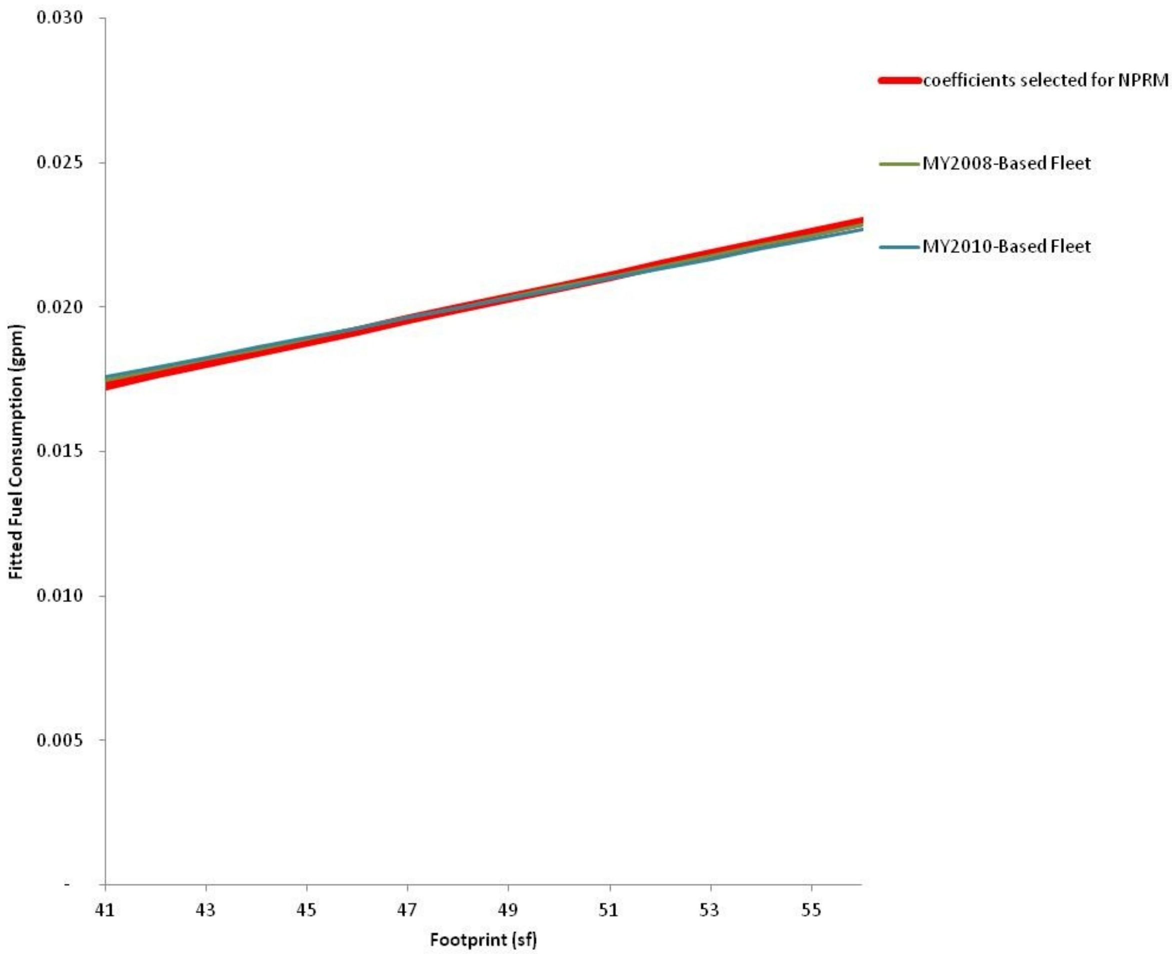

Figure V-26 Sales-Weighted OLS with Normalization for Differences in Weight/Footprint, Passenger Cars, MY2008- and MY2010-Based Fleets Multiplicatively Adjusted

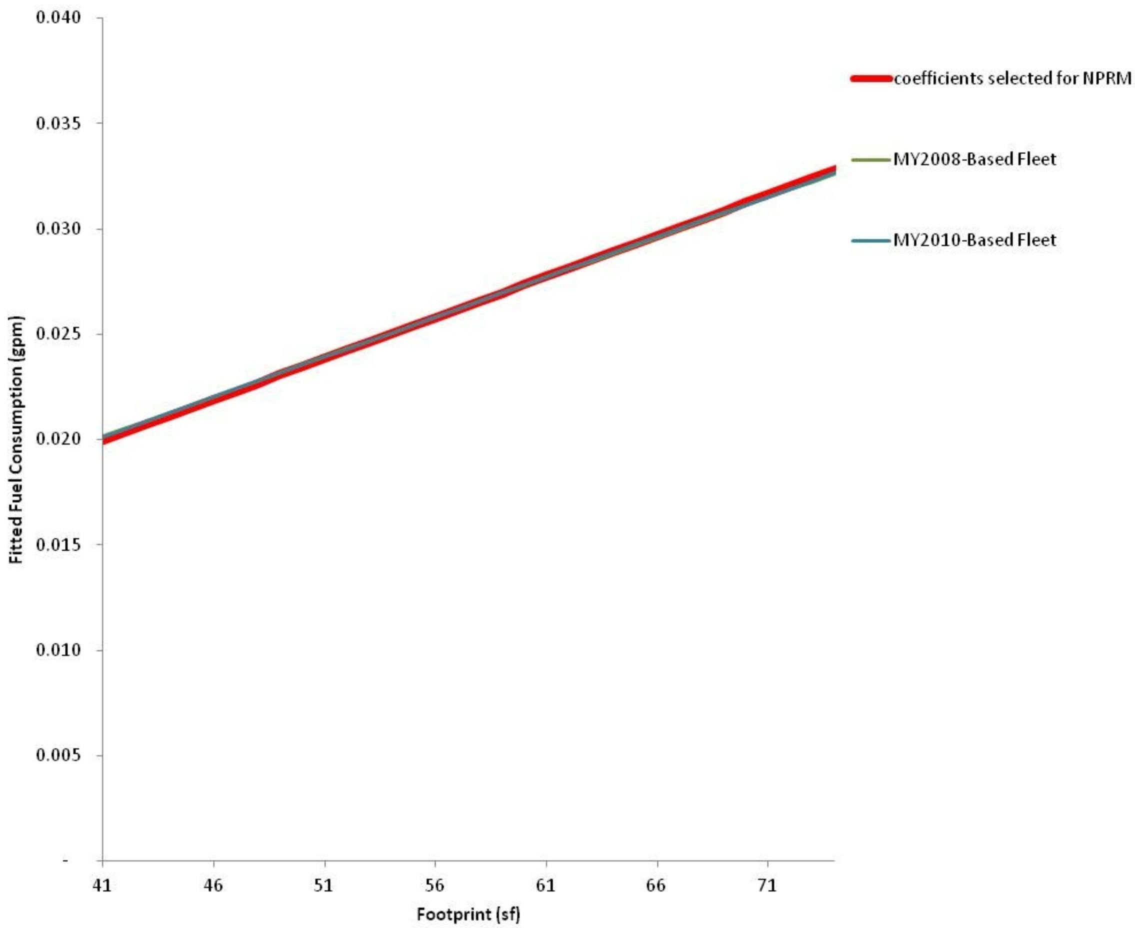

Figure V-27 Sales-Weighted OLS with Normalization for Differences in Weight/Footprint, Light Trucks, MY2008- and MY2010-Based Fleets Multiplicatively Adjusted

The above figures show, for both for passenger cars and light trucks, that applying the techniques selected for the NPRM to either the corrected MY 2008-based fleet projection or the MY 2010-based fleet projection would produce regulatory alternatives with highly similar, but slightly flatter slopes than those in the NPRM. At any given average stringency, these slightly flatter slopes would produce slightly greater incentives for manufacturers to respond to new standards by reducing vehicle size. In addition, the slightly flatter slopes would slightly increase the stringency of targets for the largest vehicles relative to stringency of targets for the smallest vehicles. As discussed in II.C.4.a of the preamble, considering the accumulated effects of light truck CAFE standards having increased steadily since MY2004, and GHG standards from MY 2012, NHTSA is concerned that flatter slopes could induce manufacturers of large light trucks toward overly aggressive penetration rates of advanced technologies into the sector, raising significant issues of cost, lead time and consumer acceptance which NHTSA regards as inappropriate. As discussed above, NHTSA remain concerned that about manufacturer incentives to reduce the capability to carry and/or tow heavy loads using full-size light trucks.

NHTSA has thus looked at a range of analytical techniques for establishing a fitted line including using two market forecasts and using different approaches for the normalization for differences in technology content, normalization for differences in other vehicle attributes (*e.g.*, power/weight or weight/footprint or, plausibly, seating capacity, interior volume, towing capacity, etc.), and statistical techniques (*e.g.*, unweighted, sales-weighted, MAD, OLS). Considering (a) that the reasonable analytical techniques examined by NHTSA produces a range of fitted lines, (b) that the future composition of the light vehicle market is subject to some uncertainty, and (c) that other aspects of NHTSA's analysis are informed by policy implications, in NHTSA's judgment, there is no single analytical method that is the sole "correct" way to establish the two fitted lines (one for passenger cars, one for light trucks) NHTSA uses to specify final standards. NHTSA' updated analysis shows newly-fitted lines producing regulatory alternatives very close to the corresponding regulatory alternatives considered in the NPRM. This confirms that the standards are within the range of technically supportable possibilities.

While NHTSA's analysis indicates that slopes spanning relatively wide ranges could be technically supportable, NHTSA notes that the final car standard is very similar to the slope of the MY 2016 standard, despite being based on a different analytical approach than the previous rule. As explained above, NHTSA has selected a truck curve differing from that adopted for the previous rule (both slope and upper cut-point); NHTSA expects that doing so will account for the future characteristics of the larger (work) trucks, and the manufacturers serving the future market for such trucks. The upper size cut-points for cars, and the lower size cut-point for both cars and trucks, are the same as in the previous rule. Without these adjustments, NHTSA believes that there would either be incentives for manufacturers to reduce the utility of these trucks, or that the manufacturer's compliance costs for reaching the targets would be disproportionately high.

Thus, in NHTSA's judgment, the curves strike a reasonable and appropriate balance between the affected policy considerations—better reflecting the reasonable penetration rates of the technologies needed to achieve the standards and the lead time needed for implementation of those technologies, minimizing the incentive for manufacturers to respond to standards in ways that may either result in decreased utility or compromise safety (by downsizing vehicles with footprints on the sloped portion of mathematical functions defining fuel economy and GHG targets), and encouraging widespread penetration of technologies throughout both the car and light truck fleets at reasonable cost while achieving very significant energy and environmental benefits. Having repeated the analysis documented in the NPRM, and having done so based on two fleets (the corrected MY 2008-based market forecast, and the MY 2010-based market forecast), NHTSA has demonstrated that, as proposed, the passenger car and light truck curves are well within technically supportable ranges. Slightly flatter standards would directionally have a potentially compromising effect on the safety-related incentives reflected by the promulgated curves, and potentially force more aggressive penetration of advanced technologies into work trucks in a way that raises issues of both increased cost and consumer acceptance.

Conversely, slightly steeper standards would tend to increase the potential that manufacturers would respond to the standards by increasing vehicle size beyond levels the market would otherwise demand, in lieu of applying some fuel-saving technologies. For these reasons, NHTSA is today promulgating standards using lines matching those used to develop proposed standards for the NPRM.

Additional discussion of the feasibility of the final standards is available in Preamble section IV.F.

How does NHTSA use the assumptions in its modeling analysis?

In developing today's CAFE standards, NHTSA has made significant use of results produced by the CAFE Compliance and Effects Model (commonly referred to as "the CAFE Model" or "the Volpe model"), which DOT's Volpe National Transportation Systems Center developed specifically to support NHTSA's CAFE rulemakings. The model, which has been constructed specifically for the purpose of analyzing potential CAFE standards, integrates the following core capabilities:

(1) Estimating how manufacturers could apply technologies in response to new fuel economy standards,

(2) Estimating the costs that would be incurred in applying these technologies,

(3) Estimating the physical effects resulting from the application of these technologies, such as changes in travel demand, fuel consumption, and emissions of carbon dioxide and criteria pollutants, and

(4) Estimating the monetized societal benefits of these physical effects.

An overview of the model follows below. Separate model documentation provides a detailed explanation of the functions the model performs, the calculations it performs in doing so, and how to install the model, construct inputs to the model, and interpret the model's outputs. Documentation of the model, along with model installation files, source code, and sample inputs are available at NHTSA's Web site. The model documentation is also available in the docket for today's proposed rule, as are inputs for and outputs from analysis of today's CAFE standards.

How does the model operate?

As discussed above, the agency uses the CAFE model to estimate how manufacturers could attempt to comply with a given CAFE standard by adding technology to fleets that the agency anticipates they will produce in future model years. This exercise constitutes a simulation of manufacturers' decisions regarding compliance with CAFE standards.

This compliance simulation begins with the following inputs: (a) the baseline and reference market forecast discussed in Section II.B of the preamble, Chapter III above, and Chapter 1 of the joint TSD, (b) technology-related estimates discussed in Section II.D of the preamble, below in this Chapter, and Chapter 3 of the joint TSD, (c) economic inputs discussed in Section II.E of the preamble, Chapters VII and VIII below, and Chapter 4 of the joint TSD, and (d) inputs defining baseline and potential new CAFE standards, discussed in Section II.C of the preamble, and Chapter 2 of the joint TSD. For each manufacturer, the model applies technologies in a sequence that follows a defined engineering logic ("decision trees," discussed in the MY 2011 final rule and in the model documentation) and a cost-minimizing strategy in order to identify a set of technologies the manufacturer could apply in response to new CAFE standards.[169] The model applies technologies to each of the projected individual vehicles in a manufacturer's fleet, considering the combined effect of regulatory and market incentives. Depending on how the model is exercised, it will apply technology until one of the following occurs:

(1) The manufacturer's fleet achieves compliance[170] with the applicable standard, and continuing to add technology in the current model year would be attractive neither in terms of stand-alone (*i.e.*, absent regulatory need) cost effectiveness nor in terms of facilitating compliance in future model years;[171]

(2) The manufacturer "exhausts"[172] available technologies; or

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[169] NHTSA does its best to remain scrupulously neutral in the application of technologies through the modeling analysis, to avoid picking technology "winners." The technology application methodology has been reviewed by the agency over the course of several rulemakings, and commenters have been generally supportive of the agency's approach. *See*, *e.g.,* 74 FR 14238–14246 (Mar. 30, 2009).

[170] The model has been modified to provide the ability—as an option—to account for credit mechanisms (*i.e.*, carry-forward, carry-back, transfers, and trades) when determining whether compliance has been achieved. For purposes of determining maximum feasible CAFE standards, NHTSA cannot consider these mechanisms, and exercises the CAFE model without enabling these options.

[171] In preparation for the MY2012-2016 rulemaking, the model was modified in order to apply additional technology in early model years if doing so will facilitate compliance in later model years. This is designed to simulate a manufacturer's decision to plan for CAFE obligations several years in advance, which NHTSA believes better replicates manufacturers' actual behavior as compared to the year-by-year evaluation which EPCA would otherwise require.

[172] In a given model year, the model makes additional technologies available to each vehicle model within several constraints, including (a) whether or not the technology is applicable to the vehicle model's technology class, (b) whether the vehicle is undergoing a redesign or freshening in the given model year, (c) whether engineering aspects of the vehicle make the technology unavailable (*e.g.,* secondary axle disconnect cannot be applied to two-wheel drive vehicles), and (d) whether technology application remains within "phase in caps" constraining the overall share of a manufacturer's fleet to which the technology can be added in a given model year. Once enough technology is added to a given manufacturer's fleet in a given model year that these constraints make further technology application unavailable, technologies are "exhausted" for that manufacturer in that model year.

(3) For manufacturers estimated to be willing to pay civil penalties, the manufacturer reaches the point at which doing so would be more cost-effective (from the manufacturer's perspective) than adding further technology.[173]

As discussed below, the model has also been modified in order to—as an option—apply more technology than may be necessary to achieve compliance in a given model year, or to facilitate compliance in later model years. This ability to simulate "voluntary overcompliance," discussed elsewhere in this FRIA as a "market-driven baseline," reflects the potential that manufacturers will apply some technologies to some vehicles if doing so would be sufficiently inexpensive compared to the expected reduction in owners' outlays for fuel.

The model accounts explicitly for each model year, applying most technologies when vehicles are scheduled to be redesigned or freshened, and carrying forward technologies between model years. The CAFE model accounts explicitly for each model year because EPCA requires that NHTSA make a year-by-year determination of the appropriate level of stringency and then set the standard at that level, while ensuring ratable increases in average fuel economy.[174] The multiyear planning capability and (optional) simulation of "voluntary overcompliance" and EPCA credit mechanisms increase the model's ability to simulate manufacturers' real-world behavior, accounting for the fact that manufacturers will seek out compliance paths for several model years at a time, while accommodating the year-by-year requirement.

The model also calculates the costs, effects, and benefits of technologies that it estimates could be added in response to a given CAFE standard.[175] It calculates costs by applying the cost estimation techniques discussed herein, and by accounting for the number of affected vehicles. It

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[173] This possibility was added to the model to account for the fact that under EPCA/EISA, manufacturers must pay fines if they do not achieve compliance with applicable CAFE standards. 49 U.S.C. 32912(b). NHTSA recognizes that some manufacturers will find it more cost-effective to pay fines than to achieve compliance, and believes that to assume these manufacturers would exhaust available technologies before paying fines would cause unrealistically high estimates of market penetration of expensive technologies such as diesel engines and strong hybrid electric vehicles, as well as correspondingly inflated estimates of both the costs and benefits of any potential CAFE standards. NHTSA thus includes the possibility of manufacturers choosing to pay fines in its modeling analysis in order to achieve what the agency believes is a more realistic simulation of manufacturer decision-making. Unlike flex-fuel and other credits, NHTSA is not barred by statute from considering fine-payment in determining maximum feasible standards under EPCA/EISA. 49 U.S.C. 32902(h).

[174] 49 U.S.C. 32902(a) states that at least 18 months before the beginning of each model year, the Secretary of Transportation shall prescribe by regulation average fuel economy standards for automobiles manufactured by a manufacturer in that model year, and that each standard shall be the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that year. NHTSA has long interpreted this statutory language to require year-by-year assessment of manufacturer capabilities. 49 U.S.C. 32902(b)(2)(C) also requires that standards increase ratably between MY 2011 and MY 2020.

[175] As for all of its other rulemakings, NHTSA is required by Executive Order 12866 (as amended by Executive Order 13563) and DOT regulations to analyze the costs and benefits of CAFE standards. Executive Order 12866, 58 FR 51735 (Oct. 4, 1993); DOT Order 2100.5, "Regulatory Policies and Procedures," 1979, *available at http://regs.dot.gov/rulemakingrequirements.htm* (last accessed November 13, 2011).

accounts for effects such as changes in vehicle travel, changes in fuel consumption, and changes in greenhouse gas and criteria pollutant emissions. It does so by applying the fuel consumption estimation techniques also discussed herein, and the vehicle survival and mileage accumulation forecasts, the rebound effect estimate and the fuel properties and emission factors discussed in Chapter VIII below. Considering changes in travel demand and fuel consumption, the model estimates the monetized value of accompanying benefits to society, as also discussed in Chapter VIII below. The model calculates both the undiscounted and discounted value of benefits that accrue over time in the future.

The CAFE model has other capabilities that facilitate the development of a CAFE standard. The integration of (a) compliance simulation and (b) the calculation of costs, effects, and benefits facilitates analysis of sensitivity of results to model inputs. The model can also be used to evaluate many (*e.g.,* 200 per model year) potential levels of stringency sequentially, and identify the stringency at which specific criteria are met. For example, it can identify the stringency at which net benefits to society are maximized, the stringency at which a specified total cost is reached, or the stringency at which a given average required fuel economy level is attained. This allows the agency to compare more easily the impacts in terms of fuel savings, emissions reductions, and costs and benefits of achieving different levels of stringency according to different criteria. The model can also be used to perform uncertainty analysis (*i.e.,* Monte Carlo simulation), in which input estimates are varied randomly according to specified probability distributions, such that the uncertainty of key measures (*e.g.,* fuel consumption, costs, benefits) can be evaluated.

Has NHTSA considered other models?

As discussed in the most recent CAFE rulemaking, while nothing in EPCA requires NHTSA to use the CAFE model, and in principle, NHTSA could perform all of these tasks through other means, the model's capabilities have greatly increased the agency's ability to rapidly, systematically, and reproducibly conduct key analyses relevant to the formulation and evaluation of new CAFE standards.[176]

NHTSA notes that the CAFE model not only has been formally peer-reviewed and tested and reviewed through three rulemakings, but also has some features especially important for the analysis of CAFE standards under EPCA/EISA. Among these are the ability to perform year-by-year analysis, and the ability to account for engineering differences between specific vehicle models.

[176] 75 FR 25598-25599.

EPCA requires that NHTSA set CAFE standards for each model year at the level that would be "maximum feasible" for that year.[177] Developing maximum feasible CAFE standards requires the ability to analyze each model year and, when developing regulations covering multiple model years, to account for the interdependency of model years in terms of the appropriate levels of stringency for each year modeled. Also, as part of the evaluation of the economic practicability of the standards, as required by EPCA, NHTSA has traditionally assessed the annual costs and benefits of the standards. In response to comments regarding an early version of the CAFE model, DOT modified the CAFE model in order to account for dependencies between model years and to better represent manufacturers' product planning cycles, in a way that still allowed NHTSA to comply with the statutory requirement to determine the appropriate level of the standards for each model year.

The CAFE model also accounts for important engineering differences between specific vehicle models enabling the capability for the model to reduce the risk of applying technologies that may be incompatible with a specific vehicle or that may already be present on a given vehicle model Additionally, by combining technologies incrementally and on a model-by-model basis, the CAFE model is able to avoid unlikely technology combinations by recognizing these important vehicle to vehicle engineering differences.

The CAFE model also produces a single vehicle-level output file that, for each vehicle model, shows which technologies were present at the outset of modeling, which technologies were superseded by other technologies, and which technologies were ultimately present at the conclusion of modeling. For each vehicle, the same file shows resultant changes in vehicle weight, fuel economy, and cost. This provides for efficient identification, analysis, and correction of errors, a task with which the public can now assist the agency, since all inputs and outputs are public.

Such considerations, as well as those related to the efficiency with which the CAFE model is able to analyze attribute-based CAFE standards and changes in vehicle classification, and to perform higher-level analysis such as stringency estimation (to meet predetermined criteria), sensitivity analysis, and uncertainty analysis, lead the agency to conclude that the model remains the best available to the agency for the purposes of analyzing potential new CAFE standards.

What changes has DOT made to the model?

Between promulgation of the MY 2012-2016 CAFE standards and today's final rule regarding MY 2017-2025 standards, the CAFE model has been revised to make some minor improvements, and to add some significant new capabilities: (1) accounting for electricity used

[177] 49 U.S.C. 32902(a) requires that NHTSA set CAFE standards at the maximum feasible level for each fleet, for each model year.

to charge electric vehicles (EVs) and plug-in hybrid electric vehicles (PHEVs), (2) accounting for use of ethanol blends in flexible-fuel vehicles (FFVs), (3) accounting for costs (*i.e.*, "stranded capital") related to early replacement of technologies, (4) accounting for previously-applied technology when determining the extent to which a manufacturer could expand use of the technology, (5) applying technology-specific estimates of changes in consumer value, (6) simulating the extent to which manufacturers might utilize EPCA's provisions regarding generation and use of CAFE credits, (7) applying estimates of fuel economy adjustments (and accompanying costs) reflecting increases in air conditioner efficiency, (8) reporting privately-valued benefits, (9) simulating the extent to which manufacturers might voluntarily apply technology beyond levels needed for compliance with CAFE standards, and (10) estimating changes in highway fatalities attributable to any applied reductions in vehicle mass. These capabilities are described below, and in greater detail in the CAFE model documentation.[178]

To support evaluation of the effects electric vehicles (EVs) and plug-in hybrid vehicles (PHEVs) could have on energy consumption and associated costs and environmental effects, DOT has expanded the CAFE model to estimate the amount of electricity that would be required to charge these vehicles (accounting for the potential that PHEVs can also run on gasoline). The model calculates the cost of this electricity, as well as the accompanying upstream criteria pollutant and greenhouse gas emissions.

Similar to this expansion to account for the potential the PHEVs can be refueled with gasoline or recharged with electricity, DOT has expanded the CAFE model to account for the potential that other flexible-fuel vehicles can be operated on multiple fuels. In particular, the model can account for ethanol FFVs consuming E85 or gasoline and reports consumption of both fuels as well as corresponding costs and upstream emissions.

Among the concerns raised in the past regarding how technology costs are estimated has been one that stranded capital costs be considered. Capital becomes "stranded" when capital equipment is retired or its use is discontinued before the equipment has been fully depreciated and the equipment still retains some value or usefulness. DOT has modified the CAFE model to, if specified for a given technology, when that technology is replaced by a newly applied technology, apply a stream of costs representing the stranded capital cost of the replaced technology. This cost is in addition to the cost for producing the newly applied technology in the first year of production.

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[178] http://www.nhtsa.gov/Laws+&+Regulations/CAFE+-+Fuel+Economy/CAFE+Compliance+and+Effects+Modeling+System:+The+Volpe+Model (last accessed: November 14, 2011)

As documented in prior CAFE rulemakings, the CAFE model applies "phase-in caps" to constrain technology application at the vehicle manufacturer level. They are intended to reflect a manufacturer's overall resource capacity available for implementing new technologies (such as engineering and development personnel and financial resources), thereby ensuring that resource capacity is accounted for in the modeling process. This helps to ensure technological feasibility and economic practicability in determining the stringency of the standards. When the MY 2012-2016 rulemaking analysis was completed, the model performed the relevant test by comparing a given phase-in cap to the amount (*i.e.*, the share of the manufacturer's fleet) to which the technology had been added by the model. DOT has since modified the CAFE model to take into account the extent to which a given manufacturer has already applied the technology (*i.e.*, as reflected in the market forecast specified as a model inputs), and to apply the relevant test based on the total application of the technology.

The CAFE model requires inputs defining the technology-specific cost and efficacy (*i.e.*, percentage reduction of fuel consumption), and has, to date, effectively assumed that these input values reflect application of the technology in a manner that holds vehicle performance and utility constant. Considering that some technologies may, nonetheless, offer owners greater or lesser value (beyond that related to fuel outlays, which the model calculates internally based on vehicle fuel type and fuel economy), DOT has modified the CAFE model to accept and apply technology-specific estimates of any value gain realized or loss incurred by vehicle purchasers.[179]

For the MY 2012-2016 CAFE rulemaking analysis, DOT modified the CAFE model to accommodate specification and accounting for credits a manufacturer is assumed to earn by producing flexible fuel vehicles (FFVs). Although NHTSA cannot consider such credits when determining maximum feasible CAFE standards, the agency presented an analysis that included FFV credits, in order to communicate the extent to which use of such credits might cause actual costs, effects, and benefits to be lower than estimated in NHTSA's formal analysis. As DOT explained at the time, it was unable to account for other EPCA credit mechanisms, because attempts to do so had been limited by complex interactions between those mechanisms and the multiyear planning aspects of the CAFE model. DOT has since modified the CAFE model to provide the ability to account for any or all of the following flexibilities provided by EPCA: FFV credits, credit carry-forward and carry-back (between model years), credit transfers (between passenger car and light truck fleets), and credit trades (between manufacturers). The model accounts for EPCA-specified limitations applicable to these flexibilities (*e.g.*, limits on the amount of credit that can be transferred between passenger car and light truck fleets). These capabilities in the model provide a basis for more accurately estimating costs, effects, and

[179] For example, a value gain could be specified for a technology expected to improve ride quality, and a value loss could be specified for a technology expected to reduce vehicle range.

benefits that may actually result from new CAFE standards. Insofar as some manufacturers actually do earn and use CAFE credits, this provides NHTSA with the ability to examine outcomes more realistically than EPCA allows for purposes of setting new CAFE standards.

In preparation for today's analysis, DOT has further modified the CAFE model to provide the ability to account for owners' operating costs including financing, insurance, scheduled maintenance, and out-of-warranty repairs. Among these, the model includes only scheduled maintenance and out-of-warranty repairs in overall estimates of societal costs. DOT also made some further changes to the CAFE modeling system. To facilitate external analysis, the CAFE model now produces "flat" text files (comma separated value or "CSV", format) as model output. DOT also corrected some errors DOT staff identified in the version of the model supporting the NPRM, the most significant of which include the following: First, the model was corrected to ensure that advanced diesel technology is not applied without accounting for incremental costs and effects of TURB2, CEGR1, or CEGR2—engine technologies placed before diesels on the model's decision tree for engine technologies. Second, the model was corrected to ensure that when fuel-saving technologies are applied to a flexible fuel vehicle (FFV), the vehicle's fuel economy when operating on E85 is increased in parallel with its fuel economy when operating on gasoline. Third, the model was corrected to ensure that, when calculating the "effective cost" for purposes of deciding among potential technology applications, the model refers to fuel prices estimated to prevail after the vehicle's purchase. Further details regarding the model's design and operation are presented in the model documentation available on NHTSA's web site.

NHTSA is today setting CAFE standards reflecting EPA's proposal to change fuel economy calculation procedures such that a vehicle's fuel consumption improvement will be accounted for if the vehicle has technologies that reduce the amount of energy needed to power the air conditioner. To facilitate analysis of these standards, DOT has modified the CAFE model to account for these adjustments, based on inputs specifying the average amount of improvement anticipated, and the estimated average cost to apply the underlying technology.

Considering that past CAFE rulemakings indicate that most of the benefits of CAFE standards are realized by vehicle owners, DOT has modified the CAFE model to estimate not just social benefits, but also private benefits. The model accommodates separate discount rates for these two valuation methods (*e.g.*, a 3% rate for social benefits with a 7% rate for private benefits). When calculating private benefits, the model includes changes in outlays for fuel taxes (which, as economic transfers, are excluded from social benefits) and excludes changes in economic externalities (*e.g.*, monetized criteria pollutant and greenhouse gas emissions).

Since 2003, the CAFE model (and its predecessors) has provided the ability to estimate the extent to which a manufacturer with a history of paying civil penalties allowed under EPCA might decide to add some fuel-saving technology, but not enough to comply with CAFE standards. In simulating this decision-making, the model considers the cost to add the technology, the calculated reduction in civil penalties, and the calculated present value (at the time of vehicle purchase) of the change in fuel outlays over a specified "payback period" (*e.g.*, 5 years). For a manufacturer assumed to be willing to pay civil penalties, the model stops adding technology once paying fines becomes more attractive than continuing to add technology, considering these three factors. As an extension of this simulation approach, DOT has modified the CAFE model to, if specified, simulate the potential that a manufacturer would add more technology than required for purposes of compliance with CAFE standards. When set to operate in this manner, the model will continue to apply technology to a manufacturer's CAFE-compliant fleet until applying further technology will incur more in cost than it will yield in calculated fuel savings over a specified "payback period" that is set separately from the payback period applicable until compliance is achieved. In its analysis supporting MY 2012-2016 standards adopted in 2010, NHTSA estimated the extent to which reductions in vehicle mass might lead to changes in the number of highway fatalities occurring over the useful life of the MY 2012-2016 fleet. NHTSA performed these calculations outside the CAFE model (using vehicle-specific mass reduction calculations from the model), based on agency analysis of relevant highway safety data. DOT has since modified the CAFE model to perform these calculations, using an analytical structure indicated by an update to the underlying safety analysis. The model also applies an input value indicating the economic value of a statistical life, and includes resultant benefits (or disbenefits) in the calculation of total social benefits.

In comments on recent NHTSA rulemakings, some reviewers have suggested that the CAFE model should be modified to estimate the extent to which new CAFE standards would induce changes in the prices of vehicles and therefore in the mix of vehicles in the new vehicle fleet. NHTSA agrees that a "market share" model, also called a consumer vehicle choice model, could provide useful information regarding the possible effects of potential new CAFE standards.

In response, NHTSA has contracted with GRA, Incorporated and the Brookings Institution to develop a vehicle choice model estimated at the vehicle configuration level that can be implemented as part of DOT's CAFE model. Also included in this contract are researchers based at the University of California – Davis and the University of California – Irvine. The Brookings-led researchers are utilizing data found in the National Household Transportation Survey to estimate realistic patterns of vehicle substitution and deferral of new vehicle purchases in response to changes in vehicle attributes, such as prices and fuel efficiency, which are caused by increases or decreases in the CAFE standards.

In comments on recent NHTSA rulemakings, some reviewers have suggested that the CAFE model should be modified to estimate the extent to which new CAFE standards would induce changes in the mix of vehicles in the new vehicle fleet. NHTSA agrees that a "market shift" model, also called a consumer vehicle choice model, could provide useful information regarding the possible effects of potential new CAFE standards. NHTSA has contracted with the Brookings Institution (which has subcontracted with researchers at U.C. Davis, U.C. Irvine) to develop a vehicle choice model estimated at the vehicle configuration level that can be implemented as part of DOT's CAFE model. As discussed further in Section V of the PRIA, past efforts by DOT staff demonstrated that a vehicle could be added to the CAFE model, but did not yield credible coefficients specifying such a model. While the NHTSA-sponsored effort is still underway, if a suitable and credibly calibrated vehicle choice model becomes available in the future, DOT may integrate a vehicle choice model into the CAFE model to support future rulemakings.

NHTSA anticipates this integration of a vehicle choice model would be structurally and operationally similar to the integration we implemented previously. As under the version applied in support of today's announcement, the CAFE model would begin with an agency-estimated market forecast, estimate to what extent manufacturers might apply additional fuel-saving technology to each vehicle model in consideration of future fuel prices and baseline or alternative CAFE standards and fuel prices, and calculate resultant changes in the fuel economy (and possibly fuel type) and price of individual vehicle models. With an integrated market share model, the CAFE model would then estimate how the sales volumes of individual vehicle models would change in response to changes in fuel economy levels and prices throughout the light vehicle market, possibly taking into account interactions with the used vehicle market. Having done so, the model would replace the sales estimates in the original market forecast with those reflecting these model-estimated shifts, repeating the entire modeling cycle until converging on a stable solution.

Based on past experience, we anticipate that this recursive simulation will be necessary to ensure consistency between sales volumes and modeled fuel economy standards, because achieved CAFE levels depend on sales mix and, under attribute-based CAFE standards, required CAFE levels also depend on sales mix. NHTSA anticipates, therefore, that application of a market share model would impact estimates of all of the following for a given schedule of CAFE standards: overall market volume, manufacturer market shares and product mix, required and achieved CAFE levels, technology application rates and corresponding incurred costs, fuel consumption, greenhouse gas and criteria pollutant emissions, changes in highway fatalities, and economic benefits.

Past testing by DOT/NHTSA staff did not indicate major shifts in broad measures (*e.g.*, in total costs or total benefits), but that testing emphasized shorter modeling periods (*e.g.*, 1-5 model years) and less stringent standards than reflected in today's announcement. Especially without knowing the characteristics of a future vehicle choice model, it is difficult to anticipate the potential degree to which its inclusion would impact analytical outcomes.

NHTSA invited comment on changes made to the CAFE model prior to the NPRM's release, and regarding the above-mentioned prospects for inclusion of a vehicle choice model. The agency received comments only regarding the possibility of utilizing a vehicle choice model. Two environmental organizations—the National Resources Defense Council (NRDC) and the Union of Concerned Scientists (UCS)—urged the agency not to include any vehicle choice model in its analysis, citing concerns regarding uncertainties surrounding such models, and in NRDC's case, the potential that use of a choice model would lead NHTSA to adopt less stringent standards than if the agency continues to ignore potential market effects.[180] On the other hand, the American Fuel and Petrochemical Manufacturers (AFPM) indicated serious concern that the proposal was based on an analysis that did not incorporate a vehicle choice model, citing this as a serious deficiency that must be addressed to properly understand the implications of this proposal.[181] AFPM suggested the proposed standards were not feasible, and indicated that use of a peer-reviewed consumer choice model and a new proposal would assist NHTSA's development of a revised proposal that is feasible and coincides with Congress' mandate in this area.[182] The Alliance of Automobile Manufacturers indicated that NHTSA should develop a vehicle choice model to inform the planned midterm review, and indicated that such a model should use real-world data, be developed in a transparent manner with full peer review, and assess uncertainties in its predictions.[183] As mentioned above, we do not yet have available a credible consumer choice model suitable for integration with our CAFE modeling system. However, we do not agree with NRDC and UCS that integration of a vehicle choice model should be rejected out of hand, or that application of a vehicle choice model would lead the agency to adopt less stringent standards. Nor do we agree with AFPM that the proposed standards were not feasible. We agree with the Alliance that NHTSA should continue efforts to develop a vehicle choice model suitable for integration with the CAFE modeling system and application toward informing the planned midterm review.

Does the model set the standards?

Since NHTSA began using the CAFE model in CAFE analysis, some commenters have interpreted the agency's use of the model as the way by which the agency chooses the maximum feasible fuel economy standards. As the agency explained in its most recent CAFE rulemaking, this is incorrect.[184] Although NHTSA currently uses the CAFE model as a tool to inform its consideration of potential CAFE standards, the CAFE model does not determine the CAFE

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[180] NRDC, EPA Docket: EPA-HQ-OAR-2010-0799-9472, p. 19; UCS, EPA Docket: EPA-HQ-OAR-2010-0799-9567, p. 14.
[181] AFPM, EPA Docket: EPA-HQ-OAR-2010-0799-9485, p. 4.
[182] *Id.*, p. 8.
[183] Alliance, NHTSA Docket: NHTSA-2010-0131-0262, p. 19.
[184] 75 FR 25600.

standards that NHTSA proposes or promulgates as final regulations. The results it produces are completely dependent on inputs selected by NHTSA, based on the best available information and data available in the agency's estimation at the time standards are set. Ultimately, NHTSA's selection of appropriate CAFE standards is governed and guided by the statutory requirements of EPCA, as amended by EISA: NHTSA sets the standard at the maximum feasible average fuel economy level that it determines is achievable during a particular model year, considering technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the nation to conserve energy.

How does NHTSA make the model available and transparent?

Model documentation, which is publicly available in the rulemaking docket and on NHTSA's website, explains how the model is installed, how the model inputs (all of which are available to the public)[185] and outputs are structured, and how the model is used. The model can be used on any Windows-based personal computer with Microsoft Office 2003 or 2007 and the Microsoft .NET framework installed (the latter available without charge from Microsoft). The executable version of the model and the underlying source code are also available at NHTSA's Web site. The input files used to conduct the core analysis documented in this proposed rule are available in the public docket. With the model and these input files, anyone is capable of independently running the model to repeat, evaluate, and/or modify the agency's analysis.

Because the model is available with unrestricted access on NHTSA's web site, the agency has no way of knowing how widely the model has been used. The agency is, however, aware that the model has been used by other federal agencies, vehicle manufacturers, private consultants, academic researchers, and foreign governments. Some of these individuals have found the model complex and challenging to use. Insofar as the model's sole purpose is to help DOT staff efficiently analyze potential CAFE standards, DOT has not expended significant resources trying to make the model as "user friendly" as commercial software intended for wide use. However, DOT wishes to facilitate informed comment on the proposed standards, and encourages reviewers to contact the agency promptly if any difficulties using the model are encountered.

NHTSA arranged for a formal peer review of an older version of the model, has responded to reviewers' comments, and has considered and responded to model-related comments received over the course of four CAFE rulemakings. In the agency's view, this steady and expanding outside review over the course of nearly a decade of model development has helped DOT to significantly strengthen the model's capabilities and technical quality, and has greatly increased

[185] We note, however, that files from any supplemental analysis conducted that relied in part on confidential manufacturer product plans cannot be made public, as prohibited under 49 CFR part 512.

transparency, such that all model code is publicly available, and all model inputs and outputs are publicly available in a form that should allow reviewers to reproduce the agency's analysis. NHTSA is currently planning a formal peer review of the current CAFE model, pending integration of a vehicle choice model (as discussed above), as the agency anticipates that this will be a sufficiently major revision to the model to warrant a new peer review.

How does NHTSA determine a technology path to compliance with alternative CAFE standards?

The agency assumes, in this analysis, that manufacturers will add a variety of technologies to each of their vehicle models in order to improve their fuel economy performance. In order to evaluate proposed CAFE standards and regulatory alternatives, it is essential to understand what is feasible within the timeframe of the final rule. Determining the technological feasibility of the 2017-2025 standards requires a thorough study of the technologies expected to be available to the manufacturers during that timeframe. This chapter includes an assessment of the cost, effectiveness, and the availability, development time and manufacturability of the technology within either the normal redesign periods of a vehicle line or in the design of a new vehicle. As we describe below, when a technology can be applied can affect the cost as well as the technology penetration rate (or phase-in caps) that are assumed in the analysis. This chapter will also offer a detailed explanation of how NHTSA applies technologies to determine a feasible compliance path for the industry for the Preferred Alternative and the other regulatory alternatives analyzed by the agency in this rulemaking.

The agency considered technologies in many categories that manufacturers could use to improve the fuel economy of their vehicles during the MYs 2017-2025 timeframe. Many of the technologies described in this chapter are available today, are well known, and could be incorporated into vehicles once product development decisions are made. These are "nearer-term" technologies and are identical or very similar to those considered in the MYs 2012-2016 final rule analysis (of course, many of these technologies will likely be applied to the light-duty fleet in order to achieve the 2012-2016 CAFE standards; such technologies would be part of the baseline fleet for this analysis[186]). Other technologies considered may not currently be in production, but are under development now and are expected to be in production in the next five to ten years. Examples of these technologies are downsized and turbocharged engines operating at combustion pressures even higher than today's turbocharged engines, and an emerging hybrid architecture mated with an 8 speed transmission—a combination that is not available today. These are technologies which the agency believes can, for the most part, be applied both to cars and trucks, and which are expected to achieve significant improvements in fuel economy at

[186] The technologies in the baseline fleet, which meets the MY 2016 CAFE standard, are projections made by NHTSA's CAFE model. Some technologies may be significantly represented in this baseline fleet.

reasonable costs in the MYs 2017 to 2025 timeframe. The agency notes that we did not consider in our analysis technologies that are currently in an initial stage of research because of the uncertainties involved in estimating their costs and effectiveness and in assessing whether the technologies will be ready to implement at significant penetration rates during the timeframe of the MY2017-2025 standards. Examples of such technologies would be camless valve actuation and fuel cell vehicles.[187] The agency acknowledges that due to the relatively long period between the date of this final rule and the rulemaking timeframe of the MY2017-2025 standards, the possibility exists that new and innovative technologies not considered in this analysis will make their way into the fleet (perhaps even in significant numbers). The agency plans to assess these technologies afresh, along with all of the technologies considered in this final rule, as part of our mid-term evaluation.

How does NHTSA determine what technologies are already in the baseline vehicle fleet?

As in the MY 2012-2016 final rule, EPA in consultation with NHTSA developed the baseline fleet using the 2008 and 2010 CAFE compliance data. The 2008 baseline fleet was used in the NPRM analysis, but the final rule will perform its analysis using both the 2008 baseline and the new 2010 baseline. The agencies then used EPA's emission certification and fuel economy database and a combination of publicly available data from sources like Ward's Automotive Group, Motortrend.com and Edmunds.com to determine the fuel-economy-improving/CO_2-reducing technologies already present in the individual baseline vehicles. The baseline fleets including the technologies already present on each vehicle are contained in the market data file model inputs. A more detailed discussion of how the baseline vehicle fleets were constructed can be found in Chapter III of this document and Chapter 1 of the joint TSD.

How does NHTSA determine what technologies can be applied beyond those in the baseline vehicle fleet?

As discussed above, many of the technologies considered for the MY 2017-2025 timeframe are the same ones considered for the MY 2012-2026 rulemaking, which are available in varying degrees today and which the agency will be able to be incorporated more fully throughout the fleet between now and 2025. NHTSA, with EPA, gathered information about these technologies for the MYs 2012-2016 rulemaking from a wide variety of sources, discussed at length in the FRIA accompanying the MYs 2012-2016 final rule. We refer readers to that document for more information.

[187] Fuel cell vehicles may be especially useful in lieu of full battery electric technology for the larger trucks. We may consider this possibility for the final rule.

Since the MYs 2012-2016 final rule, EPA has contracted with Ricardo and expanded the technology selections available for the agencies' consideration, based on some of Ricardo's advanced engineering development work for EPA and on some recently-obtained literature sources, such as the development of Lotus Sabre[188] engine and MAHLE[189] engine. Based on this research, the agencies are considering significantly more advanced gasoline engines for MYs 2017-2025 than we have considered for prior rulemakings. Ricardo also performed simulation analysis for EPA which the agencies have used to update the effectiveness for a majority of the technologies considered in this FRM analysis. Detailed information for Ricardo's contract and body of work supporting this rulemaking can be found in Docket # NHTSA-2010-0131.

For the reader's reference, the technologies considered by the NHTSA and EPA models for this FRM are briefly described below. For purposes of how NHTSA applies them in our model, the technologies fit generally into five broad categories: engine, transmission, vehicle, electrification/accessory, and hybrid technologies. A more detailed description of each technology, and the costs and effectiveness of each, is described in greater detail below in this chapter; Chapter 3 of the joint TSD also contains information on the individual technologies. Types of engine technologies applied in the analysis for this FRM that improve fuel economy include the following:

- *Low-friction lubricants (LUB1)* – low viscosity and advanced low friction lubricants oils are now available with improved performance and better lubrication.
- *Reduction of engine friction losses (EFR1)* – can be achieved through low-tension piston rings, roller cam followers, improved material coatings, more optimal thermal management, piston surface treatments, and other improvements in the design of engine components and subsystems that improve engine operation.
- *Second level of low-friction lubricants and engine friction reduction (LUB2_EFR2)* – As technologies advance between now and 2017-2025, we expect further developments enabling lower viscosity and lower friction lubricants and more engine friction reduction technologies to be available.
- *Cylinder deactivation (DEACS and DEACD)* – deactivates the intake and exhaust valves and prevents fuel injection of some cylinders during light-load operation. The engine runs temporarily as though it were a smaller engine, which substantially reduces pumping losses.
- *Variable valve timing (CCPS, ICP and DCP)* – alters the timing or phase of the intake valve, exhaust valve, or both, primarily to reduce pumping losses, increase specific power, and control residual gases.

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188 Turner, J.W.G., R.J. Pearson, R. Curtis, and B. Holland, Lotus Engineering. "Sabre: a cost-effective engine technology combination for high efficiency, high performance and low CO_2 emissions." *Available at* http://www.midlandslotus.co.uk/forum/topic/35578-sabre-a-cost-effective-engine-technology-combination-for-high-efficie/ (last accessed Oct. 31, 2011).

189 Frazer, N., H. Blaxhill, G. Lumsden, and M. Bassett, Mahle Powertrain. "Challenges for Increased Efficiency through Gasoline Engine Downsizing," SAE Paper 2009-01-1053. *Available at* http://papers.sae.org/2009-01-1053/ (last accessed Oct. 31, 2011).

- *Discrete variable valve lift* (DVVLS, DVVLD and VVA) – increases efficiency by optimizing air flow over a broader range of engine operation, which reduces pumping losses. Accomplished by controlled switching between two or more cam profile lobe heights.
- *Continuous variable valve lift (CVVL)* – is an electromechanically controlled system in which cam period and phasing is changed as lift height is controlled. This yields a wide range of performance optimization and volumetric efficiency, including enabling the engine to be valve throttled.
- *Stoichiometric gasoline direct-injection technology (SGDI and SGDIO)* – injects fuel at high pressure directly into the combustion chamber to improve cooling of the air/fuel charge within the cylinder, which allows for higher compression ratios and increased thermodynamic efficiency.
- *Turbocharging and downsizing (TRBDS1 and TRBDS2)* - increases the available airflow and specific power level, allowing a reduced engine size while maintaining performance. This reduces pumping losses at lighter loads in comparison to a larger engine. In this FRM, the agencies considered three levels of boosting (18 bar brake mean effective pressure (BMEP), 24 bar BMEP and 27 bar BMEP), as well as four levels of downsizing (from I4 to smaller I4 or I3, from V6 to I4 and from V8 to both V6 and I4). 18 bar BMEP is applied with 33 percent downsizing, 24 bar BMEP is applied with 50 percent downsizing, and 27 bar BMEP is applied with 56 percent downsizing. To achieve the same level of torque when downsizing the displacement of an engine by 50 percent, approximately double the manifold absolute pressure (2 bar) is required. Accordingly, with 56 percent downsizing, the manifold absolute pressure range increases up to 2.3 bar. Ricardo states in their 2011 vehicle simulation project report that advanced engines in the 2020–2025 timeframe can be expected to have advanced boosting systems that increase the pressure of the intake charge up to 3 bar.[190]
- *Exhaust-gas recirculation boost (CEGR1 and CEGR2)* - increases the exhaust-gas recirculation used in the combustion process to increase thermal efficiency and reduce pumping losses. Levels of exhaust gas recirculation approach 25 percent by volume in the highly boosted engines modeled by Ricardo (this, in turn raises the boost requirement by approximately 25 percent). This technology is only applied to 24 bar and 27 bar BMEP engines in this FRM and considered required for 27 bar BMEP engines.
- *Diesel engines (ADSL)* – have several characteristics that give superior fuel efficiency, including reduced pumping losses due to lack of (or greatly reduced) throttling, and a combustion cycle that operates at a higher compression ratio, with a very lean air/fuel mixture, than an equivalent-performance gasoline engine. This technology requires additional enablers, such as NO_x trap catalyst after-treatment or selective catalytic reduction NO_x after-treatment.

Types of transmission technologies applied in this FRM analysis, consistent with the proposal, include:

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[190] U.S. EPA, "Project Report: Computer Simulation of Light-Duty Vehicle Technologies for Greenhouse Gas Emission Reduction in the 2020-2025 Timeframe", Contract No. EP-C-11-007, Work Assignment 0-12, November, 2011, Docket ID NHTSA-2010-0131

- *Improved automatic transmission controls (IATC)* – optimizes shift schedule to maximize fuel efficiency under wide ranging conditions, and minimizes losses associated with torque converter slip through lock-up or modulation.
- *Six- and seven-speed automatic transmissions (NAUTO)* – the gear ratio spacing and transmission ratio are optimized to enable the engine to operate in a more efficient operating range over a broader range of vehicle operating conditions.
- *Dual clutch transmission (DCT)* - are similar to a manual transmission, but the vehicle controls shifting and launch functions. A dual-clutch automated shift manual transmission uses separate clutches for even-numbered and odd-numbered gears, so the next expected gear is pre-selected, which allows for faster, smoother shifting.
- *Eight-speed automatic transmissions (8SPD)* – the transmission gear ratios are optimized to enable the engine to operate in a more efficient operating range over a broader range of vehicle operating conditions.
- *High Efficiency Gearbox (automatic, DCT or manual) (HETRANS and HETRANSM)* – continuous improvement in seals, bearings and clutches, super finishing[191] of gearbox parts, and development in the area of transmission lubrication, all aimed at reducing frictional and other parasitic load in the system for an automatic, DCT or manual type transmission.
- *Shift Optimization* (*SHFTOPT)* – tries to keep the engine operating near its most efficient point for a given power demand. The shift controller attempts to emulate a traditional continuously-variable transmission (CVT) by selecting the best gear ratio for fuel economy at a given required vehicle power level to take full advantage of high BMEP engines.
- *Manual 6-speed transmission (6MAN)* – offers an additional gear ratio, often with a higher overdrive gear ratio, than a 5-speed manual transmission.
- *High Efficiency Gearbox for manual transmission (HETRANSM)* – Similar technologies as applied for high efficiency gearbox for automatic and DCT can also be applied to manual transmissions to reduce drag in the system.

Types of vehicle technologies applied in this FRM analysis, consistent with the proposal, include:

- *Low-rolling-resistance tires (ROLL1 and ROLL2)* – have characteristics that reduce frictional losses associated with the energy dissipated in the deformation of the tires under load, thereby reducing the energy needed to move the vehicle. There are two levels of rolling resistance reduction considered in this FRM analysis which assume 10 percent and 20 percent rolling resistance reduction, respectively. The agencies expect that tire manufacturers will be able to achieve widespread, production application of the 20 percent rolling resistance reduction level in time for MY 2017 and later.

[191] "Super finishing" is a metalworking process that improves surface finish and workpiece geometry. Super finishing can make pieces more durable and allow for closer tolerances, higher load bearing surfaces, and better sealing capabilities, but it can also be more expensive than traditional metal finishing techniques.

- *Low-drag brakes (LDB)* – reduce the sliding friction of disc brake pads on rotors when the brakes are not engaged because the brake pads are pulled away from the rotors.
- *Front or secondary axle disconnect for four-wheel drive systems (SAX)* – provides a torque distribution disconnect between front and rear axles when torque is not required for the non-driving axle, which reduces associated parasitic energy losses.
- *Aerodynamic drag reduction (AERO1 and AERO2)* – is achieved by changing vehicle shape or reducing frontal area, including skirts, air dams, underbody covers, and more aerodynamic side view mirrors. The new, second level of aerodynamic reductions involve employing aerodynamic aids which may include such features as active grille shutters, rear visors, larger under body panels or low-profile, and possibly dynamic, roof racks. There are two levels of aerodynamic drag reduction considered in this FRM analysis which assume 10 percent and 20 percent drag reduction, respectively.
- *Mass reduction (MR1, MR2, MR3, MR4 and MR5)*– Mass reduction encompasses a variety of techniques to make vehicles lighter, ranging from improved design and better component integration to application of lighter and higher-strength materials. A lighter vehicle can go further on a gallon of gas, all else equal; mass reduction can also lead to collateral fuel economy benefits due to downsized engines and/or ancillary systems (transmission, steering, brakes, suspension, etc.). The maximum mass reduction level considered in this FRM for any vehicle is 20 percent.

Types of accessory/hybridization/electrification technologies applied in this FRM analysis:

- *Electric power steering (EPS) and electro-hydraulic power steering (EHPS)* – is an electrically-assisted steering system that has advantages over traditional hydraulic power steering because it replaces a continuously operated hydraulic pump and only operates when needed, thereby reducing parasitic losses from the accessory drive.
- *Improved accessories (IACC1 and IACC2)* –There are two levels of IACC applied in this FRM analysis, consistent with the proposal. The first level of IACC includes an electric water pump and cooling fans and a high efficiency alternator; the second level of IACC includes some mild alternator regenerative braking in addition to what is included in the first level of IACC. This excludes other electrical accessories such as electric oil pumps and electrically driven air conditioner compressors.
- *Air Conditioner Systems* – For purposes of improvements in fuel economy that can count toward CAFE compliance, these technologies include improved compressors, expansion valves, heat exchangers and the control of these components for the purposes of improving fuel efficiency when the A/C is operating. These technologies are covered separately in Chapter 5 of the joint TSD.
- *12-volt Stop-Start (MHEV)* – also known as idle-stop or 12V micro hybrid and commonly implemented as a 12-volt belt-driven integrated starter-generator, this is the most basic hybrid system that facilitates idle-stop capability. Along with other enablers, this system replaces a common alternator with an enhanced power starter-alternator, both belt driven, and a revised accessory drive system.
- *Mild Hybrid/Integrated Starter Generator (ISG) – ISG provides idle-stop* capability and launch assistance and uses a high voltage battery with increased energy capacity over typical automotive batteries. The higher system voltage allows the use of a smaller, more powerful electric motor and reduces the weight of the motor, inverter, and battery wiring harnesses. This system replaces a standard alternator with an enhanced power, higher

voltage, higher efficiency belt-driven starter-alternator that can recover braking energy while the vehicle slows down (regenerative braking). This technology was not used as an enabling technology in the NPRM analysis, because we had incomplete information on the technology at that time. Since the proposal, the agencies have obtained better data on the costs and effectiveness of this technology (see Section 3.4.3 of the joint TSD). Therefore, the agencies have revised their technical analysis on both and found that the technology is now competitive with the others in the CAFE model technology decision trees and EPA's technology packages. Further, this technology has been used for "game changing" credit for pick-up trucks and can act as a bridge technology for strong hybrid. For these reasons, the technology is now included in the analysis.

- *P2 Hybrid (SHEV1 and SHEV2)* –a newly emerging hybrid technology that uses a transmission integrated electric motor placed between the engine and a gearbox or CVT, much like the IMA system described below except with a wet or dry separation clutch which is used to decouple the motor/transmission from the engine. In addition, a P2 Hybrid would typically be equipped with a larger electric machine, as compared to an IMA system. Disengaging the clutch allows all-electric operation and more efficient brake-energy recovery. Engaging the clutch allows efficient coupling of the engine and electric motor and, when combined with a DCT transmission, provides similar or improved fuel efficiency to other strong hybrid systems with reduced cost.
- *Plug-in hybrid electric vehicles (PHEV1 and PHEV2)* – are hybrid electric vehicles with the means to charge their battery packs from an outside source of electricity (such as the electric grid), as well as a gasoline engine. These vehicles have larger battery packs than non-plug-in hybrid electric vehicles with more energy storage and a greater capability to be discharged. They also use a control system that allows the battery pack to be substantially depleted under electric-only or blended mechanical/electric operation, allowing for reduced fuel use during "charge depleting" operation.
- *Electric vehicles (EV1, EV2, EV3 and EV4)* – are vehicles with all-electric drive and with vehicle systems powered by energy-optimized batteries charged from grid electricity and regenerative braking. EVs with 75 mile and 150 mile ranges have been included in the modeling for this FRM and FRIA as potential technologies.

Types of accessory/hybridization/electrification technologies discussed but not applied in this FRM analysis, for a variety of reasons, include:

- *Integrated Motor Assist (IMA)/Crank integrated starter generator (CISG)* – provides idle-stop capability and uses a high voltage battery with increased energy capacity over typical automotive batteries. The higher system voltage allows the use of a smaller, more powerful electric motor and reduces the weight of the wiring harness. This system replaces a standard alternator with an enhanced power, higher voltage and higher efficiency starter-alternator that is crankshaft mounted and can recover braking energy while the vehicle slows down (regenerative braking). The IMA technology is not included as an enabling technology in this analysis as the industry trends toward more cost effective hybrid configurations, although it is included as a baseline technology because it exists in the 2008 and 2010 baseline fleets.

- *Power-split Hybrid (PSHEV)* – is a hybrid electric drive system that replaces the traditional transmission with a single planetary gearset and two motor/generators. The smaller motor/generator uses the engine to either charge the battery or supply additional power to the drive motor. The second, more powerful motor/generator is permanently connected to the vehicle's final drive and always turns with the wheels. The planetary gear splits engine power between the first motor/generator and the drive motor to either charge the battery or supply power to the wheels. The power-split hybrid technology is not included as an enabling technology in this analysis as the industry is expected to trend toward more cost-effective hybrid configurations, although it is included as a baseline technology because it exists in the 2008 and 2010 baseline fleets.

- *2-Mode Hybrid (2MHEV)* – is a hybrid electric drive system that uses an adaptation of a conventional stepped-ratio automatic transmission by replacing some of the transmission clutches with two electric motors that control the ratio of engine speed to vehicle speed, while clutches allow the motors to be bypassed. This improves both the transmission torque capacity for heavy-duty applications and reduces fuel consumption at highway speeds relative to other types of hybrid electric drive systems. The 2-mode hybrid technology is not included as an enabling technology in this analysis as the industry is expected to trend toward more cost effective hybrid configurations, although it is included as a baseline technology because it exists in the 2008 and 2010 baseline fleets.

What does NHTSA then do with those technologies? We apply them to vehicles using the CAFE model.

As in the MYs 2012-2016 final rule, each technology is assigned to one of the five following categories based on the system it affects or impacts: engine, transmission, electrification/accessory, hybrid or vehicle. Each of these categories has its own decision tree that the CAFE model uses to apply technologies sequentially during the compliance analysis. The decision trees were designed and configured to allow the CAFE model to apply technologies in a cost-effective, logical order that also considers ease of implementation. For example, software or control logic changes are implemented before replacing a component or system with a completely redesigned one, which is typically a much more expensive option. In some cases, and as appropriate, the model may combine the sequential technologies shown on a decision tree and apply them simultaneously, effectively developing dynamic technology packages on an as-needed basis. For example, if compliance demands indicate, the model may elect to apply LUB, EFR, and ICP on a dual overhead cam engine, if they are not already present, in one single step.

For this FRM analysis, the decision trees were updated to include additional technologies that the agency assumes will be available in the MYs 2017-2025 time frame.
Each technology within the decision trees has an incremental cost and an incremental effectiveness estimate associated with it, and estimates are specific to a particular vehicle subclass. Each technology's incremental estimate takes into account its position in the decision tree path, which starts with the most cost-effective/simplest technology options at the top. If a technology is located further down the decision tree, the estimates for the costs and effectiveness values attributed to that technology are influenced by the incremental estimates of costs and effectiveness values for prior technology applications. In essence, this approach accounts for

"in-path" effectiveness synergies, as well as cost effects that occur between the technologies in the same path. When comparing cost and effectiveness estimates from various sources and those provided by commenters, it is important that the estimates evaluated are analyzed by the agency in the proper context, especially as concerns their likely position in the decision trees and other technologies that may be present or missing. Not all estimates available in the public domain or offered for the agencies' consideration can be evaluated in an "apples-to-apples" comparison with those used by the CAFE model, since in some cases the order of application, or included technology content, is inconsistent with that assumed by NHTSA in the decision tree.

In the MY 2011 final rule, significant revisions had been made to the sequence of technology applications within the decision trees, and in some cases the paths themselves had been modified and additional paths had been added. These revisions were maintained for the MYs 2012-2016 final rule and this FRM analysis. The additional paths allow for a more accurate application of technology, insofar as the model now considers the existing configuration of the vehicle when applying technology. In this analysis, single overhead camshaft (SOHC), dual overhead camshaft (DOHC) and overhead valve (OHV) configured engines have separate paths that allow for unique path-dependent versions of certain engine technologies. Thus, the cylinder deactivation technology (DEAC) now consists of three unique versions that depend on whether the engine being evaluated is an SOHC, DOHC or OHV design; these technologies are designated by the abbreviations DEACS, DEACD and DEACO, respectively, to designate which engine path they are located on. Similarly the last letter for the Coupled Cam Phasing (CCP) and Discrete Variable Valve Lift (DVVL) abbreviations are used to identify which path the technology is applicable to.

Use of separate valvetrain paths and unique path-dependent technology variations also ensures that the incremental cost and effectiveness estimates properly account for technology effects so as not to "double-count." For example, in the SOHC path, the incremental effectiveness estimate for DVVLS assumes that some pumping loss reductions have already been accomplished by the preceding technology, CCPS, which reduces or diminishes the effectiveness estimate for DVVLS because part of the efficiency gain associated with the reduction of the pumping loss mechanism has already occurred. This accounting approach resolves this potential double-counting issue.

In addition to incorporating new technologies for the MYs 2017-2025 time frame, the decision trees were also revised to include unique paths, based on engine displacement and cylinder configuration, for all turbocharged and downsized, cooled EGR, and diesel engines. This allows for more accurate accounting of incurred costs from the application of these advanced engine technologies. For each of these advanced engine technologies there are now three unique versions that depend on whether or not the engine is more similar to an inline 4-cylinder, a V6, or a V8 engine, and are defined by small displacement ("SD"), midsize displacement ("MD") and large displacement ("LD") designations, respectively. For example, the advanced diesel technology (ADSL) now consists of three unique versions that are designated by the abbreviations ADSL_SD, ADSL_MD and ADSL_LD.

To address any potential confusion, NHTSA would like to draw attention to the retention of previously applied technologies when more advanced technologies (*i.e.*, those further down the decision tree) were applied. For this final rule, as in the proposal and previous rulemakings, previously-applied technologies are retained in combination with the new technology being applied as appropriate and feasible, but not always. For instance, one exception to this would be the application of advanced diesel technology, where the entire engine is assumed to be replaced, so gasoline engine technologies do not (indeed, cannot) carry over. This exception for advanced diesels, along with a few other technologies, is documented below in the detailed discussion of each decision tree and corresponding technologies.

As the CAFE model steps through the decision trees and applies technologies, it accumulates total or "NET" cost and effectiveness values. Net costs are accumulated using an additive approach while net effectiveness estimates are accumulated multiplicatively. As with the MY 2012-2016 final rule, the decision trees have been expanded so that NHTSA is better able to track the incremental and net/cumulative cost and effectiveness of each technology, which substantially improves the "accounting" of costs and effectiveness for this FRM.[192] To help readers better understand the accumulation process, and in response to comments expressing confusion on this subject, the following examples demonstrate how the CAFE model calculates net values.

Accumulation of net cost is explained first, as this is the simpler process. This example uses the Transmission decision tree sequentially applying IATC, NAUTO, DCT, 8SPD, HETRANS, SHFTOPT technologies to a midsize passenger car using the cost and effectiveness estimates from its input sheet. As seen in Table V-10 below, for example, the net cost to apply all the

[192] In addition to the (simplified) decision trees, as published in this document, NHTSA also utilized "expanded" decision trees in this final rule analysis. Expanded decision trees graphically represent each unique path, considering the branch points available to the CAFE model, which can be utilized for applying fuel saving technologies. For instance, the engine decision tree shown in this document has 21 boxes representing engine technologies, whereas the expanded engine decision tree requires a total of 90 boxes to accurately represent all available application variants. Expanded decision trees presented a significant improvement in the overall assessment and tracking of applied technologies since they allowed NHTSA staff to accurately view and assess both the incremental and the accumulated, or net cost and effectiveness at any stage of technology application in a decision tree. Because of the large format of the expanded decision trees, they could not be included in the Federal Register, so NHTSA refers the reader to Docket No. NHTSA-2010-0131. Expanded decision trees for the engine, electrification/transmission/hybridization, and the vehicle technologies (three separate decision trees) were developed for each of the 12 vehicle technology application classes and have been placed in the docket for the reader's reference.

transmission technologies would be ($61.88 + -$38.73 + -$73.88 + $255.18 + $248.38 + $1.65 = $454.48). Net costs are calculated in a similar manner for all the decision trees.

Table V-10. Example of CAFE Model Net Cost Calculation

Example Net Cost (MY2017) Calculation: Transmission Path, Midsize Vehicle Subclass		
Tech. Abrev.	**INCR Cost**	**NET Cost**
IATC	$ 61	$ 61
NAUTO	$ (39)	$ 22
DCT	$ (74)	$ (52)
8SPD	$ 225	$ 173
HETRANS	$ 248	$ 421
SHFTOPT	$ 2	$ 423

The same decision tree, technologies, and vehicle are used for the example below which demonstrates the model's net effectiveness calculation. Table V-11 below shows average incremental effectiveness estimates in column two; this value is calculated in the same manner as the cost estimates above (average of lower and upper value taken from the input sheet). To calculate the change in fuel consumption due to application of the IATC technology with incremental effectiveness of 3.0 percent (or 0.030 in decimal form, column 3), when applied multiplicatively, means that the vehicle's current fuel consumption 'X' would be reduced by a factor of (1 – 0.030) = 0.970,[193] or mathematically 0.970*X. To represent the changed fuel consumption in the normal fashion (as a percentage change), this value is subtracted from 1 (or 100%) to show the net effectiveness in column 5.

As the NAUTO technology is applied, the vehicle's fuel consumption is already reduced to 0.970 of its original value. Therefore the reduction for an additional incremental 2.04 percent results in a new fuel consumption value of 0.9502, or a net 4.98 percent effectiveness, as shown in the table. Net effectiveness is calculated in a similar manner for the all decision trees. All incremental effectiveness estimates were derived with this multiplicative approach in mind; calculating the net effectiveness using an additive approach will yield a different and incorrect net effectiveness.

Table V-11. Example of CAFE model Net Effectiveness Calculation

[193] A decrease in fuel consumption (FC) means the fuel economy (FE) will be increased since fuel consumption and economy are related by the equation FC = 1/FE.

Example Net Effectiveness Calculation: Transmission Path, Midsize Vehicle Subclass				
Tech. Abrev.	**INCR Eff. %**	**Eff. (decimal)**	**Multiplicative FC Reduction Current FC * (1- INCR)**	**NET Eff. (1-Red)**
IATC	3.00%	0.0300	1 * (1-0.03) = 0.970	3.00%
NAUTO	2.04%	0.0204	0.970 * (1 - 0.0204) = 0.9502	4.98%
DCT	4.06%	0.0406	0.9502 * (1 - 0.0406) = 0.9116	8.84%
8SPD	4.57%	0.0457	0.9116 * (1 - 0.0457) = 0.8700	13.00%
HETRANS	2.68%	0.0268	0.8700 * (1- 0.0268) = 0.8467	15.33%
SHFTOPT	4.08%	0.0408	0.8467 * (1 - 0.0408) = 0.8121	18.79%

To improve the accuracy of accumulating net cost and effectiveness estimates, "path-dependent corrections" were employed in the MYs 2012-2016 final rule and are being utilized in this final rule. The previous 2008 analysis for the MYs 2011-2015 NPRM had the potential to either overestimate or underestimate net cost and effectiveness depending on which decision tree path the CAFE model followed when applying the technologies. For example, if in the 2008 NPRM analysis a diesel technology was applied to a vehicle that followed the OHV path, the net cost and effectiveness could be different from the net estimates for a vehicle that followed the OHC path, even though the intention was to have the same net cost and effectiveness. In order to account for this, "in path"-dependent correction tables were added to the input sheets. The model uses path-dependent correction factors, found in the synergy tables of the technology input sheets, to correct net cost and effectiveness estimate differences that occur when multiple paths lead into a single technology that is intended to have the same net cost and effectiveness no matter which path was followed. Path-dependent corrections were used when applying cylinder deactivation (on the DOHC path) and turbocharging and downsizing. For the cylinder deactivation the fuel consumption reduction and cost estimates stated in the following sections and the input sheets are for an engine with DVVL. The above-mentioned correction factors are then used to adjust the estimates for an engine with CVVL.

Similarly, the fuel consumption reduction and cost estimates stated in following sections and the input sheets for turbocharging and downsizing are for an SOHC engine. Correction factors are then used to adjust the estimates for the different paths (*i.e.*, DOHC or OHV).

What's new in this rulemaking from the MY 2012-2016 final rule?

Since the MY 2012-2016 final rule, additional analyses and studies have been initiated to improve the technology cost and effectiveness estimates used as inputs for this and future CAFE rulemakings. Some of these analyses and studies have been completed already, and their results were available for use in this FRM analysis. The following sections briefly describe some of the new inputs that NHTSA and EPA have incorporated for this analysis.

More Vehicle Technologies (LUB2-EFR2, Higher BMEP Engine, P2, Level II of Tire Rolling Resistance, Level II of Aerodynamic Drag Reduction)

The agencies have applied several new technologies and also included a new additional level of effectiveness for several technologies in this FRM analysis. The agencies are employing an additional level of engine friction reduction (representing engine friction reductions of 20 percent, compared to the 10 percent reductions previously assumed), an additional level of aerodynamic drag reduction (representing drag reductions of 20 percent), and an additional level of tire rolling resistance reduction (representing a rolling resistance reduction of 20 percent).

Other changes to the technologies employed in the modeling include, based on Ricardo's work for EPA, the addition of higher BMEP engines than considered in prior rulemaking analyses, such as 24 bar and 27 bar BMEP engines; and two additional technology options which have been added to the transmission decision tree, high efficiency gearbox and shift optimization. New to this final rule is the ISG mild hybrid, which was not considered in the proposal. The strong hybrid technologies used in the MYs 2012-2016 final rule, power split and 2-mode hybrid, have been replaced in this FRM analysis by P2 hybrid, which is applied instead of the other two technologies due to its lower cost and higher effectiveness. Transmission technologies are revised significantly as well, insofar as the "6-, 7- and 8- speed transmission" group is now divided into two groups, a "6-speed transmission" group and an "8-speed transmission" group, based on information gathered by the agencies. All of these changes reflect the agencies' expectation for technology development before and during MYs 2017-2025 timeframe. The agencies believe that these technologies will provide a cost effective path in reducing fuel consumption and GHGs.

Updated Effectiveness Estimates

EPA contracted with Ricardo Engineering to provide vehicle simulation support for the proposal. This simulation work provided the basis for the effectiveness estimates for a number of the technologies most heavily relied on in the agencies' analysis of potential standards for MYs 2017-2025 and was carried over into this final rule. Some of technology effectiveness estimates that were informed by the 2010/2011 Ricardo study were advanced engine friction reductions, higher BMEP engines, advanced transmissions, start-stop systems and P2 hybrids. More information about the Ricardo work is available in TSD Chapter 3 or Docket NHTSA-2010-0131.

For the final rule, NHTSA conducted a vehicle simulation project with Argonne National Laboratory (ANL) that performed additional analyses on mild hybrid technologies and advanced transmissions to help NHTSA develop effectiveness values better tailored for the CAFE model's incremental structure. The effectiveness estimates that were developed by ANL for the mild hybrid vehicles were applied by both agencies for the final rule. Additionally, NHTSA updated the effectiveness estimates of advanced transmissions when coupled with naturally-aspirated engines based on ANL's simulation work for the final rule.

More Costs from FEV Teardown Study

Since the MYs 2012-2016 final rule, FEV, contracted by EPA, has completed two more tear-down studies that the agencies used for this FRM analysis: a tear-down study comparing the cost of an 8-speed automatic transmission to a 6-speed automatic transmission, and a tear-down study of a power-split hybrid to determine the incremental costs of converting a conventional gasoline powered vehicle (a V6 Ford Fusion) to a power-split hybrid (a Ford Fusion hybrid). The results for individual components in power-split hybrid teardown were subsequently used to cost another hybrid technology, the P2 hybrid, which employs similar hardware.

Updates for the Cost of HEV, PHEV, EV

The agencies have reconsidered the costs for HEVs, PHEVs, EVs, and FCEVs as the result of two issues. First, electrified vehicle technologies are developing rapidly: different battery materials and different hybrid systems are proliferating, and battery costs are coming down. And second, the analysis for the MYs 2012-2016 final rule employed a single $/kWh estimate, and did not consider the specific vehicle and technology application for the battery when we estimated the cost of the battery.[194] Specifically, batteries used in HEVs (high power density applications) versus EVs (high energy density applications) need to be considered appropriately to reflect the design differences, the chemical material usage differences, and differences in cost per kW-hr as the power to energy ratio of the battery changes for different applications. To

[194] However, we believe that this had little impact on the results of the cost analyses in support of the MYs 2012-2016 final rule, as the agencies projected that the standards could be met with an increase of less than 2 percent penetration of hybrid technology, and no increase in plug-in or full electric vehicle technology.

address these issues for this final rule, the agencies have used a battery cost model, BatPaC,[195] developed by Argonne National Laboratory (ANL) for the Vehicle Technologies Program of the U.S. Department of Energy's (DOE) Office of Energy Efficiency and Renewable Energy. The model developed by ANL allows users to estimate unique battery pack cost using user-customized input sets for different hybridization applications, such as strong hybrid, PHEV and EV. Since the publication of the TAR, ANL's battery cost model has been peer-reviewed and ANL has updated the model to incorporate many suggestions from peer-reviewers. Additionally, the model has been updated since the proposal to include certain agency requests, including an option to select between liquid or air thermal management and that adequate surface area and cell spacing be determined accordingly. Also, the agencies requested a feature to allow battery packs to be configured as subpacks in parallel or modules in parallel, as additional options for staying within voltage and cell size limits for large packs. EPA staff used this newly updated model to derive battery costs for this FRM analysis. The agencies added new configurations of HEV, PHEV and EV vehicles to the ANL model for this FRM analysis that include the P2 HEV configuration, different mileage ranges for PHEVs and different mileage ranges for EVs. Details regarding these vehicle technologies are discussed in Chapter 3 of the joint TSD.

Updates for the Cost of Mass Reduction and Level of Mass Reduction

The cost of mass reduction has been updated since to the MYs 2012-2016 final rule. In the last rulemaking, a constant cost of $1.32/lb was used. In this FRM analysis, a linear cost curve is used at a rate of $4.29/lb/percent of mass reduction. Additionally, the amount of mass reduction considered by the agencies as available for purposes of this analysis is generally increased. The maximum amount of mass reduction applied to vehicles in NHTSA's analysis is 20 percent, although varying amounts are applied to different types of vehicles in order to ensure that a safety neutral path is developed: specifically, less mass reduction is applied to smaller vehicles, such as compact cars, and more is allowed to be applied to larger vehicles, such as large pickup trucks and SUVs. The mass reduction section below contains detailed descriptions for mass reduction costs, available technologies and the agencies' work plan for refining these estimates for the final rule.

Modification of ICM

For the analysis in this FRM, NHTSA and EPA have revisited the technologies evaluated by EPA staff and relied primarily on the modified Delphi based technologies develop the ICMs. For this FRM analysis, the agencies are using the following basis for estimating ICMs:

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[195] BatPac Model and peer-review report are in docket NHTSA-2010-0131.

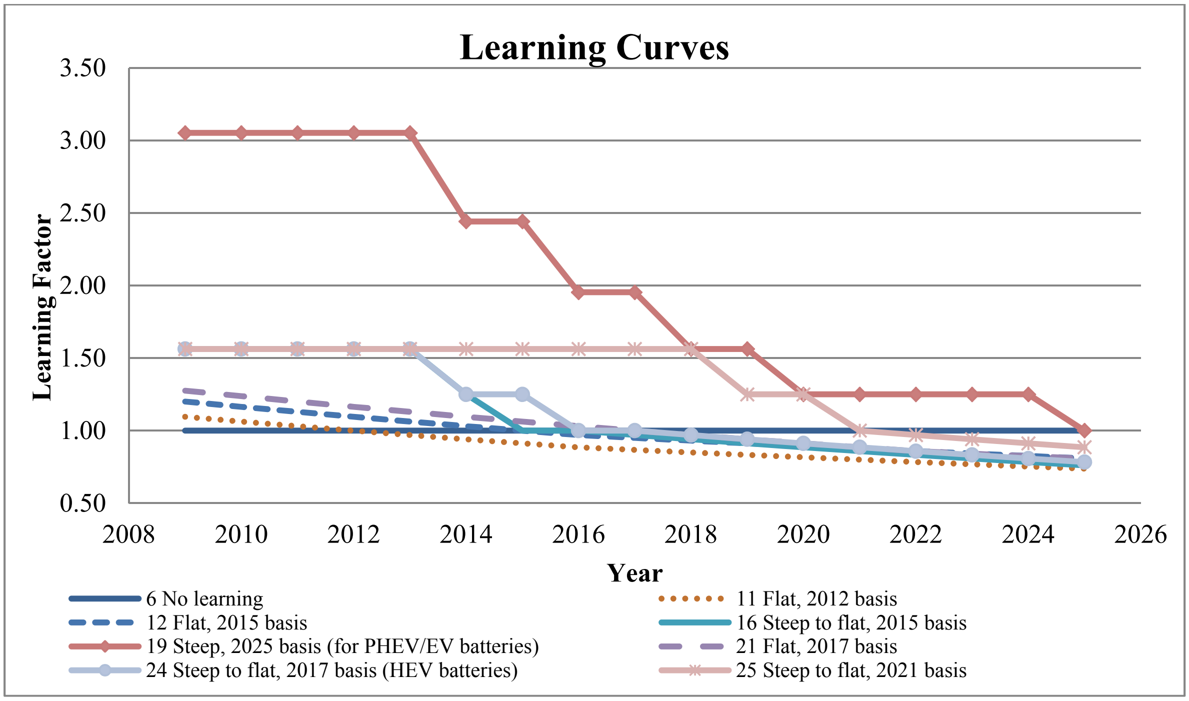
- All low complexity technologies will be estimated to equal the ICM of the modified Delphi based low technology - passive aerodynamic improvements.
- All medium complexity technologies will be estimated to equal the ICM of the modified Delphi based medium technology - engine turbo downsizing.
- Strong hybrids and non-battery PHEVs will be estimated to equal the ICM of the high complexity consensus based high technology – hybrid electric vehicle.
- PHEVs with battery packs and full electric vehicles will be estimated to equal the ICM of the high complexity modified Delphi based high technology – plug-in hybrid electric vehicle.

In addition to shifting the proxy basis for each technology group, the agencies reexamined each technology's complexity designation and adjusted the grouping of technologies. Some new technologies are also added to the groupings. Other changes to the ICMs for this rulemaking include basing them on the expected long-term average RPE rather than that of any one specific year (2007), which involved normalizing them to an average RPE multiplier level of 1.5; and distinguishing the ICMs into two parts, one applied to warranty cost and one applied to non-warranty cost. The latter was done because the agencies believe that learning curves are more appropriately applied only to direct costs, with indirect costs established up front based on the ICM and then held constant while direct costs are reduced by learning.
More detailed information about how the agencies applied ICMs in this FRM analysis can be found in Chapter VII of this FRIA.

More and Refined Learning Schedules

In MYs 2012-2016 rulemaking, the agency applied two types of learning, "time-based" learning and "volume-based" learning. For this FRM the agency has, however, adopted new terminology to distinguish the two different learning applications. Emerging technologies are adjusted using what we now call the "steep "learning schedule, which involves 20% decreases, while mature technologies are modified using one of a number of "flat" schedules, involving the smaller 3%, 2%, or 1% decreases. The "flat" curves assume a learning rate of 3% over the previous years' cost for a number of years, followed by 2% over several more years, followed by 1% indefinitely. The "steep" curves assume larger decreases of 20% every 2 years during the initial years of production, for a maximum of two learning cycles, before converting to the "flat" learning curve rates. For this FRM analysis, the agency has determined where on the learning curve each technology lies and then applied learning effects based on those determinations. Figure V-28 shows how these determinations impact the level of learning effects applied in our analysis. Chapter VII of this FRIA contains a detailed discussion of the changes to the ICM and their application to individual technologies.

Figure V-28. Learning Factors used in the Analysis to accommodate Technologies at Different Places on the Learning Curve and Having Costs Based in Different Years



Inclusion of Stranded Capital Costs

There is also the potential for stranded capital[196] if technologies are introduced too rapidly for some indirect costs to be fully recovered. Due to the capital-intensive nature of producing automotive components, it is possible for substantial capital investments in manufacturing equipment and facilities to become "stranded." While the FEV tear-down analysis results are assumed to be generally valid for the 2017-2025 timeframe for fully mature, high sales volumes, FEV perform a supplemental analysis to consider potential stranded capital costs. For a select group of technologies NHTSA has included that ability account for stranded capital costs, as supplied by FEV, into the analysis. The agency refers readers to Chapter 3 of the joint TSD for a more detailed description of how FEV estimated stranded capital costs and later in this chapter the agency describes how stranded capital costs were integrated into the analysis.

What's new in this final rulemaking from NPRM?

Inclusion of Mild Hybrid/Belt Integrated Starter Generator (BISG)

[196] The potential for stranded capital occurs when manufacturing equipment and facilities cannot be used in the production of a new technology.

Mild hybrid/ISG technology was mentioned but not included in the proposal because the agencies had incomplete information at that time. Since the proposal, the agencies have obtained better data on the costs and effectiveness of this technology (see the detailed discussion later in this chapter). Therefore, the agencies have revised their technical analysis on both the cost and effectiveness and found that the technology is now competitive with the others in NHTSA's technology decision trees and EPA's technology packages. The effectiveness estimates are based on full-vehicle simulation modeling by Argonne National Laboratory (ANL) and the cost estimates are from the FEV teardown of the Saturn Vue (non-battery components) and ANL's BatPaC model (Li-ion battery).

Updated Transmission Effectiveness Estimates

For the final rule, NHTSA conducted a vehicle simulation project with ANL that performed additional analyses on mild hybrid technologies and advanced transmissions to help NHTSA develop effectiveness values better tailored for the CAFE model's incremental structure. The effectiveness estimates that were developed by ANL for the mild hybrid vehicles were applied by both agencies for the final rule. Additionally, NHTSA updated the effectiveness estimates of advanced transmissions when coupled with naturally-aspirated engines based on ANL's simulation work for the final rule.

Updated allocation of stranded capital costs

The allocation of stranded capital costs to the different technologies were changed slightly from the NPRM to more closely align with how the FEV derived stranded capital costs were meant to be applied. The stranded capital costs themselves did not change. The only change was how the stranded capital costs were applied to the unique technologies.

How are technologies applied in the CAFE model?

As discussed above, the CAFE model uses decision trees to determine the order in which technologies are applied to each vehicle in our analysis. The following paragraphs explain, in greater detail, the decision tree logic and revisions to the decision trees from the MY 2012-2016 final rule that have been incorporated for this FRM.

Engine Technology Decision Tree

For this FRM, NHTSA modified the engine decision tree and the model's technology application logic that was employed in the MYs 2012-2016 final rule by revising some of the paths and adding new technologies that the agencies assume will be available in the MYs 2017-2025 timeframe. Figure V-29 below shows a simplified decision tree for the engine technology category.

As was the case in the MYs 2012-2016 final rule, SOHC, DOHC and OHV engines continue to have separate paths to allow the model to apply unique path-dependent valvetrain technologies (Variable Valve Timing, Variable Valve Lift, and cylinder deactivation) that are tailored to those specific engine types. These path-dependent valvetrain technologies are designated by the letter "S" for SOHC, "D" for DOHC and "O" for OHV at the end of each technologies acronym. From example, cylinder deactivation (DEAC) on the SOHC is designated as DEACS. This approach also improves the accuracy of our accounting for net cost and effectiveness, because the unique cost and effectiveness estimates for each engine type can account for the fact that SOHC engines only have one camshaft per bank of cylinders, DOHC engines have two camshafts per bank of cylinders and OHV engines only have one camshaft regardless of whether or not the engine is an inline or V configuration.

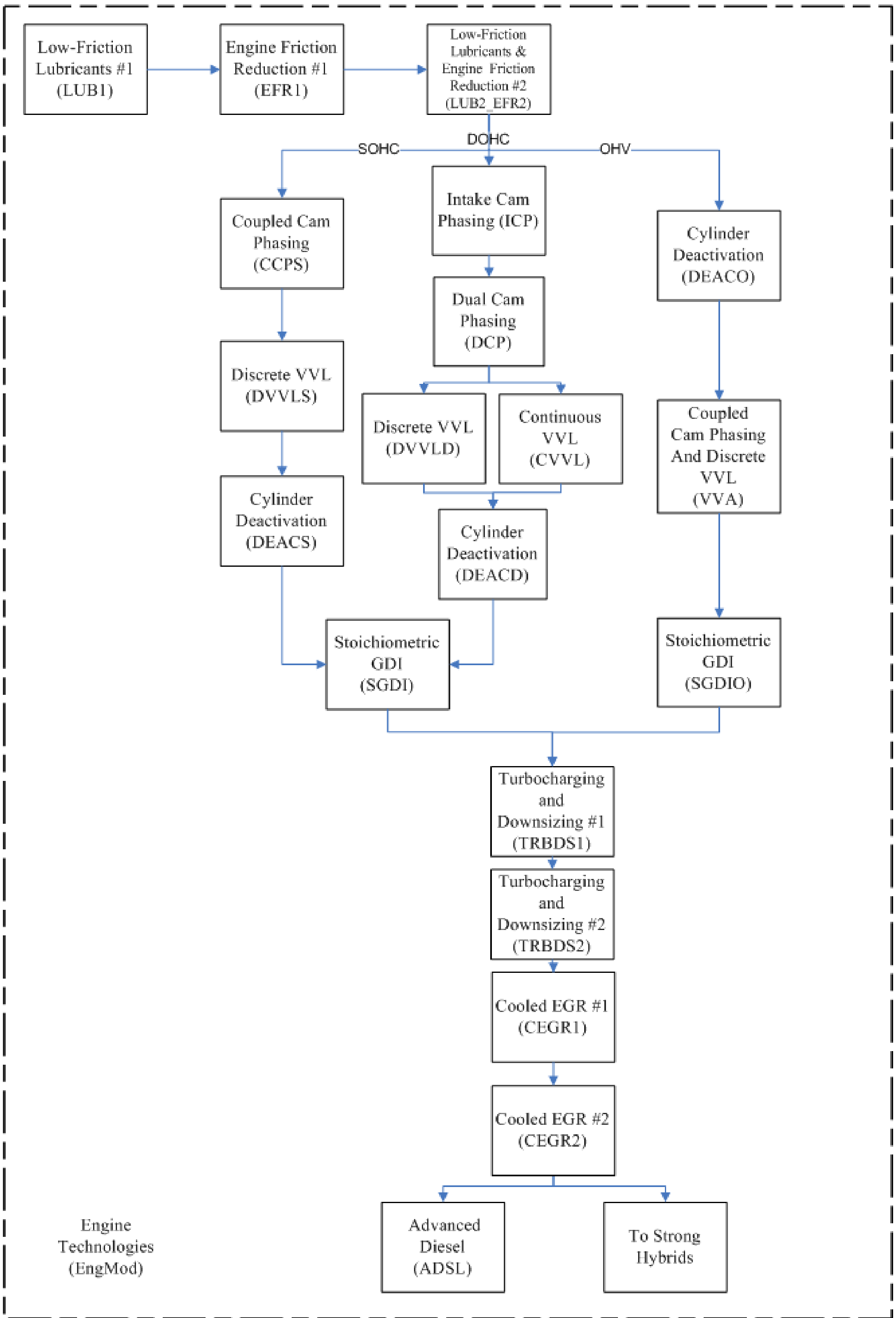
A number of changes have been made to the engine decision tree for the MYs 2017-2025 analysis in order to reflect changes in our technology assumptions for this rulemaking as compared to the MYs 2012-2016 final rule. As explained above, a second step of low-friction lubricants and engine friction (LUB2_EFR2) is included in the agencies' analysis and has thus been added to the decision tree, as a single technology following EFR1. On the OHV path, coupled cam phasing (CCP) and discrete variable valve lift (DVVL) have been combined into one technology, variable valve actuation (VVA). This was done because, and as discussed below, cylinder deactivation (DEAC), which utilizes lost motion devices that enable DVVL operation, precedes both CCP and DVVL so when applying CCP it seems logical to apply DVVL, at no cost due to being enabled by DEAC, to utilize the additional valve control the conversion to DOHC has been deleted from the OHV path based on the assumption that manufacturers are more likely to proceed to a turbocharged and downsized engine, which has a higher potential for fuel consumption reductions, rather than to a naturally aspirated DOHC engine in the event that they need to replace the existing OHV engine Additionally, the OHV path now has its own unique stoichiometric gasoline direct injection technology (SGDIO).

The combustion restart (CBRST) technology has been deleted as an enabling engine technology based on the assumption that it is likely that manufacturers will accomplish stop-start functionality by way of a 12V integrated starter/generator (MHEV).
The turbocharging and downsizing and cooled EGR technologies are considered to be a completely new engines that have been converted to DOHC (if not already a DOHC in the baseline vehicle) with LUB, EFR, LUB2_EFR2 (post MY 2016) DCP and SGDI applied. For this final rule, the agency has added a second step of turbocharging and downsizing (TRBDS2)

with a higher Brake Mean Effective Pressure (BMEP[197]) level. The EGR Boost technology from the MYs 2012-2016 technology has been renamed to cooled EGR (CEGR1 and CEGR2) and has been expanded to include two steps with the second utilizing higher BMEP levels. For this analysis, the conversion to Diesel is now only one technology following CEGR2, and has been renamed advanced diesel (ADSL) Similar to the turbocharged and downsized engines, ADSL is considered to be a completely new engine that replaces the gasoline engine (although it carries over the LUB, EFR and LUB2_EFR2 technologies, which are assumed to still be applicable to diesels). We note that because in the TRBDS1 all engines are converted to DOHC engines; there are not path-dependent variations of the TRBDS2, CEGR1, CEGR2 and ADSL technologies, which means that the same technology state is reached by the modified vehicle regardless of the path the model followed to achieve it. Therefore, in conducting the analysis, the *net* cost and effectiveness estimates for the different engine paths are considered to be the same (regardless of path), and the *incremental* cost and effectiveness estimates are adjusted as appropriate to account for the path-dependent variations.

[197] BMEP refers to brake mean effective pressure, a common engineering metric which describes the specific torque of an engine, as a way of comparing engines of different sizes. It is usually expressed in units of bar, or kPa. Current naturally aspirated production engines typically average 10-12 bar BMEP, while modern turbocharged engines are now exceeding 20 bar BMEP with regularity. Simply put, a 20 bar BMEP turbocharged engine will provide twice the torque of an equivalent sized engine that achieves 10 bar BMEP.

Figure V-29. Engine Technology (EngMod) Decision Tree



Electrification/Accessory Technology Decision Tree

After reviewing this decision tree, NHTSA made some revisions from the version used in the MYs 2012-2016 final rule. Specifically, since the agencies are considering a second level of Improved Accessories (IACC) after the first level to consider technologies such as mild levels of alternator regenerative braking, the decision tree was modified to include that additional technology option. Belt Mounted Integrated Starter Generator (BISG) and Crank Mounted ISG (CISG) are now combined into one technology, Integrated Starter Generator (ISG). ISG was not used in the analysis for the proposal but is included in the final rule analysis. The updated decision tree is shown in Figure V-30.

Electric Power Steering (EPS) is the first technology in this decision tree, since it is a primary enabler for stop-start systems and mild and strong hybrids, and is followed by the first level of Improved Accessories (IACC1), as in the MY 2012-2016 final rule. IACC1 is then followed by a second level of improved accessory (IACC2), which includes a mild level of regenerative braking, as stated above. Micro-Hybrid (MHEV), a 12-volt system that offers basic idle stop/start functionality only, follows IACC2. An ISG technology block is placed on the decision tree to represent the higher voltage system with stop/start and higher level of energy recovery through regenerative braking, and some power assist. The ISG mild hybrid system was not considered in the proposal and is new for this final rule. All Electrification/Accessory technologies can be applied to both automatic and manual transmission vehicles.

Transmission Technology Decision Tree

For the NPRM and final rule, NHTSA reviewed the transmission technology decision tree and the model's technology application logic used in the MYs 2012-2016 final rule, and made some revisions. This decision tree, shown in Figure V-30, contains two paths: one for automatic/dual clutch transmissions and one for manual transmissions. The CVT path used in MYs 2012-2016 final rule has been removed due to the assumed low market penetration of CVTs in the U.S. in the rulemaking timeframe.

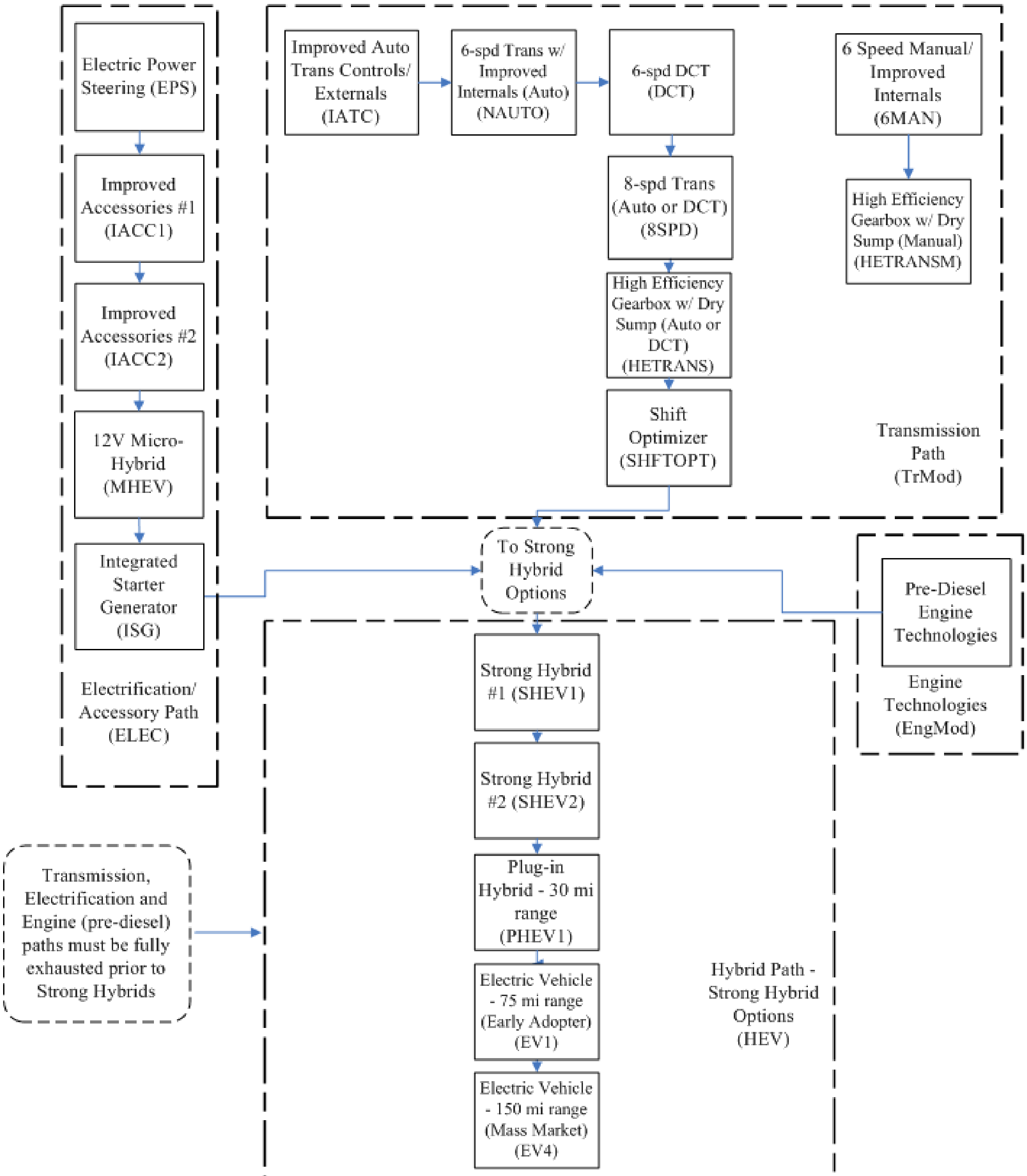
On the automatic/dual clutch path, the decision tree first optimizes the current transmission by improving the control system via the Improved Automatic Transmissions Controls and other Externals (IATC) technology. After IATC, the decision tree moves to 6-speed automatic transmission with improved internals (NAUTO). The NAUTO technology is followed by the 6-speed Dual Clutch Transmission (DCT) technology. Dual Clutch Transmission (DCT) designs do not suffer torque interrupt when shifting; a characteristic associated with automated manual transmission (AMT) designs. In response to comments from manufacturers expressing concern that torque interrupt will not be acceptable to consumers, AMT designs are not included in this analysis. The DCT technology is disabled for vehicles with towing requirements, such as Midsize Light Truck (LT), Large LT and Minivan LT vehicle subclasses. After DCT, the decision tree progresses to an 8-speed transmission (8SPD). For vehicles with towing requirements, the 8SPD technology represents an 8-speed automatic. However, for all other vehicles the 8SPD technology represents a transition to an 8-speed DCT from a 6-speed DCT. Following the 8SPD technology are two new technologies added for this FRM: high efficiency gear box (HETRANS) and shift optimization (SHFTOPT). Each of these technologies can be applied to both DCT and automatic transmissions.

As in the 2012-2016 final rule analysis, the manual transmission path has only two technology applications: conversion to a 6-Speed Manual with Improved Internals (6MAN), and high efficiency gearbox (HETRANSM). NHTSA anticipates limited use of manual transmissions with more than 6 speeds within the MYs 2017-2025 timeframe.

Hybrid Technology Decision Tree

NHTSA also reviewed the hybrid technology decision tree and the model's technology application logic used in the MY 2012-2016 final rule, and made revisions to this decision tree anticipating that more HEV, PHEV and EV vehicles will penetrate the market for the MYs 2017-2025 rulemaking period. The model continues to apply only strong hybrid technologies when both the Electrification/Accessory and Transmission (automatic/dual clutch transmissions only) technologies have been fully added to the vehicle, as seen in Figure V-30. When the CAFE model applies strong hybrids, it accounts for the fact that some of the fuel consumption reductions have already been included when technologies like EPS, IACC, and ISG have been previously applied. The decision tree contains two levels of strong hybrid technologies: SHEV1 and SHEV2. SHEV1 is applied when defining the MYs 2012-2016 baseline and SHEV2 is applied in the MYs 2017-2025 analysis. SHEV2 represents a second generation of strong hybrids that includes advances in engine and transmission technologies assumed to be available in MYs 2017-2025. The model's logic will allow a vehicle with the SHEV1 technology, either as applied by the model or present in the baseline, to be converted to SHEV2 in the MYs 2017-2025 timeframe. After SHEV2, the decision tree advances to a 30-mile range plug-in hybrid (PHEV1). Should the need arise in the future to incorporate another PHEV technology with a different range, a placeholder technology, PHEV2, has been added to the decision tree. Following SHEV2 in the decision tree are four electric vehicle (EV) technologies: EV1, EV2, EV3 and EV4. EV1 is a 75-mile range EV assumed to be marketed to early adopters of the EV technology. EV2 and EV3 are not used in this analysis and are reserved for adding different versions of EVs with different ranges. EV4 represents a 150-mile range EV that is assumed to be marketed as a mass market vehicle.

Figure V-30. Electrification/Accessory, Transmission and Hybrid Technology Decision Tree



Vehicle Technology Decision Tree

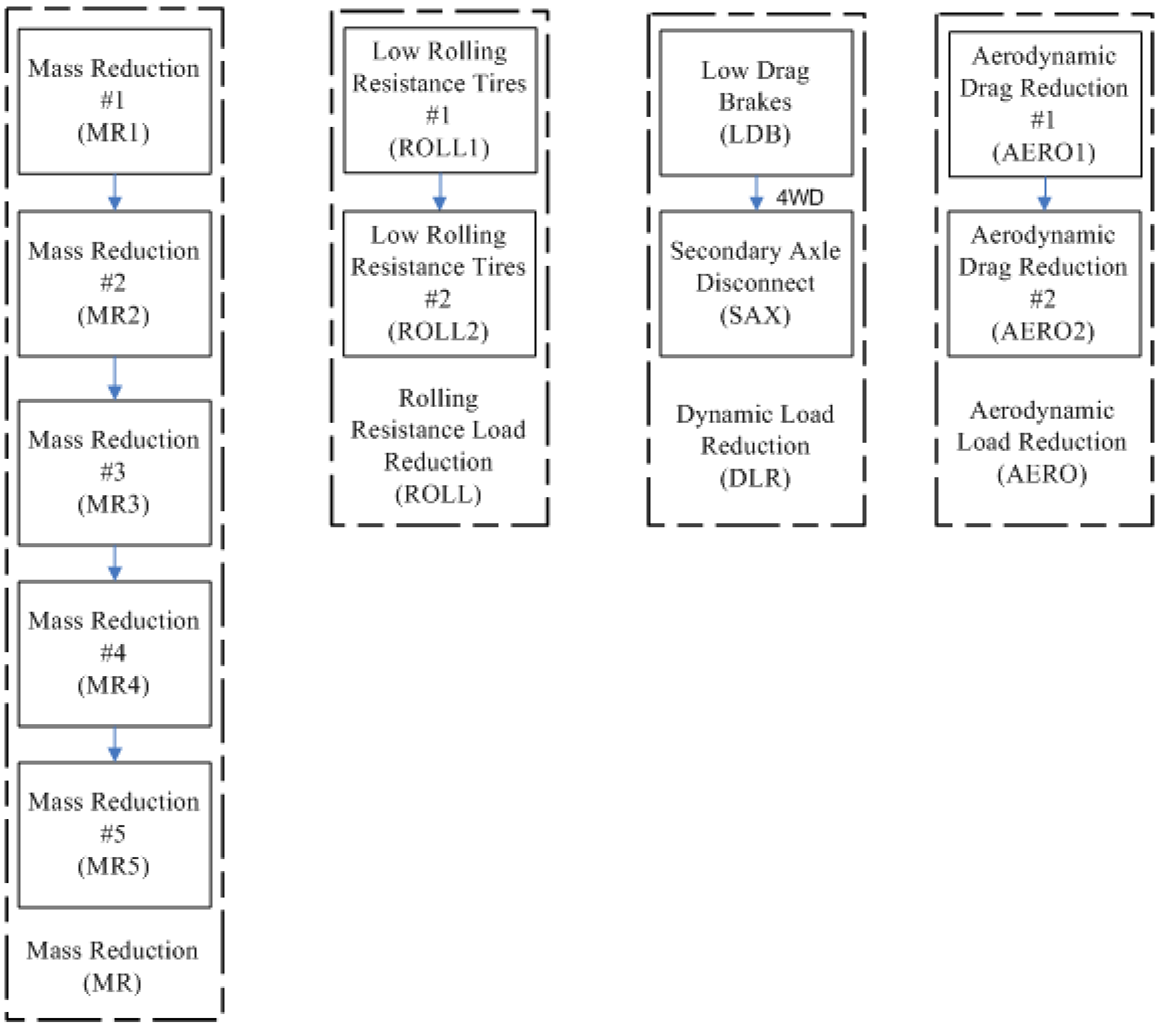
After reviewing this decision tree, NHTSA made some revisions to the vehicle technology tree from the version used in the MYs 2012-2016 final rule. The MY 2012-2016 final rule utilized three Material Substitution (MS) technologies in a dedicated path in the Vehicle Technology Decision tree. For this FRM, Material Substitution has been renamed Mass Reduction (MR) and has been expanded to five levels as shown in Figure V-15. All have a different definition (in terms of the amount of mass reduction that they can represent) than was used in the prior rule and the definition for the level of mass reduction differs with each vehicle subclass. For example, only MR1 and MR2 are used for midsize passenger cars representing a total of mass reduction of 5 percent, while MR1 to MR5 are used for large pickup trucks representing a total mass reduction of 20 percent. Section 0 contains detailed description of how mass reductions are applied in this analysis.

Low Drag Brakes (LDB) and Secondary Axle Disconnect (SAX) have the same definition and path as used in the MYs 2012-2016 final rule, with SAX still applied to 4WD vehicles only.

Low Rolling Resistance Tires (ROLL) is separated from LDB and SAX path. There are 3 levels of Low Rolling Resistance Tire in the decision tree, ROLL1, ROLL2 and ROLL3. However, only ROLL1 and ROLL2 are used in this final rule; the third level is reserved for potential future use.

Aerodynamic Drag Reduction also remains a separate path and there are now two levels of aerodynamic drag reduction in this final rule analysis, AERO1 and AERO2. The MYs 2012-2016 final rule only had one level of AERO.

Figure V-31. Vehicle Technology Decision Tree



Is this model year an appropriate time to add the technology? (year of availability; refresh and redesign schedule)

Manufacturers typically plan vehicle changes to coincide with certain stages of a vehicle's life cycle that are appropriate for the change, or in this case the technology being applied. In the automobile industry there are two terms that describe *when* technology changes to vehicles occur: redesign and refresh (*i.e.,* freshening). Vehicle *redesign* usually refers to significant changes to a vehicle's appearance, shape, dimensions, and powertrain. Redesign is traditionally associated with the introduction of "new" vehicles into the market, often characterized as the "next generation" of a vehicle, or a new vehicle platform. Vehicle *refresh* usually refers to less extensive vehicle modifications, such as minor changes to a vehicle's appearance, a moderate upgrade to a powertrain system, or small changes to the vehicle's feature or safety equipment content. Refresh is traditionally associated with mid-cycle cosmetic changes to a vehicle, within its current generation, to make it appear "fresh." Vehicle refresh generally occurs no earlier than two years after a vehicle redesign, or at least two years before a scheduled redesign.

There are many factors that can affect when or how often redesigns occur, such as availability of capital and engineering resources and the extent of platform and component sharing between vehicle models, or even between manufacturers, if cooperation is involved. Historically high-volume cars have followed roughly a 5-year redesign cycle to remain competitive in the market. On the other hand, a few of the niche market or small-volume manufacturer vehicles (*i.e.* luxury and performance vehicles), as well as large trucks and full size vans, have historically followed longer 6- to 8-year redesign cycles. Managing product lines and refresh and redesign cycles is a complex task undertaken by manufacturers to respond to consumer preference trends and to comply with regulations in the most cost- and resource-effective way possible. The agency believes that manufacturers can and will accomplish much improvement in fuel economy and GHG reductions while applying technology consistent with their redesign schedules. While manufacturers look to make common design and technology changes across a vehicle platform, consumer preference trends and regulation can sometimes require manufacturers to use flexibilities such vehicle-specific designs and technology changes in addition to broader vehicle platform level changes at refresh/redesign times in order to stay competitive and ensure compliance. As fuel economy standards become more stringent over time, NHTSA believes that manufacturers will use every opportunity to improve the fuel economy performance of their vehicles.

For the majority of technologies discussed in this final rule, manufacturers will only be able to apply them at a refresh or redesign, because their application would be significant enough to involve some level of engineering, testing, and calibration work.[198] Some technologies (*e.g.,* those that require significant revision) are nearly always applied only when the vehicle is expected to be redesigned, like turbocharging and engine downsizing, or conversion to diesel or hybridization. Other technologies, like cylinder deactivation, electric power steering, and low rolling resistance tires can be applied either when the vehicle is expected to be refreshed or when it is expected to be redesigned, while low friction lubricants, can be applied at any time, regardless of whether a refresh or redesign event is conducted. Accordingly, the model will only apply a technology at the particular point deemed suitable. These constraints are intended to produce results consistent with how we assume manufacturers will apply technologies in the

[198] For example, applying material substitution through weight reduction, or even something as simple as low rolling-resistance tires, to a vehicle will likely require some level of validation and testing to ensure that the vehicle may continue to be certified as compliant with NHTSA's Federal Motor Vehicle Safety Standards (FMVSS). Weight reduction might affect a vehicle's crashworthiness; low rolling-resistance tires might change a vehicle's braking characteristics or how it performs in crash avoidance tests.

future based on how they have historically implemented new technologies. For each technology under consideration, NHTSA specifies whether it can be applied any time, at refresh/redesign, or only at redesign. The data forms another input to the CAFE model.

For this final rule, NHTSA developed redesign and refresh schedules for each of a manufacturer's vehicles included in the analysis, essentially based on the last known redesign year for each vehicle, and projected forward using a 4 to 8-year redesign and a 2–3 year refresh cycle. NHTSA used publicly-available data to estimate the last known redesign schedule for the vehicles produced by the manufacturers.[199] The agency also used this public data along with engineering judgment to estimate the number of years between redesigns to develop the unique redesign schedules for each vehicle model in the analysis. Thus, if a vehicle was last redesigned in MY 2008 and is assumed to have 6 years between redesigns, the redesign cycle will be as follows: MY 2008, MY 2014, and MY 2020. The refresh schedules were determined in a similar fashion, based on those of the baseline fleet and using the 2 to 3 year cycle assumption. NHTSA believes that this approach is reasonable given the nature of the current baseline, which as a single year (MY 2008) of CAFE certification data, as discussed in Chapter III above, does not contain its own refresh and redesign cycle cues for future model years. This approach also helps to ensure the complete transparency of the agency's analysis.[200] For the final rule NHTSA intends to update the baseline fleet, hopefully using the more current MY 2010 CAFE certification data in lieu of the MY 2008 certification data, and the agency will reassess vehicle redesign schedules as part of this update. The agency seeks comment on the approach taken to estimate vehicle redesign schedules and on the schedules themselves. No comments were submitted on this issue.

We note that this approach taken for this final rule is different from what NHTSA has employed previously for determining redesign and refresh schedules. For the MYs 2012-2016 final rule,

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[199] Sources included, but were not limited to, manufacturers' web sites, industry trade publications (*e.g.*, Automotive News), and commercial data sources (*e.g.*, Ward's Automotive, etc.).

[200] While the greater transparency of using historical certification data is an undeniable benefit, using adjusted historical data rather than estimated future data also impacts how NHTSA is able to model the refresh/redesign cycle in its analysis of year-by-year maximum feasible CAFE standards. For example, manufacturers have indicated (either publicly or in their product plans) that some vehicles that exist in the MY 2008 certification-data based fleet will be discontinued (*i.e.*, no longer produced or sold) prior to or within the rulemaking period. Conversely, some vehicle models have already been or will be introduced to the market during the rulemaking time frame, like GM's Chevy Volt and Chrysler's anticipated new models based on Fiat platforms. Since these vehicles were not sold in 2008, they do not exist in the MY 2008 certification data, and thus do not exist in the model's market data file for this NPRM analysis. To address this problem, the agency assumes that future vehicles are replacements for vehicles currently in the market and will tend to follow the same cycles as their predecessors, so it is appropriate to reflect the same redesign cycle in the market data file.

NHTSA believes that it is reasonable to expect that the manufacturer will produce a similar vehicle, or some group of similar vehicles, to compete in the same market segment—whether the manufacturer will offer the same vehicle model, a fully redesigned but otherwise similar version of that model, or an entirely new vehicle or group of vehicles, sold as a new model or nameplate of a similar type. This is how NHTSA addresses the issue of the GM Volt: although it does not appear in the baseline market data file, it will be considered as one of the existing GM models of similar type and in the same market segment once it becomes available.

NHTSA assumed that passenger cars would normally be redesigned every 5 years, consistent with industry trends over the last 10-15 years, unless a manufacturer had submitted product plans indicating that they expected to pursue a more rapid redesign and refresh schedule.[201] In the MYs 2012-2016 final rule, NHTSA also projected a 5-year redesign cycle for the majority of light trucks.[202] In the MY 2011 final rule, NHTSA reviewed manufacturers' planned redesign and refresh schedules as stated in their confidential submissions and incorporated them into the market data file, or relied on other sources of information where that data did not exist. Even within the context of the phase-in caps discussed below, NHTSA considers these model-by-model scheduling constraints of refresh and redesign schedules necessary in order to produce an analysis that reasonably accounts for the need for a period of stability following the redesign of any given vehicle model. If engineering, tooling, testing, and other redesign-related resources were unlimited, every vehicle model could be redesigned every year. In reality, however, every vehicle redesign consumes resources simply to address the redesign, and thus cost expenditures occur. Phase-in caps, which are applied at the level of a manufacturer's entire fleet, do not, by themselves, constrain the scheduling of changes to any particular vehicle model. Conversely, scheduling constraints to address vehicle freshening and redesign do not necessarily yield realistic overall penetration rates for a particular technology type (*e.g.*, for strong hybrids), while phase-in caps do. Thus, the two constraints work together in the model to ensure that the timing and application rate for various fuel-saving technologies is feasible for manufacturers on a year-by-year basis, as required by EPCA/EISA.[203]

The baseline market data file, available on NHTSA's website, contains the refresh and redesign dates developed by NHTSA for this final rule. Table V-12 below provides whether particular technologies are "anytime" technologies, "redesign only" technologies, or "refresh or redesign" technologies, for purposes of this final rule.

[201] Exceptions were made for high performance vehicles and other vehicles that traditionally had longer than average design cycles due to their unique design characteristics and their evolutionary, as opposed to revolutionary product development practices (*e.g.*, the Porsche 911 has remained the same basic vehicle for many years).

[202] NHTSA recognized in the MY 2011 CAFE rulemaking that light trucks are currently redesigned every 5 to 7 years, with some vehicles (like full-size vans) having longer redesign periods. However, in the most competitive SUV and crossover vehicle segments, the redesign cycle currently averages slightly above 5 years. NHTSA concluded that the light truck redesign schedule will be shortened in the future due to competitive market forces. Thus, for almost all light trucks scheduled for a redesign in the early portions of the rulemaking period, NHTSA projected a 5-year redesign cycle.

[203] 49 U.S.C. § 32902(a) requires that NHTSA set CAFE standards at the maximum feasible level for each fleet, for each model year.

Table V-12. Technology Refresh and Redesign Application

Technology	Abbr.	Redesign Only	Redesign or Refresh	Anytime
Low Friction Lubricants - Level 1	LUB1			X
Engine Friction Reduction - Level 1	EFR1		X	
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2		X	
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS		X	
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	X		
Cylinder Deactivation on SOHC	DEACS		X	
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP		X	
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP		X	
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	X		
Continuously Variable Valve Lift (CVVL)	CVVL	X		
Cylinder Deactivation on DOHC	DEACD		X	
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	X		
Cylinder Deactivation on OHV	DEACO		X	
Variable Valve Actuation - CCP and DVVL on OHV	VVA	X		
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	X		
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	X		
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	X		
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	X		
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	X		
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	X		
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	X		
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	X		
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	X		
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	X		
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	X		
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	X		
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	X		
Advanced Diesel - Small Displacement	ADSL_SD	X		
Advanced Diesel - Medium Displacement	ADSL_MD	X		
Advanced Diesel - Large Displacement	ADSL_LD	X		
6-Speed Manual/Improved Internals	6MAN	X		
High Efficiency Gearbox (Manual)	HETRANSM	X		
Improved Auto. Trans. Controls/Externals	IATC		X	
6-Speed Trans with Improved Internals (Auto)	NAUTO	X		
6-speed DCT	DCT	X		
8-Speed Trans (Auto or DCT)	8SPD	X		
High Efficiency Gearbox (Auto or DCT)	HETRANS	X		
Shift Optimizer	SHFTOPT		X	
Electric Power Steering	EPS		X	
Improved Accessories - Level 1	IACC1		X	
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2		X	
12V Micro-Hybrid (Stop-Start)	MHEV	X		
Integrated Starter Generator	ISG	X		
Strong Hybrid - Level 1	SHEV1	X		
Conversion from SHEV1 to SHEV2	SHEV1_2	X		
Strong Hybrid - Level 2	SHEV2	X		
Plug-in Hybrid - 30 mi range	PHEV1	X		
Plug-in Hybrid	PHEV2	X		
Electric Vehicle (Early Adopter) - 75 mile range	EV1	X		
Electric Vehicle (Early Adopter) - 100 mile range	EV2	X		
Electric Vehicle (Early Adopter) - 150 mile range	EV3	X		
Electric Vehicle (Broad Market) - 150 mile range	EV4	X		
Fuel Cell Vehicle	FCV	X		
Mass Reduction - Level 1	MR1		X	
Mass Reduction - Level 2	MR2	X		
Mass Reduction - Level 3	MR3	X		

Mass Reduction - Level 4	MR4	X		
Mass Reduction - Level 5	MR5	X		
Low Rolling Resistance Tires - Level 1	ROLL1		X	
Low Rolling Resistance Tires - Level 2	ROLL2		X	
Low Rolling Resistance Tires - Level 3	ROLL3		X	
Low Drag Brakes	LDB		X	
Secondary Axle Disconnect	SAX		X	
Aero Drag Reduction, Level 1	AERO1		X	
Aero Drag Reduction, Level 2	AERO2	X		

Can the technology be applied to this vehicle? (division of vehicles into subclasses)

As part of its consideration of technological feasibility, the agency evaluates whether each technology could be implemented on all types and sizes of vehicles, and whether some differentiation is necessary in applying certain technologies to certain types and sizes of vehicles, and with respect to the cost incurred and fuel consumption and CO_2 emissions reduction achieved when doing so. The 2010 NAS Report differentiated technology application using eight vehicle "classes" (4 car classes and 4 truck classes).[204]NAS's purpose in separating vehicles into these classes was to create groups of "like" vehicles, *i.e.,* vehicles similar in size, powertrain configuration, weight, and consumer use, and for which similar technologies are applicable. NAS also used these vehicle classes along with powertrain configurations (*e.g.,* 4 cylinder, 6 cylinder or 8 cylinder engines) to determine unique cost and effectiveness estimates for each class of vehicles.

NHTSA similarly differentiates vehicles by "subclass" for the purpose of applying technologies to "like" vehicles and assessing their incremental costs and effectiveness. These technology subclasses should not be confused with the regulatory classifications pursuant to 49 CFR Part 523. NHTSA assigns each vehicle manufactured in the rulemaking period to one of 12 subclasses: for passenger cars, Subcompact, Subcompact Performance, Compact, Compact Performance, Midsize, Midsize Performance, Large, and Large Performance; and for light trucks, Small SUV/Pickup/Van, Midsize SUV/Pickup/Van, Large SUV/Pickup/Van, and Minivan. The agency sought comment on the appropriateness of these 12 subclasses for the MYs 2017-2025 timeframe. NHTSA did not receive any comments on this issue.

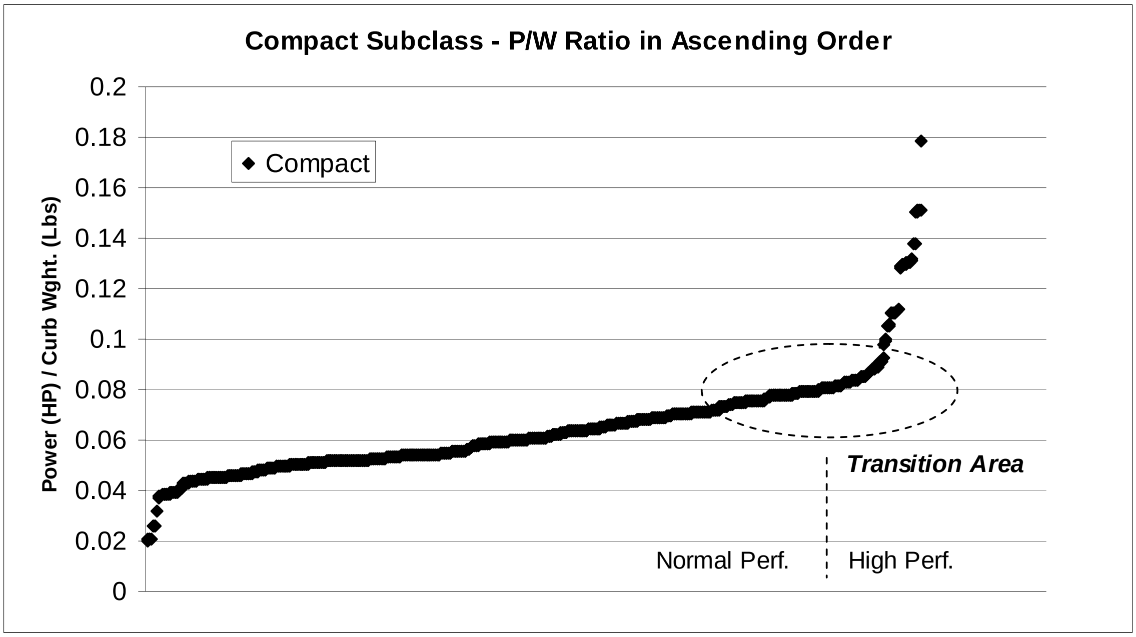
For this FRM, NHTSA divides the vehicle fleet into subclasses based on model inputs, and applies subclass-specific estimates, also from model inputs, of the applicability, cost, and effectiveness of each fuel-saving technology. The model's estimates of the cost to improve the fuel economy of each vehicle model thus depend upon the subclass to which the vehicle model is assigned. Each vehicle's subclass is stored in the market forecast file. When conducting a

[204] The NAS classes included two-seater convertibles and coupes; small cars; intermediate and large cars; high-performance sedans; unit-body standard trucks; unit-body high-performance trucks; body-on-frame small and midsize trucks; and body

compliance analysis, if the CAFE model seeks to apply technology to a particular vehicle, it checks the market forecast to see if the technology is available and if the refresh/redesign criteria are met. If these conditions are satisfied, the model determines the vehicle's subclass from the market data file, which it then uses to reference another input called the technology input file. NHTSA reviewed its methodology for dividing vehicles into subclasses for purposes of technology application that it used in the MY 2011 final rule and for the MYs 2012-2016 rulemaking, and concluded that the same methodology would be appropriate for this FRM for MYs 2017–2025. The methodology is as follows:

NHTSA examined the car and truck segments separately. First, for the car segment, NHTSA plotted the footprint distribution of vehicles in the baseline vehicle fleet and divided that distribution into four equivalent footprint range segments. The footprint ranges were named Subcompact, Compact, Midsize, and Large classes in ascending order. Cars were then assigned to one of these classes based on their specific footprint size. Vehicles in each range were then manually reviewed by NHTSA staff to evaluate and confirm that they represented a fairly reasonable homogeneity of size, weight, powertrains, consumer use, etc. However, each group contained some vehicles that were sports or high-performance models. Since different technologies and cost and effectiveness estimates may be appropriate for these type vehicles, NHTSA employed a performance subclass within each car subclass to maximize the accuracy of technology application. To determine which specific cars would be assigned to the performance subclasses, NHTSA graphed (in ascending rank order) the power-to-weight ratio for each vehicle in a subclass. An example of the Compact subclass plot is shown below in Figure V-32. The subpopulation was then manually reviewed by NHTSA staff to determine an appropriate transition point between "performance" and "non-performance" models within each class.

Figure V-32 Power/Weight Ratio for Compact Subclass



A total of eight classes (including performance subclasses) were identified for the car segment: Subcompact, Subcompact Performance, Compact, Compact Performance, Midsize, Midsize Performance, Large and Large Performance. In total, the number of cars that were ultimately assigned to a performance subclass was less than 10 percent. Table V-6 provides examples of the types of vehicles assigned to each car subclass.

Table V-13. Passenger Car Subclasses Example Vehicles

Class	Example vehicles
Subcompact	Chevrolet Aveo, Hyundai Accent
Subcompact Performance	Mazda MX-5, BMW Z4
Compact	Chevrolet Cobalt, Nissan Sentra and Altima
Compact Performance	Audi S4, Mazda RX8
Midsize	Chevrolet Impala, , Toyota Camry, Honda Accord, Hyundai Azera
Midsize Performance	Chevrolet Corvette, Ford Mustang (V8), Nissan 350Z
Large	Audi A8, Cadillac CTS and DTS
Large Performance	Bentley Arnage, Mercedes-Benz CL600

For light trucks, as in the MYs 2012-2016 final rule, NHTSA found less of a distinction in the anticipated vehicle fleet during the model years covered by the rulemaking between SUVs and pickup trucks than appeared to exist in earlier rulemakings. We anticipate fewer ladder-frame and more unibody pickups, and that many pickups will share common powertrains with SUVs. Thus, SUVs and pickups are grouped in the same subclasses. Additionally, it made sense to carry forward NHTSA's decision from the MYs 2012-2016 final rule to employ a separate minivan class, because minivans (*e.g.*, the Honda Odyssey) are more car-like and differ significantly in terms of structural and other engineering characteristics as compared to other vans (*e.g.*, Ford's E-Series—also known as Econoline—vans) intended for more passengers and/or heavier cargo and which are more truck-like.

Thus, the remaining vehicles (other vans, pickups, and SUVs) were then segregated into three footprint ranges and assigned a class of Small Truck/SUV, Midsize Truck/SUV, and Large Truck/SUV based on their footprints. NHTSA staff then manually reviewed each population for inconsistent vehicles based on engine cylinder count, weight (curb and/or gross), or intended usage, since these are important considerations for technology application, and reassigned vehicles to classes as appropriate. This system produced four truck segment subclasses—minivans and small, medium, and large SUVs/Pickups/Vans. Table V-14 provides examples of the types of vehicles assigned to each truck subclass.

Table V-14. Light Truck Subclasses Example Vehicles

Class	Example vehicles
Minivans	Dodge Grand Caravan, Toyota Sienna
Small SUV/Pickup/Van	Ford Escape & Ranger, Nissan Rogue
Midsize SUV/Pickup/Van	Chevrolet Colorado, Jeep Wrangler, Toyota Tacoma

Large SUV/Pickup/Van	Chevrolet Silverado, Ford E-Series, Toyota Sequoia

As mentioned above, NHTSA employed this method for assigning vehicle subclasses for this final rule after reviewing the process used in the MYs 2012-2016 final rule and concluding that it continued to be a reasonable approach for purposes of this rulemaking. NHTSA believes that this method continues to substantially improve the overall accuracy of the results as compared to systems employed previously, due to the close manual review by NHTSA staff to ensure proper assignments, the use of performance subclasses in the car segment, and the condensing of subclasses in the truck segment, all of which further refine the system without overly complicating the CAFE modeling process. Nevertheless, NHTSA invites comments on the method of assigning vehicles to subclasses for the purposes of technology application in the CAFE model, and on the issue of technology-application subclasses generally. The agency is also seeking comment on the continued appropriateness of maintaining separate "performance" vehicle classes or if as fuel economy stringency increases the market for performance vehicles will decrease. NHTSA did not receive any comments on these issues.

We note that EPA uses different classifications in its Lumped Parameter Model (LPM), OMEGA model, and cost analysis. Because the LPM uses only 6 vehicle classes, and because NHTSA relied on EPA's technology effectiveness estimates obtained through the LPM analysis for this rulemaking in the interest of harmonization, NHTSA needed to map its 12 vehicle subclasses into the LPM's 6 vehicle classes for purposes of developing subclass-specific technology effectiveness estimates. Table V-15 shows how NHTSA's vehicle classification lines up with EPA's classifications for purposes of developing the joint cost and effectiveness estimates.

Table V-15 Mapping between NHTSA and EPA Vehicle Classifications

NHTSA/CAFE model Classification	EPA Vehicle Class for Cost Purpose	EPA Lumped Parameter Model Classification	Example
Subcompact Subcompact Perf PC	Subcompact/Small Car	Small Car	Yaris
Compact Compact Perf PC			
Midsize PC Midsize Perf PC	Standard Car	Standard Car	Camry
Large PC Large Perf PC	Large Car	Large Car	Chrysler 300
Small LT	Small MPV	Small MPV	Saturn Vue
Midsize LT	Large MPV	Large MPV	Dodge Grand Caravan
Minivan LT			
Large LT	Truck	Truck	Ford F150

How much of the technology can be applied to the fleet this year? (phase-in caps)

Besides the refresh/redesign cycles used in the CAFE model, which constrain the rate of technology application at the vehicle level so as to ensure a period of stability following any modeled technology applications, the other constraint on technology application employed in NHTSA's analysis is "phase-in caps." Unlike vehicle-level cycle settings, phase-in caps constrain technology application at the vehicle manufacturer level.[205] Phase-in caps are intended to function as a proxy for a number of real-world limitations in deploying new technologies in the auto industry. These limitations can include, but are not intended to be limited to, engineering resources at the OEM or supplier level, financial resources, restrictions on intellectual property that limit deployment, and/or limitations in material or component supply as

[205] While phase-in caps are expressed as specific percentages of a manufacturer's fleet to which a technology may be applied in a given model year, phase-in caps cannot always be applied as precise limits, and the CAFE model in fact allows "override" of a cap in certain circumstances. When only a small portion of a phase-in cap limit remains, or when the cap is set to a very low value, or when a manufacturer has a very limited product line, the cap might prevent the technology from being applied at all since any application would cause the cap to be exceeded. Therefore, the CAFE model evaluates and enforces each phase-in cap constraint after it has been exceeded by the application of the technology (as opposed to evaluating it before application), which can result in the described overriding of the cap.

a market for a new technology develops. The inclusion of phase-in caps helps to ensure that resource capacity and other limitations are accounted for in the modeling process. At a high level, phase-in caps, refresh/redesign cycles and the logic of the model itself work in conjunction with one another to avoid the modeling process out-pacing an OEM's limited pool of available resources during the rulemaking time frame and the years leading up to the rulemaking time frame, especially in years where many models may be scheduled for refresh or redesign. We emphasize that phase-in caps are not used to prescribe technology application rates; to NHTSA, phase-in caps represent the maximum amount of technology that the industry could apply in a given year recognizing the limitations described above. Phase-in caps, in combination with other constraints, thus help to ensure technological feasibility and economic practicability in determining the stringency of the standards. Despite the available lead time, these constraints remain important for this round of rulemaking: even though this rulemaking is being proposed 5 years before it takes effect, OEM's will still be utilizing their limited resources to meet the MYs 2012-2016 CAFE standards.

NHTSA has been developing the concept of phase-in caps for purposes of the agency's modeling analysis over the course of the last several CAFE rulemakings, as discussed in greater detail in the MY 2011 final rule, in the MY 2012-2016 final rule and Chapter 3 of the Joint TSD. The MYs 2012-2016 final rule, like the MY 2011 final rule, employed non-linear phase-in caps (that is, caps that varied from year to year) that were designed to respond to previously received comments on technology deployment.

For purposes of this FRM, as in the MY 2011 and MYs 2012-2016 final rules, NHTSA combines phase-in caps for some groups of similar technologies, such as valve phasing technologies that are applicable to different forms of engine design (SOHC, DOHC, OHV), since they are very similar from an engineering and implementation standpoint. When the phase-in caps for two technologies are combined, the maximum total application of either or both to any manufacturer's fleet is limited to the value of the cap.[206]

In developing phase-in cap values for purposes of this FRM, NHTSA reviewed the MYs 2012-2016 final rule's phase-in caps, which for the majority of technologies were set to reach 85 or 100 percent by MY 2016, although more advanced technologies like diesels and strong hybrids reached only 15 percent by MY 2016. The phase-in caps used in the MYs 2012-2016 final rule were developed to harmonize with the similar caps used in EPA's modeling, and reflected the fact that manufacturers, as part of the agreements supporting the National Program, appeared to be anticipating higher technology application rates than assumed by NHTSA in prior rulemaking analyses. NHTSA determined that these phase-in caps for MY 2016 were still reasonable and

[206] *See* 74 FR at 14270 (Mar. 30, 2009) for further discussion and examples.

thus used those caps as the starting point for the MYs 2017-2025 phase-in caps. For many of the carryover technologies, this means that for MYs 2017-2025 the phase-in caps are assumed to be 100 percent. For the phase-in caps for the newly defined technologies that will be entering the market just before or during the MYs 2017-2025 time frame, as discussed in more detail in Chapter 3 of the Joint TSD, NHTSA, along with EPA, used confidential OEM submissions, trade press articles, company publications and press releases to estimate their values using engineering judgment,. For example, advanced cooled EGR engines are assigned a phase-in cap of 3 percent per year through MY 2021, and then 10 percent per year through 2025. The agency sought comment on the appropriateness of both the carryover phase-in caps and the newly defined ones proposed in the NPRM. The American Fuel and Petrochemical Manufacturers (AFPM) commented on their belief that the projections of electrification penetration were too high. They believed that the problem could be corrected by using smaller phase-in cap values for these technologies. They also commented that the phase-in caps were arbitrary and that the agencies should switch to using a consumer choice model. Additionally, NHTSA's analysis shows that automakers can have low applications of strong hybrid, plug-in hybrid, and electric vehicle technologies, well under the phase-in caps, and still comply with the standards.

Table V-16 shows phase-in rates, on a year-by-year basis, for the technologies used in the CAFE model for this FRM analysis. Most technologies are available at a rate of either 85 percent or 100 percent beginning in 2016. Some advanced technologies expected to enter the market in the near future, such as EGR Boost, follow a 3 percent annual cap increase from 2016 to 2021, and then approximately 10 percent from 2021 to 2025. Diesels follow an annual 3 percent increase in phase-in cap through 2025. Hybrids follow a 3 percent annual increase from 2016 to 2012, then 5 percent from 2021 to 2015. PHEVs and EVs follow a 1 percent annual cap increase.

Lower phase-in caps for Alternative Fueled Vehicles (AFVs) reflect additional investment in infrastructure that is required to achieve high levels of conversion to a new fuel type. These limited phase-in caps also reflect as-yet-unknown consumer responses to HEVs, PHEVs and BEVs.

Table V-16. Phase-in Caps for Technologies Used in 2017+ FRM Analysis for CAFE Model

Technology	Abbr.	MY 2009	MY 2010	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015	MY 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Low Friction Lubricants - Level 1	LUB1	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Engine Friction Reduction - Level 1	EFR1	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	0%	0%	0%	0%	0%	0%	12%	24%	36%	48%	60%	72%	84%	96%	100%
Variable Valve Timing (VVT) - CCP on SOHC	CCPS	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Cylinder Deactivation on SOHC	DEACS	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Cylinder Deactivation on DOHC	DEACD	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Cylinder Deactivation on OHV	DEACO	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - SD	TRBDS1_SD	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - MD	TRBDS1_MD	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - LD	TRBDS1_LD	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - SD	TRBDS2_SD	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	45%	60%	75%	75%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - MD	TRBDS2_MD	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	45%	60%	75%	75%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - LD	TRBDS2_LD	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	45%	60%	75%	75%
CEGR- Level 1 (24 bar BMEP) – SD	CEGR1_SD	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	45%	60%	75%	75%
CEGR - Level 1 (24 bar BMEP) – MD	CEGR1_MD	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	45%	60%	75%	75%
CEGR - Level 1 (24 bar BMEP) – LD	CEGR1_LD	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	45%	60%	75%	75%
CEGR - Level 2 (27 bar BMEP) – SD	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	3%	6%	9%	12%	15%	25%	35%	45%	50%
CEGR - Level 2 (27 bar BMEP) – MD	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	3%	6%	9%	12%	15%	25%	35%	45%	50%
CEGR - Level 2 (27 bar BMEP) – LD	CEGR2_LD	0%	0%	0%	0%	0%	0%	0%	0%	3%	6%	9%	12%	15%	25%	35%	45%	50%
Advanced Diesel - Small	ADSL_SD	0%	0%	0%	0%	3%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%

Displacement																		
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	3%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	3%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%	6%
6-Speed Manual/Improved Internals	6MAN	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	0%	0%	0%	0%	0%	12%	24%	36%	48%	60%	72%	84%	96%	100%
Improved Auto. Trans. Controls/Externals	IATC	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
6-Speed Trans with Improved Internals (Auto)	NAUTO	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
6-speed DCT	DCT	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
8-Speed Trans (Auto or DCT)	8SPD	0%	0%	0%	0%	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%
High Efficiency Gearbox (Auto or DCT)	HETRANS	0%	0%	0%	0%	0%	0%	0%	0%	12%	24%	36%	48%	60%	72%	84%	96%	100%
Shift Optimizer	SHFTOPT	0%	0%	0%	0%	0%	0%	0%	0%	20%	40%	60%	80%	100%	100%	100%	100%	100%
Electric Power Steering	EPS	5%	20%	35%	50%	65%	80%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Improved Accessories - Level 1	IACC1	5%	20%	35%	50%	65%	80%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Improved Accessories - Level 2	IACC2	0%	0%	0%	0%	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%
12V Micro-Hybrid (Stop-Start)	MHEV	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Integrated Starter Generator	ISG	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	35%	40%	45%	50%
Strong Hybrid - Level 1	SHEV1	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	35%	40%	45%	50%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	35%	40%	45%	50%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	3%	6%	9%	12%	15%	18%	21%	24%	27%	30%	35%	40%	45%	50%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%
Plug-in Hybrid	PHEV2	0%	0%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%	11%	12%	13%	14%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	1%	2%	3%	4%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	1%	2%	3%	4%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	1%	2%	3%	4%	5%	5%	5%	5%	5%	5%	5%	5%	5%	5%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	1%	2%	3%	4%	5%	6%	7%	8%	9%	10%
Mass Reduction - Level 1	MR1	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Mass Reduction - Level 2	MR2	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Mass Reduction - Level 3	MR3	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Mass Reduction - Level 4	MR4	0%	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%	100%	100%	100%
Mass Reduction - Level 5	MR5	0%	0%	0%	0%	0%	0%	0%	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%
Low Rolling Resistance Tires - Level 1	ROLL1	20%	35%	50%	65%	80%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	0%	0%	0%	0%	0%	0%	15%	30%	45%	60%	75%	90%	100%	100%	100%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	20%	35%	50%	65%	80%	95%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Secondary Axle Disconnect	SAX	15%	25%	35%	45%	55%	65%	75%	85%	95%	100%	100%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 1	AERO1	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%	100%	100%	100%	100%	100%	100%	100%

Once the technology is applied, how much does it improve fuel economy? (effectiveness estimates)

In the MYs 2012-2016 final rule, NHTSA and EPA based technology effectiveness estimates on two primary sources: NHTSA's 2011 final rule, which was supported by recommendations from Ricardo, Inc. under contract to NHTSA; and EPA's 2008 Staff Technical Report,[207],which was supported by vehicle simulation modeling performed by Ricardo in 2007.
EPA built upon its 2008vehicle simulation work by again hiring Ricardo to perform additional vehicle simulation modeling that could be used to derive the effectiveness estimates for this final rule. Ricardo used its proprietary dynamic vehicle simulation model, which they developed and implemented in MSC.EASY5™, for this simulation work. MSC.EASY5™ is a commercially available software package used in industry for vehicle system analysis. In the current study, Ricardo has expanded the technology list previously modeled and included the following new engine and vehicle technologies:

- Advanced, highly downsized, high BMEP turbocharged engine
- High efficiency 8-speed automatic and DCT transmission
- Optimized shift schedule to achieve best Brake Specific Fuel Consumption (BSFC)
- Atkinson-cycle engines for hybrid vehicles

The new analysis also includes modeling of the following hybrid architectures used in the FRM analysis:

- Stop-start technology
- P2 hybrid

Detailed information about Ricardo's work for this project can be found at Docket No, NHTSA-2010-0131, and also in Section 3.2.1 of Chapter 3 of the joint TSD.
Because the Ricardo findings are for predefined packages/combinations of technologies, the agencies needed a way to extract the individual effectiveness for each technology in order to be able to apply them one at a time or create different packages/combinations of technologies. To that end, EPA used the new Ricardo results to calibrate and update EPA's Lumped Parameter Model (LPM), available at Docket No. NHTSA 2010-0131.The lumped parameter tool is a spreadsheet model used to develop the technology effectiveness estimates for this FRM analysis. The LPM represents energy consumption in terms of average performance over the fuel economy test procedure, rather than explicitly analyzing specific drive cycles. The tool begins with an apportionment of fuel consumption across several loss mechanisms and accounts for the average extent to which different technologies affect these loss mechanisms using estimates of

[207] EPA Staff Technical Report: Cost and Effectiveness Estimates of Technologies Used to Reduce Light-Duty Vehicle Carbon Dioxide Emissions. EPA420-R-08-008, March 2008. (Docket NHTSA-2010-0131)

engine, drivetrain and vehicle characteristics that are averaged over the EPA fuel economy drive cycle.

As part of the calibration/updating process, EPA adjusted the LPM inputs to ensure that the results closely aligned with those of the Ricardo work. Thus the results of this analysis using the LPM were generally consistent with Ricardo's most recent full-scale vehicle simulation modeling.[208] Detailed information about how the LPM works and how EPA used it to develop technology effectiveness values for this analysis can be found in Chapter 3 of the joint TSD.

The technology effectiveness inputs used in the CAFE model for this analysis are based on entirely on the outputs of the newly updated LPM, and thus incorporate the Ricardo simulation work from 2007 and 2011. Table V-17 to Table V-27 below define how NHTSA mapped technology effectiveness calculations from the LPM into CAFE model-specific inputs. The LPM defines technologies specific to EPA's OMEGA model so NHTSA had to create a process of mapping technologies in the LPM that are consistent with those found in the CAFE model's decision trees. For example, to generate the effectiveness for the Improved Automatic Transmission Controls/Externals (IATC) NHTSA had to enable both "Early Upshift" and "Aggressive Torque Converter Lockup" in the LPM. NHTSA used this mapping technique to calculate the absolute effectiveness of each technology relative to a baseline vehicle. NHTSA then used these absolute effectiveness estimates, for each step in the decision trees, to calculate the incremental effectiveness estimates for each technology, which is what the CAFE model ultimately needs to analyze a heterogeneous fleet baseline fleet on a model year by model year basis.

Table V-17. CAFE Model and LPM Mapping for Engine Technologies (non-Valvetrain Dependent Engine Technologies)

NHTSA Techs	LPM Selection	
Model Years	**2012-2016**	**2017+**
LUB1	Low Fric Lubes	Low Fric Lubes
EFR1	Low Fric Lubes EF Reduction (Level=1)	Low Fric Lubes EF Reduction (Level=1)
LUB2_EFR2		EF Reduction (Level=2)

[208] Regardless of a generally consistent set of results for the vehicle class and set of technologies studied, the lumped parameter tool is not a full vehicle simulation and cannot replicate the physics of such a simulation.

Table V-18. CAFE Model and LPM Mapping for Engine Technologies

(SOHC Path)

NHTSA Techs	LPM Selection	
Model Years	**2012-2016**	**2017+**
SOHC Path		
CCPS	Low Fric Lubes EF Reduction (Level=1) CCP	EF Reduction (Level=2) CCP
DVVLS	Low Fric Lubes EF Reduction (Level=1) CCP DVVL	EF Reduction (Level=2) CCP DVVL
DEACS	Low Fric Lubes EF Reduction (Level=1) CCP DEAC	EF Reduction (Level=2) CCP DEAC
SGDI	Low Fric Lubes EF Reduction (Level=1) CCP DEAC GDI (stoich)	EF Reduction (Level=2) CCP DEAC GDI (stoich)
TRBDS1 18bar	Low Fric Lubes EF Reduction (Level=1) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=33%)	EF Reduction (Level=2) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=33%)
TRBDS2 24bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=50%)
CEGR1 24bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) w/ cooled EGR Turbo/Downsize (gas engines only) (Percent=50%)
CEGR2 27bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) w/ cooled EGR Turbo/Downsize (gas engines only) (Percent=56%)
Adv Diesel		Advanced Diesel (2020)

Table V-19. CAFE Model and LPM Mapping for Engine Technologies (DOHC DVVL Path)

NHTSA Techs	LPM Selection	
Model Years	**2012-2016**	**2017+**
DOHC DVVL Path		
ICP	Low Fric Lubes EF Reduction (Level=1) ICP	EF Reduction (Level=2) ICP
DCP	Low Fric Lubes EF Reduction (Level=1) DCP	EF Reduction (Level=2) DCP
DVVLD	Low Fric Lubes EF Reduction (Level=1) DCP DVVL	EF Reduction (Level=2) DCP DVVL
DEACD	Low Fric Lubes EF Reduction (Level=1) DCP DEAC	EF Reduction (Level=2) DCP DEAC
SGDI	Low Fric Lubes EF Reduction (Level=1) DCP DEAC GDI (stoich)	EF Reduction (Level=2) DCP DEAC GDI (stoich)
TRBDS1 18bar	Low Fric Lubes EF Reduction (Level=1) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=33%)	EF Reduction (Level=2) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=33%)
TRBDS2 24bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=50%)
CEGR1 24bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) w/ cooled EGR Turbo/Downsize (gas engines only) (Percent=50%)
CEGR2 27bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) w/ cooled EGR Turbo/Downsize (gas engines only) (Percent=56%)
Adv Diesel		Advanced Diesel (2020)

Table V-20. CAFE Model and LPM Mapping for Engine Technologies (DOHC CVVL Path)

NHTSA Techs	LPM Selection	
Model Years	**2012-2016**	**2017+**
DOHC CVVL Path		
CVVL	Low Fric Lubes EF Reduction (Level=1) DCP CVVL	EF Reduction (Level=2) DCP CVVL
DEACD	This is ignored because effectiveness is less than CVVL	
SGDI	Low Fric Lubes EF Reduction (Level=1) DCP CVVL GDI (stoich)	EF Reduction (Level=2) DCP CVVL GDI (stoich)
TRBDS1 18bar	Low Fric Lubes EF Reduction (Level=1) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=33%)	EF Reduction (Level=2) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=33%)
TRBDS2 24bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=50%)
CEGR1 24bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) w/ cooled EGR Turbo/Downsize (gas engines only) (Percent=50%)
CEGR2 27bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) w/ cooled EGR Turbo/Downsize (gas engines only) (Percent=56%)
Adv Diesel		Advanced Diesel (2020)

Table V-21. CAFE Model and LPM Mapping for Engine Technologies (OHV Path)

NHTSA Techs	LPM Selection	
Model Years	**2012-2016**	**2017+**
OHV Path		
DEACO	Low Fric Lubes EF Reduction (Level=1) DEAC	EF Reduction (Level=2) DEAC
VVA	Low Fric Lubes EF Reduction (Level=1) CCP DEACO	EF Reduction (Level=2) CCP DEACO
SGDI	Low Fric Lubes EF Reduction (Level=1) CCP DEACO GDI (stoich)	EF Reduction (Level=2) CCP DEACO GDI (stoich)
TRBDS1 18bar	Low Fric Lubes EF Reduction (Level=1) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=33%)	EF Reduction (Level=2) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=33%)
TRBDS2 24bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) Turbo/Downsize (gas engines only) (Percent=50%)
CEGR1 24bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) w/ cooled EGR Turbo/Downsize (gas engines only) (Percent=50%)
CEGR2 27bar		EF Reduction (Level=2) DCP DVVL GDI (stoich) w/ cooled EGR Turbo/Downsize (gas engines only) (Percent=56%)
Adv Diesel		Advanced Diesel (2020)

Table V-22. CAFE Model and LPM Mapping for Transmission Technologies

<u>**NHTSA Techs**</u>	<u>**LPM Selection**</u>	
Model Years	**2012-2016**	**2017+**
IATC	Early upshift (formerly ASL) Agg TC Lockup	Early upshift (formerly ASL) Agg TC Lockup
Baseline for the following technologies is 5-speed automatic transmission		
NAUTO	6-spd gearbox Early upshift (formerly ASL) Agg TC Lockup High efficiency gear box (auto) (Percent= 7%)	6-spd gearbox Early upshift (formerly ASL) Agg TC Lockup High efficiency gear box (auto) (Percent= 7%)
DCT (Dry)	6-spd gearbox DCT Dry Early upshift (formerly ASL) High efficiency gear box (auto) (Percent= 7%)	6-spd gearbox DCT Dry Early upshift (formerly ASL) High efficiency gear box (auto) (Percent= 7%)
DCT (Wet)	6-spd gearbox DCT Wet Early upshift (formerly ASL) High efficiency gear box (auto) (Percent= 7%)	6-spd gearbox DCT Wet Early upshift (formerly ASL) High efficiency gear box (auto) (Percent= 7%)
8 SPD (Auto)		8-spd gearbox Early upshift (formerly ASL) High efficiency gear box (auto) (Percent= 7%)
8 SPD (Dry DCT)		8-spd gearbox DCT Dry Early upshift (formerly ASL) High efficiency gear box (auto) (Percent= 7%)
8 SPD (Wet DCT)		8-spd gearbox DCT Wet Early upshift (formerly ASL) High efficiency gear box (auto) (Percent= 7%)
HETRANS		*(Additional Selection over previous selection)* High efficiency gear box (auto) (Percent= 25%)
SHIFTOPT		*(Additional Selection over previous selection)* Optimized shift strategy*

<u>**Notes**</u>
* Make sure "Early upshift (formerly ASL)" is turned off.

Table V-23. CAFE Model and LPM Mapping for Accessory Technologies

NHTSA Techs	LPM Selection
EPS	EPS
IACC1	EPS Electric access (12v) High eff alternator (70%)
IACC2	EPS Electric access (12v) High eff alternator (70%) Alternator regen on braking
MHEV (12v SS)	EPS Electric access (12v) High eff alternator (70%) Alternator regen on braking 12V SS (idle off only)
ISG	EPS 6-spd AT Electric access (high V) Hybrid drivetrain (15 kW motor)[a]

[a]Motor size is adjusted to 10 kW for small cars and 18 kW for pickup trucks

Table V-24. CAFE Model and LPM Mapping for Strong Hybrid Technologies (MY2012-2016 Technologies)

SHEV1 (non-towing) (subcompact PC, compact PC with dry DCT)		SHEV1 (non-towing) (midsize PC, large PC, small LT with wet DCT)		SHEV1 (towing)* (Midsize LT, Minivan and Large LT with ATX)	
	% or Level		*% or Level*		*% or Level*
Low Fric Lubes		Low Fric Lubes		Low Fric Lubes	
EF Reduction	1	EF Reduction	1	EF Reduction	1
DCP		DCP		DCP	
DVVL		DVVL		DVVL	
				Turbo/Downsize (gas engines only)	35%
6-spd gearbox		6-spd gearbox		6-spd gearbox	
DCT Dry		DCT Wet			
Early upshift (formerly ASL)		Early upshift (formerly ASL)		Early upshift (formerly ASL)	
				Agg TC Lockup	
High efficiency gearbox (auto)	7%	High efficiency gearbox (auto)	7%	High efficiency gearbox (auto)	7%
EPS		EPS		EPS	
Electric access (12V)		Electric access (12V)		Electric access (12V)	
High efficiency alternator (70%)		High efficiency alternator (70%)		High efficiency alternator (70%)	
GDI (stoich)		GDI (stoich)		GDI (stoich)	

	Motor kW		*Motor kW*		*Motor kW*
Hybrid drivetrain	17	Hybrid drivetrain	24	Hybrid drivetrain	36
Atkinson cycle engine		Atkinson cycle engine			

Notes
*Vehicle with towing will have automatic transmission and non-Atkinson cycle engine with downsizing.

Table V-25. CAFE Model and LPM Mapping for Strong Hybrid Technologies (MY2017+ Technologies)

SHEV2 (non-towing) (subcompact PC, compact PC with dry DCT)		SHEV2 (non-towing) (midsize PC, large PC, small LT with wet DCT)		SHEV2 (towing)* (Midsize LT, Minivan and Large LT with ATX)	
	% or Level		*% or Level*		*% or Level*
EF Reduction	2	EF Reduction	2	EF Reduction	2
DCP		DCP		DCP	
DVVL		DVVL		DVVL	
				Turbo/Downsize (gas engines only)	48%
8-spd gearbox		8-spd gearbox		8-spd gearbox	
DCT Dry		DCT Wet			
Optimized shift strategy		Optimized shift strategy		Optimized shift strategy	
				Agg TC Lockup	
High efficiency gearbox (auto)	25%	High efficiency gearbox (auto)	25%	High efficiency gearbox (auto)	25%
Alternator regen on braking		Alternator regen on braking		Alternator regen on braking	
EPS		EPS		EPS	
Electric access (12V)		Electric access (12V)		Electric access (12V)	
High efficiency alternator (70%)		High efficiency alternator (70%)		High efficiency alternator (70%)	
GDI (stoich)		GDI (stoich)		GDI (stoich)	
	Motor kW		*Motor kW*		*Motor kW*
Hybrid drivetrain	17	Hybrid drivetrain	24	Hybrid drivetrain	36
Atkinson cycle engine		Atkinson cycle engine			

Notes

*Vehicle with towing will have automatic transmission and non-Atkinson cycle engine with downsizing.

Table V-26. CAFE Model and LPM Mapping for Plug-in Hybrid Technologies (20-Mile Range)

PHEV 20 Mile (subcompact PC, compact PC with dry DCT)		PHEV 20 Mile (midsize PC, large PC, small LT with wet DCT)	
	% or Level		*% or Level*
EF Reduction	**2**	EF Reduction	2
DCP		DCP	
DVVL		DVVL	
8-spd gearbox		8-spd gearbox	
DCT Dry		DCT Wet	
Optimized shift strategy		Optimized shift strategy	
High efficiency gearbox (auto)	**25%**	High efficiency gearbox (auto)	25%
Alternator regen on braking		Alternator regen on braking	
EPS	**100%**	EPS	100%
Electric access (12V)		Electric access (12V)	
High efficiency alternator (70%)		High efficiency alternator (70%)	
GDI (stoich)		GDI (stoich)	

	Motor kW		*Motor kW*
Hybrid drivetrain	**30**	Hybrid drivetrain	30
Atkinson cycle engine		Atkinson cycle engine	
Plug-In	**40%**	Plug-In	40%

Table V-27. CAFE Model and LPM Mapping for Plug-in Hybrid Technologies (40-Mile Range)

PHEV 40 Mile (subcompact PC, compact PC with dry DCT)		PHEV 40 Mile (midsize PC, large PC, small LT with wet DCT)	
	% or Level		*% or Level*
EF Reduction	2	EF Reduction	2
DCP		DCP	
DVVL		DVVL	
8-spd gearbox		8-spd gearbox	
DCT Dry		DCT Wet	
Optimized shift strategy		Optimized shift strategy	
High efficiency gearbox (auto)	25%	High efficiency gearbox (auto)	25%
Alternator regen on braking		Alternator regen on braking	
EPS	100%	EPS	100%
Electric access (12V)		Electric access (12V)	
High efficiency alternator (70%)		High efficiency alternator (70%)	
GDI (stoich)		GDI (stoich)	
	Motor kW		*Motor kW*
Hybrid drivetrain	30	Hybrid drivetrain	30
Atkinson cycle engine		Atkinson cycle engine	
Plug-In	63%	Plug-In	63%

We note that the U.S. D.O.T. Volpe Center, which supports NHTSA in its CAFE rulemaking work, contracted with Argonne National Laboratory (ANL) to provide full vehicle simulation modeling support for this MYs 2017-2025 rulemaking. While modeling was not completed in time for use in the NPRM, NHTSA used this modeling to update technology effectiveness estimates and synergy factors as appropriate for the CAFE model for the final rulemaking analysis. Specifically, the results were used to define the effectiveness of mild hybrids for both agencies, and NHTSA used the results to update the effectiveness of advanced transmission technologies coupled with naturally-aspirated engines for the CAFE analysis This simulation modeling was accomplished using ANL's full vehicle simulation tool called "Autonomie," which is the successor to ANL's Powertrain System Analysis Toolkit (PSAT) simulation tool, and that includes sophisticated models for advanced vehicle technologies. The ANL simulation modeling process and results are documented in multiple reports that can be found in NHTSA's docket.[209]

[209] Docket No: NHTSA-2010-0131

ANL modeled the results for five vehicle classes. In order to incorporate ANL's results into the CAFE model, these 5 vehicles classes needed to be mapped to the CAFE model's 12 vehicle classes. Table V-28describes the mapping of ANL's 5 vehicle classes to NHTSA's 12 vehicle classes.

Table V-28. Mapping between ANL and NHTSA Vehicle Classifications

ANL Vehicle Classification	NHTSA/CAFE Model Vehicle Classification
Compact Car	Subcompact PC Subcompact Perf. PC Compact PC Compact Perf. PC
Midsize Car	Midsize PC Midsize Perf. PC Large PC Large Perf. PC
Small SUV	Small LT
Midsize SUV	Minivan LT Midsize LT
Pickup	Large LT

Table V-29(a) and (b) show the ANL results for advanced transmission technologies when coupled to naturally aspirated engines. As discussed in greater detail below in the synergies section, these results were used to adjust the effectiveness of advanced transmission technologies when coupled to naturally aspirated engines.

Table V-29a. ANL Results for Transmission Technologies

Technology	Period		Compact (%)	Midsize Car (%)	Small SUV (%)
Imp. Auto Trans Cnrt./ Externals (IATC) - TBL	2012-2016	INC	0.9%	1.4%	1.1%
		ABS	0.9%	1.4%	1.1%
	2017+	INC	0.9%	1.4%	1.1%
		ABS	0.9%	1.4%	1.1%
6-spd Auto Trans w/Imp Internals (NAUTO) - TBL	2012-2016	INC	2.0%	0.8%	1.2%
		ABS	2.9%	2.2%	2.2%
	2017+	INC	2.0%	0.8%	1.2%
		ABS	2.9%	2.2%	2.2%
6-spd Dual Clutch Trans (DCT) - TBL	2012-2016	INC	3.9%	3.7%	2.2%
		ABS	6.7%	5.8%	4.3%
	2017+	INC	3.9%	3.7%	2.2%
		ABS	6.7%	5.8%	4.3%
8-spd Trans (DCT) (8SPD) - TBL	2012-2016	INC	1.9%	2.1%	1.5%
		ABS	8.4%	7.8%	5.8%
	2017+	INC	1.9%	2.1%	1.5%
		ABS	8.4%	7.8%	5.8%
High Eff. Gearbox (+4%) (DCT)	2012-2016	INC	2.7%	2.8%	2.8%
		ABS	11.0%	10.3%	8.5%
	2017+	INC	2.7%	2.8%	2.8%
		ABS	11.0%	10.3%	8.5%

Table V-29Table V-29b. ANL Results for Transmission Technologies

Midsize SUV

2012-2016	INC	%	1.4%	$		
	ABS	%	1.4%	$		
		Imp. Auto Trans Cnrt./ Externals (IATC) - TBL				
2017+	INC	%	1.4%	$		
	ABS	%	1.4%	$		
2012-2016	INC	%	0.7%	$		
	ABS	%	2.1%	$		
		6-spd Auto Trans w/Imp Internals (NAUTO) - TBL				
2017+	INC	%	0.7%	$		
	ABS	%	2.1%	$		
2012-2016	INC	%	1.0%	$		
	ABS	%	3.1%	$		
		8-spd Auto Trans (Auto) (8SPD) - TBL				
2017+	INC	%	1.0%	$		
	ABS	%	3.1%	$		
2012-2016	INC	%	2.5%	$		
	ABS	%	5.5%	$		
		High Eff. Gearbox (+4%) (Auto) - (HETRANS) TBL				
2017+	INC	%	2.5%	$		
	ABS	%	5.5%	$		

Pickup

2012-2016	INC	%	1.6%	$		
	ABS	%	1.6%	$		
		Imp. Auto Trans Cnrt./ Externals (IATC) - TBL				
2017+	INC	%	1.6%	$		
	ABS	%	1.6%	$		
2012-2016	INC	%	0.4%	$		
	ABS	%	2.1%	$		
		6-spd Auto Trans w/Imp Internals (NAUTO) - TBL				
2017+	INC	%	0.4%	$		
	ABS	%	2.1%	$		
2012-2016	INC	%	1.5%	$		
	ABS	%	3.5%	$		
		8-spd Auto Trans (Auto) (8SPD) - TBL				
2017+	INC	%	1.5%	$		
	ABS	%	3.5%	$		
2012-2016	INC	%	2.9%	$		
	ABS	%	6.3%	$		
		High Eff. Gearbox (+4%) (Auto) - (HETRANS) TBL				
2017+	INC	%	2.9%	$		
	ABS	%	6.3%	$		

Synergies

When two or more technologies are added to a particular vehicle model to improve its fuel efficiency, the resultant fuel consumption reduction may sometimes be higher or lower than the product of the individual effectiveness values for those items.[210] This may occur because one or

[210] More specifically, the resultant is calculated as the products of the differences between the numeric value one (i.e., 1.0) and the technology-specific levels of effectiveness in reducing fuel consumption (expressed as a numeric value also, i.e., 10% = 0.10). For example, not accounting for interactions, if technologies A and B are estimated to reduce fuel consumption by 10% (i.e., 0.1) and 20% (i.e., 0.2) respectively, the "product of the individual effectiveness values" would be (1 – 0.1) times (1 – 0.2), or 0.9 times 0.8, which equals 0.72, corresponding to a

more technologies applied to the same vehicle partially address the same source (or sources) of engine, drivetrain or vehicle losses. Alternately, this effect may be seen when one technology shifts the engine operating points, and therefore increases or reduces the fuel consumption reduction achieved by another technology or set of technologies. The difference between the observed fuel consumption reduction associated with a set of technologies and the product of the individual effectiveness values in that set is referred to as a "synergy." Synergies may be positive (and thus result in greater fuel consumption reduction compared to the product of the individual effects) or negative (and thus result in less fuel consumption reduction). An example of a positive synergy might be a vehicle technology that reduces road loads at highway speeds (*e.g.*, lower aerodynamic drag or low rolling resistance tires), that could effectively extend the vehicle operating range over which cylinder deactivation may be employed, thus allowing a greater fuel consumption reduction than anticipated or predicted by analysis. An example of a negative synergy might be a variable valvetrain technology, which reduces pumping losses by altering the profile of the engine speed/load map, and a six-speed automatic transmission, which shifts the engine operating points to a portion of the engine speed/load map where pumping losses are less significant, leaving less opportunity for the combined technologies to decrease fuel consumption. As the complexity of the technology combinations is increased, and the number of interacting technologies grows accordingly, it becomes increasingly important to account for these synergies.

Because NHTSA applies technologies individually in its modeling analysis, NHTSA incorporates synergistic effects between pairings of individual technologies. The use of discrete technology pair incremental synergies is similar to that in DOE's National Energy Modeling System (NEMS).[211] Inputs to the CAFE model incorporate NEMS-identified pairs, as well as additional pairs from the specific set of technologies considered in the CAFE model. For the MYs 2012-2016 final rule and the MY 2011 final rule NHTSA used a modified version of the lumped parameter tool to evaluate accurate synergy values. During the 2011 final rule analysis, with the assistance of Ricardo, NHTSA modified the lumped parameter tool by updating the list of technologies and their associated effectiveness values, and expanding the list of synergy pairings based on further consideration of the technologies for which a competition for losses would be expected, for the purposes of evaluating appropriate synergy values. For this final rule, NHTSA used the version of the lumped parameter model as recently updated by EPA, as discussed above, to evaluate appropriate synergy values.

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combined effectiveness of (1 - .72 = .28) or 28% rather than the 30% obtained by adding 10% to 20%. The "synergy factors" discussed in this section further adjust these multiplicatively combined effectiveness values.

[211] U.S. Department of Energy, Energy Information Administration, *Transportation Sector Module of the National Energy Modeling System: Model Documentation 2009*, June 2009, Washington, DC, DOE/EIAM070(2009), at 26-27. *Available at* ftp://ftp.eia.doe.gov/modeldoc/m070(2009).pdf (last accessed Nov. 7, 2011).

As was done for the individual technology effectiveness estimates, NHTSA used the 6 unique vehicle classes in the lumped parameter tool to evaluate the synergies for each if the 12 vehicle subclasses. NHTSA systematically and thoroughly "walked" through the CAFE model's application of individual technologies, via the decision trees, to evaluate the synergies between pairs of technologies. Once the synergies for a vast majority of the technology pairs were generated, NHTSA iteratively evaluated hundreds of technology combinations, and all the steps that build up to the different combinations, to ensure that these combinations of technologies with their individual effectiveness estimates and corresponding synergy values resulted in overall fuel consumptions reductions that closely aligned with the overall fuel consumption reductions that were predicted by the lumped parameter tool. Basically, the lumped parameter tool was used to calibrate the synergy values to make sure the overall fuel consumptions reductions for the various combinations of technologies closely align with those predicted by the lumped parameter tool. The agency paid special attention to technology combinations that the model most often tends to form dynamically. This iterative process was conducted for each of the 6 vehicle classes, utilized by the lumped parameter tool, to develop vehicle class specific synergy factors. While the evaluation of technology combinations was not exhaustive, NHTSA believes that the hundreds of combinations evaluated were more than adequate to ensure accurate results, which replicate the results from the lumped parameter tool.

NHTSA notes that synergies that occur within a particular decision tree are already accounted for within the incremental effectiveness values assigned for each technology, and therefore additional synergy pairs for these technologies are not required. For example, all engine technologies take into account the synergies that occur with the preceding/existing engine technologies, and all transmission technologies take into account synergies of preceding transmission technologies, etc. These synergy factors are accounted for in the fuel consumption improvement estimates in the input files used by the CAFE model.

For applying incremental synergy factors in separate path technologies, *i.e.*, between two or more decision trees, the CAFE model uses an input table (see Table V-30a-f) that lists technology pairings and incremental synergy factors associated with those pairings (most of which are between engine technologies and transmission/ electrification/hybrid technologies). When a technology is applied to a vehicle by the CAFE model, all instances of that technology in the incremental synergy table which match technologies already applied to the vehicle (either pre-existing or previously applied by the CAFE model) are summed and applied to the fuel consumption improvement factor of the technology being applied. Synergies between the strong and plug-in hybrid technologies and transmission and electrification technologies are included in the incremental value for the specific hybrid or plug-in hybrid technology because the model applies technologies in the order of the most effectiveness for least cost and also applies all available electrification and transmission technologies before applying strong and plug-in hybrid technologies.

As discussed above, NHTSA, based on the simulation work performed by ANL has updated the effectiveness estimates for advanced transmission technologies when coupled to naturally aspirated engines for this final rule. The effectiveness estimates for advanced transmission technologies coupled with turbocharged and downsized engines, with and without CEGR, are still based on the Ricardo simulation work, consistent with the proposal. Because the effectiveness estimates for transmission technologies can only be input as a single value, NHTSA used the synergy factors to adjust the effectiveness estimates of advanced transmission technologies when coupled to naturally aspirated engines (*i.e.*, engine technologies prior to TRBDS1). The transmission effectiveness estimates found in the technology input file, as was the case in the NPRM, are still based on the Ricardo simulation work. In the case of an advanced transmission technology being applied to a naturally aspirated engine the model applies the effectiveness estimates found in the technology input file and then applies these newly added synergies to adjust the effectiveness estimate to be in line with the ANL simulation results. Once the turbocharging and downsizing technology, TRBDS1, is applied to a vehicle the model applies synergies that are the additive inverse of these newly added synergies to adjust the effectiveness to be back in line with the transmission effectiveness estimates found in the technology input file. As can be seen below, these new synergies and their inverses were added to the end of the synergy tables and start at the IATC to CCPS pairing.

Table V-30a Synergy pairings and values

		Fuel Consumption Improvement Synergy values by Vehicle Class Positive values are [positive] synergies, negative values are dissynergies. Blank cells are assumed to be zero.					
Technology A	Technology B	Subcompact PC	Subcompact Perf. PC	Compact PC	Compact Perf. PC	Midsize PC	Midsize Perf. PC
DCP	SHFTOPT	-0.60%	-0.60%	-0.60%	-0.60%	-0.60%	-0.60%
DCP	IACC1	-0.20%	-0.20%	-0.20%	-0.20%	-0.40%	-0.40%
DCP	IACC2	-0.40%	-0.40%	-0.40%	-0.40%	-0.80%	-0.80%
CCPS	SHFTOPT	-0.60%	-0.60%	-0.60%	-0.60%	-0.60%	-0.60%
CCPS	IACC1	-0.20%	-0.20%	-0.20%	-0.20%	-0.40%	-0.40%
CCPS	IACC2	-0.40%	-0.40%	-0.40%	-0.40%	-0.80%	-0.80%
DVVLS	IATC	-0.40%	-0.40%	-0.40%	-0.40%	-0.60%	-0.60%
DVVLS	MHEV	-0.50%	-0.50%	-0.50%	-0.50%	-0.30%	-0.30%
DVVLS	IACC2	-0.80%	-0.80%	-0.80%	-0.80%	-0.80%	-0.80%
DVVLS	8SPD	-0.70%	-0.70%	-0.70%	-0.70%	-0.70%	-0.70%
DEACS	IATC	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
DVVLD	IATC	-0.40%	-0.40%	-0.40%	-0.40%	-0.60%	-0.60%
DVVLD	MHEV	-0.50%	-0.50%	-0.50%	-0.50%	-0.30%	-0.30%
DVVLD	IACC2	-0.80%	-0.80%	-0.80%	-0.80%	-0.80%	-0.80%
DVVLD	8SPD	-0.70%	-0.70%	-0.70%	-0.70%	-0.70%	-0.70%
CVVL	IATC	-0.40%	-0.40%	-0.40%	-0.40%	-0.60%	-0.60%
CVVL	MHEV	-0.50%	-0.50%	-0.50%	-0.50%	-0.30%	-0.30%
CVVL	IACC2	-0.80%	-0.80%	-0.80%	-0.80%	-0.80%	-0.80%
CVVL	8SPD	-0.70%	-0.70%	-0.70%	-0.70%	-0.70%	-0.70%
DEACD	IATC	-0.40%	-0.40%	-0.40%	-0.40%	-0.40%	-0.40%
DEACO	IATC	0.00%	0.00%	0.00%	0.00%	-0.60%	-0.60%
DEACO	MHEV	-0.50%	-0.50%	-0.50%	-0.50%	-0.30%	-0.30%
DEACO	IACC1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
DEACO	IACC2	-0.80%	-0.80%	-0.80%	-0.80%	-0.80%	-0.80%
DEACO	8SPD	-0.70%	-0.70%	-0.70%	-0.70%	-0.70%	-0.70%
VVA	IATC	-0.40%	-0.40%	-0.40%	-0.40%	-0.40%	-0.40%
VVA	SHFTOPT	-0.60%	-0.60%	-0.60%	-0.60%	-0.60%	-0.60%
VVA	IACC1	-0.20%	-0.20%	-0.20%	-0.20%	-0.40%	-0.40%
VVA	IACC2	-0.40%	-0.40%	-0.40%	-0.40%	-0.80%	-0.80%
TRBDS1_SD	IATC	-0.50%	-0.50%	-0.50%	-0.50%	-0.80%	-0.80%
TRBDS1_MD	IATC	-0.50%	-0.50%	-0.50%	-0.50%	-0.80%	-0.80%
TRBDS1_LD	IATC	-0.50%	-0.50%	-0.50%	-0.50%	-0.80%	-0.80%
TRBDS1_SD	SHFTOPT	-0.20%	-0.20%	-0.20%	-0.20%	-0.70%	-0.70%
TRBDS1_MD	SHFTOPT	-0.20%	-0.20%	-0.20%	-0.20%	-0.70%	-0.70%
TRBDS1_LD	SHFTOPT	-0.20%	-0.20%	-0.20%	-0.20%	-0.70%	-0.70%
TRBDS1_SD	8SPD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRBDS1_MD	8SPD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRBDS1_LD	8SPD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRBDS1_SD	MHEV	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRBDS1_MD	MHEV	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRBDS1_LD	MHEV	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRBDS1_SD	IACC2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRBDS1_MD	IACC2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRBDS1_LD	IACC2	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
TRBDS2_SD	NAUTO	-0.50%	-0.50%	-0.50%	-0.50%	-1.20%	-1.20%

TRBDS2_MD	NAUTO	-0.50%	-0.50%	-0.50%	-0.50%	-1.20%	-1.20%

Table V-30b Synergy pairings and values

Technology A	Technology B	Subcompact PC	Subcompact Perf. PC	Compact PC	Compact Perf. PC	Midsize PC	Midsize Perf. PC
TRBDS2_LD	NAUTO	-0.50%	-0.50%	-0.50%	-0.50%	-1.20%	-1.20%
TRBDS2_SD	EPS	-0.20%	-0.20%	-0.20%	-0.20%	0.00%	0.00%
TRBDS2_MD	EPS	-0.20%	-0.20%	-0.20%	-0.20%	0.00%	0.00%
TRBDS2_LD	EPS	-0.20%	-0.20%	-0.20%	-0.20%	0.00%	0.00%
TRBDS2_SD	IACC2	-0.10%	-0.10%	-0.10%	-0.10%	0.00%	0.00%
TRBDS2_MD	IACC2	-0.10%	-0.10%	-0.10%	-0.10%	0.00%	0.00%
TRBDS2_LD	IACC2	-0.10%	-0.10%	-0.10%	-0.10%	0.00%	0.00%
CEGR1_SD	IACC2	-0.20%	-0.20%	-0.20%	-0.20%	0.00%	0.00%
CEGR1_MD	IACC2	-0.20%	-0.20%	-0.20%	-0.20%	0.00%	0.00%
CEGR1_LD	IACC2	-0.20%	-0.20%	-0.20%	-0.20%	0.00%	0.00%
CEGR2_SD	NAUTO	-0.60%	-0.60%	-0.60%	-0.60%	-0.80%	-0.80%
CEGR2_MD	NAUTO	-0.60%	-0.60%	-0.60%	-0.60%	-0.80%	-0.80%
CEGR2_LD	NAUTO	-0.60%	-0.60%	-0.60%	-0.60%	-0.80%	-0.80%
DCT	MHEV	-0.30%	-0.30%	-0.30%	-0.30%	-0.30%	-0.30%
SHFTOPT	MHEV	-0.30%	-0.30%	-0.30%	-0.30%	-0.30%	-0.30%
ROLL1	AERO1	0.20%	0.20%	0.20%	0.20%	0.20%	0.20%
ROLL2	AERO2	0.10%	0.10%	0.10%	0.10%	0.10%	0.10%
MR1	VVA	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MR1	DCP	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MR1	CCPS	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MR2	ROLL1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MR4	TRBDS1_SD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MR4	TRBDS1_MD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MR4	TRBDS1_LD	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
MR4	AERO2	0.40%	0.40%	0.40%	0.40%	0.40%	0.40%
MR5	ROLL1	0.00%	0.00%	0.00%	0.00%	0.00%	0.00%
ADSL_SD	IATC	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
ADSL_MD	IATC	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
ADSL_LD	IATC	1.0%	1.0%	1.0%	1.0%	1.0%	1.0%
NAUTO	SAX	-0.40%	-0.40%	-0.40%	-0.40%	-0.40%	-0.40%
SHEV1	AERO2	1.0%	1.0%	1.0%	1.0%	1.4%	1.4%
SHEV1	ROLL1	0.7%	0.7%	0.7%	0.7%	0.8%	0.8%
SHEV1	MR2	-0.5%	-0.5%	-0.5%	-0.5%	-0.4%	-0.4%
SHEV1	MR3	-0.2%	-0.2%	-0.2%	-0.2%	-0.1%	-0.1%
SHEV1	MR4	-0.3%	-0.3%	-0.3%	-0.3%	-0.2%	-0.2%
SHEV1	MR5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SHEV1_2	AERO2	0.2%	0.2%	0.2%	0.2%	-0.1%	-0.1%
SHEV1_2	ROLL2	0.3%	0.3%	0.3%	0.3%	0.3%	0.3%
SHEV1_2	MR2	0.1%	0.1%	0.1%	0.1%	-0.1%	-0.1%
SHEV1_2	MR3	0.0%	0.0%	0.0%	0.0%	-0.2%	-0.2%
SHEV1_2	MR4	0.0%	0.0%	0.0%	0.0%	-0.2%	-0.2%
SHEV1_2	MR5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
SHEV2	AERO2	1.2%	1.2%	1.2%	1.2%	1.3%	1.3%
SHEV2	ROLL2	1.0%	1.0%	1.0%	1.0%	1.1%	1.1%
SHEV2	MR2	-0.4%	-0.4%	-0.4%	-0.4%	-0.5%	-0.5%
SHEV2	MR3	-0.2%	-0.2%	-0.2%	-0.2%	-0.3%	-0.3%
SHEV2	MR4	-0.3%	-0.3%	-0.3%	-0.3%	-0.4%	-0.4%
SHEV2	MR5	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PHEV1	AERO2	0.1%	0.1%	0.1%	0.1%	0.0%	0.0%

PHEV1	ROLL2	0.4%	0.4%	0.4%	0.4%	0.4%	0.4%

Table V-30c Synergy pairings and values

Technology A	Technology B	Subcompact PC	Subcompact Perf. PC	Compact PC	Compact Perf. PC	Midsize PC	Midsize Perf. PC
IATC	CCPS	-1.40%	-1.40%	-1.40%	-1.40%	-1.60%	-1.60%
IATC	ICP	-1.40%	-1.40%	-1.40%	-1.40%	-1.60%	-1.60%
IATC	DEACO	-1.40%	-1.40%	-1.40%	-1.40%	-1.60%	-1.60%
NAUTO	CCPS	0.00%	0.00%	0.00%	0.00%	-1.20%	-1.20%
NAUTO	ICP	0.00%	0.00%	0.00%	0.00%	-1.20%	-1.20%
NAUTO	DEACO	0.00%	0.00%	0.00%	0.00%	-1.20%	-1.20%
DCT	CCPS	0.00%	0.00%	0.00%	0.00%	-0.40%	-0.40%
DCT	ICP	0.00%	0.00%	0.00%	0.00%	-0.40%	-0.40%
DCT	DEACO	0.00%	0.00%	0.00%	0.00%	-0.40%	-0.40%
8SPD	CCPS	-1.90%	-1.90%	-1.90%	-1.90%	-2.50%	-2.50%
8SPD	ICP	-1.90%	-1.90%	-1.90%	-1.90%	-2.50%	-2.50%
8SPD	DEACO	-1.90%	-1.90%	-1.90%	-1.90%	-2.50%	-2.50%
HETRANS	CCPS	0.50%	0.50%	0.50%	0.50%	0.00%	0.00%
HETRANS	ICP	0.50%	0.50%	0.50%	0.50%	0.00%	0.00%
HETRANS	DEACO	0.50%	0.50%	0.50%	0.50%	0.00%	0.00%
IATC	TRBDS1_SD	1.40%	1.40%	1.40%	1.40%	1.60%	1.60%
IATC	TRBDS1_MD	1.40%	1.40%	1.40%	1.40%	1.60%	1.60%
IATC	TRBDS1_LD	1.40%	1.40%	1.40%	1.40%	1.60%	1.60%
NAUTO	TRBDS1_SD	0.00%	0.00%	0.00%	0.00%	1.20%	1.20%
NAUTO	TRBDS1_MD	0.00%	0.00%	0.00%	0.00%	1.20%	1.20%
NAUTO	TRBDS1_LD	0.00%	0.00%	0.00%	0.00%	1.20%	1.20%
DCT	TRBDS1_SD	0.00%	0.00%	0.00%	0.00%	0.40%	0.40%
DCT	TRBDS1_MD	0.00%	0.00%	0.00%	0.00%	0.40%	0.40%
DCT	TRBDS1_LD	0.00%	0.00%	0.00%	0.00%	0.40%	0.40%
8SPD	TRBDS1_SD	1.90%	1.90%	1.90%	1.90%	2.50%	2.50%
8SPD	TRBDS1_MD	1.90%	1.90%	1.90%	1.90%	2.50%	2.50%
8SPD	TRBDS1_LD	1.9%	1.9%	1.9%	1.9%	2.5%	2.5%
HETRANS	TRBDS1_SD	-0.5%	-0.5%	-0.5%	-0.5%	0.0%	0.0%
HETRANS	TRBDS1_MD	-0.5%	-0.5%	-0.5%	-0.5%	0.0%	0.0%
HETRANS	TRBDS1_LD	-0.50%	-0.50%	-0.50%	-0.50%	0.00%	0.00%

Table V-30d Synergy pairings and values

Technology A	Technology B	Large PC	Large Perf. PC	Minivan LT	Small LT	Midsize LT	Large LT
DCP	SHFTOPT	-0.80%	-0.80%	-0.8%	-0.6%	-0.8%	-0.7%
DCP	IACC1	-0.40%	-0.40%	-0.1%	-0.3%	-0.1%	-0.4%
DCP	IACC2	-0.80%	-0.80%	-0.6%	-0.5%	-0.6%	-0.6%
CCPS	SHFTOPT	-0.80%	-0.80%	-0.8%	-0.6%	-0.8%	-0.7%
CCPS	IACC1	-0.40%	-0.40%	-0.1%	-0.3%	-0.1%	-0.4%
CCPS	IACC2	-0.80%	-0.80%	-0.6%	-0.5%	-0.6%	-0.6%
DVVLS	IATC	-0.80%	-0.80%	-0.7%	-0.5%	-0.7%	-0.5%
DVVLS	MHEV	-0.40%	-0.40%	-0.4%	-0.2%	-0.4%	-0.7%
DVVLS	IACC2	-0.90%	-0.90%	-0.7%	-0.6%	-0.7%	-0.8%
DVVLS	8SPD	-0.80%	-0.80%	-0.8%	-0.6%	-0.8%	-0.6%
DEACS	IATC	0.0%	0.0%	0.0%	0.0%	0.0%	-0.1%
DVVLD	IATC	-0.70%	-0.70%	-0.5%	-0.5%	-0.5%	-0.6%
DVVLD	MHEV	-0.40%	-0.40%	-0.4%	-0.2%	-0.4%	-0.7%
DVVLD	IACC2	-0.90%	-0.90%	-0.7%	-0.6%	-0.7%	-0.8%
DVVLD	8SPD	-0.80%	-0.80%	-0.8%	-0.6%	-0.8%	-0.6%
CVVL	IATC	-0.70%	-0.70%	-0.5%	-0.5%	-0.5%	-0.6%
CVVL	MHEV	-0.40%	-0.40%	-0.4%	-0.2%	-0.4%	-0.7%
CVVL	IACC2	-0.90%	-0.90%	-0.7%	-0.6%	-0.7%	-0.8%
CVVL	8SPD	-0.80%	-0.80%	-0.8%	-0.6%	-0.8%	-0.6%
DEACD	IATC	-0.10%	-0.10%	-0.2%	-0.3%	-0.2%	-0.1%
DEACO	IATC	-0.10%	-0.10%	-0.6%	-0.1%	-0.6%	-0.1%
DEACO	MHEV	-0.40%	-0.40%	-0.4%	-0.2%	-0.4%	-0.7%
DEACO	IACC1	0.0%	0.0%	-0.5%	0.0%	-0.5%	0.0%
DEACO	IACC2	-0.90%	-0.90%	-1.0%	-0.6%	-1.0%	-0.8%
DEACO	8SPD	-0.80%	-0.80%	-0.8%	-0.6%	-0.8%	-0.6%
VVA	IATC	-0.70%	-0.70%	-0.6%	-0.4%	-0.6%	-0.6%
VVA	SHFTOPT	-0.80%	-0.80%	-0.8%	-0.6%	-0.8%	-0.7%
VVA	IACC1	-0.40%	-0.40%	-0.1%	-0.3%	-0.1%	-0.4%
VVA	IACC2	-0.80%	-0.80%	-1.0%	-0.5%	-1.0%	-0.6%
TRBDS1_SD	IATC	-0.50%	-0.50%	-0.5%	-0.5%	-0.5%	-0.5%
TRBDS1_MD	IATC	-0.50%	-0.50%	-0.5%	-0.5%	-0.5%	-0.5%
TRBDS1_LD	IATC	-0.50%	-0.50%	-0.5%	-0.5%	-0.5%	-0.5%
TRBDS1_SD	SHFTOPT	-0.10%	-0.10%	-0.3%	-0.3%	-0.3%	-0.3%
TRBDS1_MD	SHFTOPT	-0.10%	-0.10%	-0.3%	-0.3%	-0.3%	-0.3%
TRBDS1_LD	SHFTOPT	-0.10%	-0.10%	-0.3%	-0.3%	-0.3%	-0.3%
TRBDS1_SD	8SPD	-0.40%	-0.40%	-0.4%	-0.4%	-0.4%	-0.4%
TRBDS1_MD	8SPD	-0.40%	-0.40%	-0.4%	-0.4%	-0.4%	-0.4%
TRBDS1_LD	8SPD	-0.40%	-0.40%	-0.4%	-0.4%	-0.4%	-0.4%
TRBDS1_SD	MHEV	-0.60%	-0.60%	-0.2%	-0.1%	-0.2%	-0.6%
TRBDS1_MD	MHEV	-0.60%	-0.60%	-0.2%	-0.1%	-0.2%	-0.6%
TRBDS1_LD	MHEV	-0.60%	-0.60%	-0.2%	-0.1%	-0.2%	-0.6%
TRBDS1_SD	IACC2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRBDS1_MD	IACC2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRBDS1_LD	IACC2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
TRBDS2_SD	NAUTO	-0.50%	-0.50%	-0.5%	-0.2%	-0.5%	-0.5%
TRBDS2_MD	NAUTO	-0.50%	-0.50%	-0.5%	-0.2%	-0.5%	-0.5%

Table V-30e Synergy pairings and values

Technology A	Technology B	Large PC	Large Perf. PC	Minivan LT	Small LT	Midsize LT	Large LT
TRBDS2_LD	NAUTO	-0.50%	-0.50%	-0.5%	-0.2%	-0.5%	-0.5%
TRBDS2_SD	EPS	-0.30%	-0.30%	-0.3%	-0.3%	-0.3%	-0.3%
TRBDS2_MD	EPS	-0.30%	-0.30%	-0.3%	-0.3%	-0.3%	-0.3%
TRBDS2_LD	EPS	-0.30%	-0.30%	-0.3%	-0.3%	-0.3%	-0.3%
TRBDS2_SD	IACC2	-0.50%	-0.50%	-0.3%	-0.3%	-0.3%	-0.3%
TRBDS2_MD	IACC2	-0.50%	-0.50%	-0.3%	-0.3%	-0.3%	-0.3%
TRBDS2_LD	IACC2	-0.50%	-0.50%	-0.3%	-0.3%	-0.3%	-0.3%
CEGR1_SD	IACC2	-0.20%	-0.20%	0.0%	0.0%	0.0%	0.0%
CEGR1_MD	IACC2	-0.20%	-0.20%	0.0%	0.0%	0.0%	0.0%
CEGR1_LD	IACC2	-0.20%	-0.20%	0.0%	0.0%	0.0%	0.0%
CEGR2_SD	NAUTO	-0.60%	-0.60%	-0.8%	-0.6%	-0.8%	-0.8%
CEGR2_MD	NAUTO	-0.60%	-0.60%	-0.8%	-0.6%	-0.8%	-0.8%
CEGR2_LD	NAUTO	-0.60%	-0.60%	-0.8%	-0.6%	-0.8%	-0.8%
DCT	MHEV	-0.30%	-0.30%	0.0%	-0.3%	0.0%	0.0%
SHFTOPT	MHEV	-0.30%	-0.30%	-0.3%	-0.3%	-0.3%	-0.3%
ROLL1	AERO1	0.20%	0.20%	0.2%	0.2%	0.2%	0.1%
ROLL2	AERO2	0.10%	0.10%	0.3%	0.2%	0.3%	0.2%
MR1	VVA	0.20%	0.20%	-0.1%	0.0%	-0.1%	0.4%
MR1	DCP	0.20%	0.20%	-0.1%	0.0%	-0.1%	0.4%
MR1	CCPS	0.20%	0.20%	-0.1%	0.0%	-0.1%	0.4%
MR2	ROLL1	0.0%	0.0%	0.0%	0.1%	0.0%	-0.1%
MR4	TRBDS1_SD	0.0%	0.0%	0.3%	0.3%	0.3%	0.6%
MR4	TRBDS1_MD	0.0%	0.0%	0.3%	0.3%	0.3%	0.6%
MR4	TRBDS1_LD	0.0%	0.0%	0.3%	0.3%	0.3%	0.6%
MR4	AERO2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
MR5	ROLL1	0.0%	0.0%	0.4%	0.5%	0.4%	0.4%
ADSL_SD	IATC	1.2%	1.2%	0.8%	1.0%	0.8%	1.0%
ADSL_MD	IATC	1.2%	1.2%	0.8%	1.0%	0.8%	1.0%
ADSL_LD	IATC	1.2%	1.2%	0.8%	1.0%	0.8%	1.0%
NAUTO	SAX	-0.40%	-0.40%	-0.40%	-0.40%	-0.40%	-0.40%
SHEV1	AERO2	1.4%	1.4%	1.4%	1.3%	1.4%	1.4%
SHEV1	ROLL1	0.8%	0.8%	0.9%	0.8%	0.9%	1.1%
SHEV1	MR2	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
SHEV1	MR3	-0.2%	-0.2%	-0.1%	-0.2%	-0.1%	-0.1%
SHEV1	MR4	-0.2%	-0.2%	-0.2%	-0.1%	-0.2%	-0.2%
SHEV1	MR5	0.0%	0.0%	-0.2%	-0.2%	-0.2%	-0.2%
SHEV1_2	AERO2	0.0%	0.0%	-0.1%	0.0%	-0.1%	-0.1%
SHEV1_2	ROLL2	0.9%	0.9%	0.7%	0.80%	0.7%	0.7%
SHEV1_2	MR2	0.0%	0.0%	0.2%	0.0%	0.2%	0.0%
SHEV1_2	MR3	-0.1%	-0.1%	-0.1%	0.0%	-0.1%	-0.1%
SHEV1_2	MR4	-0.1%	-0.1%	-0.1%	-0.2%	-0.1%	0.0%
SHEV1_2	MR5	0.0%	0.0%	-0.1%	-0.1%	-0.1%	0.0%
SHEV2	AERO2	1.4%	1.4%	1.3%	1.3%	1.3%	1.3%
SHEV2	ROLL2	1.7%	1.7%	1.6%	1.6%	1.6%	1.8%
SHEV2	MR2	-0.4%	-0.4%	-0.2%	-0.4%	-0.2%	-0.4%
SHEV2	MR3	-0.3%	-0.3%	-0.2%	-0.2%	-0.2%	-0.2%
SHEV2	MR4	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.2%
SHEV2	MR5	0.0%	0.0%	-0.3%	-0.3%	-0.3%	-0.2%
PHEV1	AERO2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
PHEV1	ROLL2	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Table V-30f Synergy pairings and values

Technology A	Technology B	Large PC	Large Perf. PC	Minivan LT	Small LT	Midsize LT	Large LT
IATC	CCPS	-1.60%	-1.60%	-1.5%	-1.3%	-1.5%	-1.3%
IATC	ICP	-1.60%	-1.60%	-1.5%	-1.3%	-1.5%	-1.3%
IATC	DEACO	-1.60%	-1.60%	-1.5%	-1.3%	-1.5%	-1.3%
NAUTO	CCPS	-1.20%	-1.20%	-1.3%	-0.8%	-1.3%	-1.7%
NAUTO	ICP	-1.20%	-1.20%	-1.3%	-0.8%	-1.3%	-1.7%
NAUTO	DEACO	-1.20%	-1.20%	-1.3%	-0.8%	-1.3%	-1.7%
DCT	CCPS	-0.40%	-0.40%	0.0%	-1.6%	0.0%	0.0%
DCT	ICP	-0.40%	-0.40%	0.0%	-1.6%	0.0%	0.0%
DCT	DEACO	-0.40%	-0.40%	0.0%	-1.6%	0.0%	0.0%
8SPD	CCPS	-2.50%	-2.50%	-3.9%	-2.7%	-3.9%	-3.8%
8SPD	ICP	-2.50%	-2.50%	-3.9%	-2.7%	-3.9%	-3.8%
8SPD	DEACO	-2.50%	-2.50%	-3.9%	-2.7%	-3.9%	-3.8%
HETRANS	CCPS	0.00%	0.00%	-0.6%	0.3%	-0.6%	-0.8%
HETRANS	ICP	0.00%	0.00%	-0.6%	0.3%	-0.6%	-0.8%
HETRANS	DEACO	0.00%	0.00%	-0.6%	0.3%	-0.6%	-0.8%
IATC	TRBDS1_SD	1.60%	1.60%	1.5%	1.3%	1.5%	1.3%
IATC	TRBDS1_MD	1.60%	1.60%	1.5%	1.3%	1.5%	1.3%
IATC	TRBDS1_LD	1.60%	1.60%	1.5%	1.3%	1.5%	1.3%
NAUTO	TRBDS1_SD	1.20%	1.20%	1.3%	0.8%	1.3%	1.7%
NAUTO	TRBDS1_MD	1.20%	1.20%	1.3%	0.8%	1.3%	1.7%
NAUTO	TRBDS1_LD	0.012	0.012	1.3%	0.8%	1.3%	1.7%
DCT	TRBDS1_SD	0.004	0.004	0.0%	1.6%	0.0%	0.0%
DCT	TRBDS1_MD	0.004	0.004	0.0%	1.6%	0.0%	0.0%
DCT	TRBDS1_LD	0.004	0.004	0.0%	1.6%	0.0%	0.0%
8SPD	TRBDS1_SD	0.025	0.025	3.9%	2.7%	3.9%	3.8%
8SPD	TRBDS1_MD	0.025	0.025	3.9%	2.7%	3.9%	3.8%
8SPD	TRBDS1_LD	2.5%	2.5%	3.9%	2.7%	3.9%	3.8%
HETRANS	TRBDS1_SD	0.0%	0.0%	0.6%	-0.3%	0.6%	0.8%
HETRANS	TRBDS1_MD	0.0%	0.0%	0.6%	-0.3%	0.6%	0.8%
HETRANS	TRBDS1_LD	0.00%	0.00%	0.60%	-0.30%	0.60%	0.80%

How much does the technology cost?

Direct Cost Estimates

As a general matter, the agencies believe that the best method to derive technology cost estimates is to conduct studies involving tear-down and analysis of actual vehicle components. A "tear-down" involves breaking down a technology into its fundamental parts and manufacturing processes by completely disassembling actual vehicles and vehicle subsystems and precisely determining what is required for its production. The result of the tear-down is a “bill of materials” for each and every part of the vehicle or vehicle subsystem. This tear-down method of costing technologies is often used by manufacturers to benchmark their products against competitive products. Historically, vehicle and vehicle component tear-down has not been done on a large scale by researchers and regulators due to the expense required for such studies. While tear-down studies are highly accurate at costing technologies for the year in which the study is intended, their accuracy, like that of all cost projections, may diminish over time as costs are extrapolated further into the future because of uncertainties in predicting commodities (and raw material) prices, labor rates, and manufacturing practices. The projected costs may be higher or lower than predicted.

Over the past several years, EPA has contracted with FEV, Inc. and its subcontractor Munro & Associates, to conduct tear-down cost studies for a number of key technologies evaluated by the agencies in assessing the feasibility of future GHG and CAFE standards. The analysis methodology included procedures to scale the tear-down results to smaller and larger vehicles, and also to different technology configurations. FEV’s methodology was documented in a report published as part of the MY 2012-2016 rulemaking process, detailing the costing of the first tear-down conducted in this work (#1 in the below list).[212] This report was peer reviewed by experts in the industry and revised by FEV in response to the peer review comments.[213] Subsequent tear-down studies (#2-5 in the below list) were documented in follow-up FEV reports made available in the public docket for the MY 2012-2016 rulemaking.[214]

Since then, FEV’s work under this contract has continued. Additional cost studies have been completed and are available for public review.[215] The most extensive study, performed after the MY 2012-2016 final rule, involved whole-vehicle tear-downs of a 2010 Ford Fusion power-split hybrid and a conventional 2010 Ford Fusion. (The latter served as a baseline vehicle for comparison.) In addition to providing power-split HEV costs, the results for individual components in these vehicles were subsequently used to cost another hybrid technology, the P2 hybrid, which employs similar hardware. This approach to costing P2 hybrids was undertaken because P2 HEVs were not yet in volume production at the time of hardware procurement for tear-down. Finally, an automotive lithium-polymer battery was torn down and costed to provide supplemental battery costing information to that associated with the NiMH battery in the Fusion

[212] U.S. EPA, “Light-Duty Technology Cost Analysis Pilot Study,” Contract No. EP-C-07-069, Work Assignment 1-3, December 2009, EPA-420-R-09-020, Docket No. NHTSA-2010-0131
[213] U.S. EPA, “Light-Duty Technology Cost Analysis Pilot Study Peer Review Report —Response to Comments Document”, December 21, 2009, Docket No. NHTSA-2010-0131
[214] U.S. EPA, “Light-duty Technology Cost Analysis – Report on Additional Case Studies,” Docket No. NHTSA-2010-0131
[215] FEV, Inc., “Light-Duty Technology Cost Analysis, Report on Additional Transmission, Mild Hybrid, and Valvetrain Technology Case Studies", Contract No. EP-C-07-069, Work Assignment 3-3, November 2011, Docket No. NHTSA-2010-0131

because we think automakers are moving to Li-ion battery technologies due to the higher energy and power density of these batteries. This HEV cost work, including the extension of results to P2 HEVs, has been extensively documented in a new report prepared by FEV.[216] Because of the complexity and comprehensive scope of this HEV analysis, EPA commissioned a separate peer review focused exclusively on it. Peer reviewer comments for the P2 and power-split HEV study generally supported FEV's methodology and results, while including a number of suggestions for improvement which were subsequently incorporated into FEV's analysis and final report. The peer review comments and responses are available in the rulemaking docket.[217] [218]

Over the course of this entire contract between EPA and FEV, FEV performed teardown-based studies were performed on each of the technologies listed below. These completed studies provide a thorough evaluation of the new technologies' costs relative to their baseline (or replaced) technologies.

1. Stoichiometric gasoline direct injection (SGDI) and turbocharging with engine downsizing (T-DS) on a DOHC (dual overhead cam) I4 engine, replacing a conventional DOHC I4 engine.
2. SGDI and T-DS on a SOHC (single overhead cam) on a V6 engine, replacing a conventional 3-valve/cylinder SOHC V8 engine.
3. SGDI and T-DS on a DOHC I4 engine, replacing a DOHC V6 engine.
4. 6-speed automatic transmission (AT), replacing a 5-speed AT.
5. 6-speed wet dual clutch transmission (DCT) replacing a 6-speed AT.
6. 8-speed AT replacing a 6-speed AT.
7. 8-speed DCT replacing a 6-speed DCT.
8. Power-split hybrid (Ford Fusion with I4 engine) compared to a conventional vehicle (Ford Fusion with V6). As explained, the results from this tear-down were extended to address P2 hybrids. In addition, costs from individual components in this tear-down study were also used by the agencies in developing cost estimates for PHEVs and EVs.
9. Mild hybrid with stop-start technology (Saturn Vue with I4 engine), replacing a conventional I4 engine.
10. Fiat Multi-Air engine technology. (Although results from this cost study are included in the rulemaking docket, they were not used by the agencies in this rulemaking's technical analyses, because of the uncertainty related to industry-wide use due to potential intellectual property issues.)

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[216] FEV, Inc., "Light-Duty Technology Cost Analysis, Power-Split and P2 HEV Case Studies", Contract No. EP-C-07-069, Work Assignment 3-3, EPA-420-R-11-015, November 2011, Docket No. NHTSA-2010-0131

[217] ICF, "Peer Review of FEV Inc. Report "Light Duty Technology Cost Analysis, Power-Split and P2 Hybrid Electric Vehicle Case Studies", EPA-420-R-11-016, November 2011, Docket No. NHTSA-2010-0131

[218] FEV, Inc. and U.S. EPA, "FEV Inc. Report 'Light Duty Technology Cost Analysis, Power-Split and P2 Hybrid Electric Vehicle Case Studies', Peer Review Report – Response to Comments Document", EPA-420-R-11-017, November 2011, Docket No. NHTSA-2010-0131

In addition, FEV and EPA extrapolated the engine downsizing costs for the following scenarios that were based on the above study cases:

1. Downsizing a SOHC 2 valve/cylinder V8 engine to a DOHC V6.
2. Downsizing a DOHC V8 to a DOHC V6.
3. Downsizing a SOHC V6 engine to a DOHC 4 cylinder engine.
4. Downsizing a DOHC 4 cylinder engine to a DOHC 3 cylinder engine.

The agencies have relied on the findings of FEV for estimating the cost of each of the technologies covered by the tear-down studies. However, we note that FEV based their costs on the assumption that these technologies would be mature when produced in large volumes (450,000 units or more for each component or subsystem). If manufacturers are not able to employ the technology at the volumes assumed in the FEV analysis with fully learned costs, then the costs for each of these technologies would be expected to be higher. There is also the potential for stranded capital[219] if technologies are introduced too rapidly for some indirect costs to be fully recovered. Because the production of automotive components is capital-intensive, it is possible for substantial capital investments in manufacturing equipment and facilities to become "stranded" (where their value is lost, or diminished).

It is difficult to quantify accurately any capital stranding associated with new technology phase-ins under the standards in this final rule because of the iterative dynamic involved – that is, the new technology phase-in rate strongly affects the potential for additional cost due to stranded capital. While the agencies consider the FEV tear-down analysis results to be generally valid for the 2017-2025 timeframe for fully mature, high sales volumes, in order to account for the possibility of stranded capital costs, the agencies asked FEV to perform a separate analysis of potential stranded capital costs associated with rapid phase-in of select technologies that FEV had already torn down, using data from FEV's primary teardown-based cost analyses. Detailed information on how FEV performed this exercise and the results of this exercise can be found in Section 3.2.2.3 of Chapter 3 of the joint TSD, and we refer readers there for more information.

DOT has modified the CAFE model, if specified for a given technology, when that technology is replaced by a newly applied technology, to apply a stream of costs representing the stranded capital cost of the replaced technology. This cost is in addition to the cost for producing the newly-applied technology. Because FEV assumed a ten year production life, for capital depreciation, any time a technology evaluated by FEV is replaced before its tenth year of being production, there is the potential for the stranding of capital. To account for this, the model determines how long a technology has been applied by the model. If a technology has been applied by the model for ten years or longer, the model does not apply these additional stranded

[219] The potential for stranded capital occurs when manufacturing equipment and facilities cannot be used in the production of a new technology.

capital costs when or if that technology gets replaced. However, if a technology is being replaced only five years after it was first applied by the model, then the model applies a stranded capital cost. FEV derived stranded capital costs for situations where a technology is replaced after three, five and eight years of production. FEV also assumed that for each of those years, the stranded capital would be recouped over a five year period. NHTSA extrapolated the FEV values to create a lookup table, Table V-31 below, which defines the stranded capital costs from years one through ten. For example, if a 6-speed DCT (DCT) is replaced by an 8-speed transmission (8SPD) 8 years after it was first applied, then the model will apply a cost of penalty of $8.04 to the 8SPD technology for 5 years. The allocation of stranded capital costs to the different technologies were changed slightly from the NPRM to more closely align with how the FEV derived stranded capital costs were meant to be employed. The stranded capital costs themselves did not change. The only change was how the stranded capital costs were applied to the unique technologies. The exact allocation of stranded capital costs can be found in the technology input file, available at Docket No. NHTSA-2010-0131. Additionally, like all other technology costs the stranded capital costs were updated from 2009$ to 2010$.

For some of the technologies, NHTSA's inputs, which are designed to be as consistent as practicable with EPA's, indicate negative incremental costs. In other words, the agency is estimating that some technologies, if applied in a manner that holds performance and utility constant, will, following initial investment (for, *e.g.*, R&D and tooling) by the manufacturer and its suppliers, incrementally improve fuel savings and reduce vehicle costs. Nonetheless, in the agency's central analysis, these and other technologies are applied only insofar as is necessary to achieve compliance with standards defining any given regulatory alternative (where the baseline no action alternative assumes CAFE standards are held constant after MY2016). The agency has also performed a sensitivity analysis involving market-based application of technology—that is, the application of technology beyond the point needed to achieve compliance, if the cost of the technology is estimated to be sufficiently attractive relative to the accompanying fuel savings. NHTSA invited comment on all of its technology estimates, and specifically requested comment on the likelihood that each technology will, if applied in a manner that holds vehicle performance and utility constant, be able to both deliver the estimated fuel savings and reduce vehicle cost. The agency also invited comment on whether, for the final rule, its central analysis should be revised to include estimated market-driven application of technology.

In their written comments on the proposal, the Center for Biological Diversity and the International Council on Clean Transportation argued that the long lead times being provided for the phase-in of new standards, stretching out as they do over two complete redesign cycles, will virtually eliminate any capital stranding, making it inappropriate to carry over what they consider to be a "relic" from shorter-term rulemakings. As discussed above, it is difficult to quantify accurately any capital stranding associated with new technology phase-ins, especially given the projected and unprecedented deployment of technologies in the rulemaking timeframe. The FEV analysis attempted to define the possible stranded capital costs, for a select set of technologies, using the above set of assumptions. Since the direct manufacturing costs developed by FEV assumed a 10 year production life (*i.e.*, capital costs amortized over 10 years) the agencies applied the FEV derived stranded capital costs whenever technologies were replaced prior to being utilized for the full 10 years. The other option would be to have assume a 5 year product life (*i.e.*, capital costs amortized over 5 years), which would have increased the direct manufacturing costs. It seems only reasonable to account for stranded capital costs in the instances where the fleet modeling performed by the agencies replaced technologies before the capital costs were fully amortized. The agencies did not derive or apply stranded capital costs to all technologies only the ones analyzed by FEV. While there is uncertainty about the possible stranded capital costs (*i.e.*, understated or overstated), their impact would not call into question the overall results of our cost analysis or otherwise affect the stringency of the standards, since costs of stranded capital are a relatively minor component of the total estimated costs of the rules.

In other comments relating to cost estimates, VW raised concerns for the costs and effectiveness for certain key technologies including electrification, lightweighting, and advanced engine technologies. For vehicle lightweighting, VW believes the cost used by the agencies is too low and the maximum cost-effective amount of mass reduction the agencies used in the NPRM analysis is too high. VW's opinion is that 10 percent of mass reduction, instead of 20 percent, is more cost-effective. After finishing the mass reduction study contracted with Electricore, NHTSA believes that 20 percent of mass reduction is cost-effective and feasible in the rulemaking period. However, NHTSA also acknowledges that each manufacturer has a different amount of lightweighting technologies already applied in its current fleet. If one OEM already has significantly more cost-effective lightweighting technologies used in its current fleet, it may have already applied the "low-hanging fruit" and may have to employ higher-cost lightweighting technologies if they chose to use lightweighting as a strategy to achieve the required fuel economy level. For high BMEP engines, VW raised particular concerns about the thermal and mechanical loads imparted on the components. These thermal and mechanical loads might impact the durability of these engines which in turn would incur additional cost to improve the durability.

Also, VW believes that high BMEP engines might need a two-stage turbocharger system to address low end torque performance, which would add more cost. VW believes, as stated in its comments, "Considering all these factors we believe that the torque curve for future engines will be constrained over the rpm range by charging limits, exhaust temperature, peak cylinder pressures and mechanical forces that may limit the practicable increase in BMEP." NHTSA acknowledges VW's concerns. NHTSA will closely monitor the development of these technologies and review the cost, effectiveness and applications of these technologies during the mid-term review.

The National Automobile Dealers Association (NADA) offered comment on the issue of maintenance and other costs, stating that the final rule should evaluate the potential impact on a vehicle's total cost of ownership, to include maintenance costs. In response, NHTSA identified a select list of technologies for which sufficient data on periodicity and cost exist to support quantification of changes in vehicle maintenance costs. This list includes costs associated with low rolling resistance tires, diesel fuel filters, and benefits resulting from electric vehicle characteristics that eliminate the need for oil changes as well as engine air filter changes. In the final rule as in the NPRM, repair costs during the warranty period remain a component of the indirect cost multiplier. A sensitivity analysis was added to examine repair costs in the post-warranty period, discussed further in Chapter X of this FRIA.

Comments received from NRDC and the Union of Concerned Scientists discouraged the use of a consumer choice model that includes market-driven application of technology. Specifically, NRDC's concern was that the model cannot capture technologies that do not already exist in the market and UCS commented that these models were once used by OEMs to dismiss hybrids, airbags, and other technologies. The Alliance of Automobile Manufacturers, American Fuel and Petrochemical Mfrs, and the Institute for Policy Integrity all commented supporting the use of a consumer choice model in the rulemaking analysis.

Table V-31 Stranded Capital Costs (2010$)

		Stranded Capital Cost Table									
Technology	**Abbr.**	**Year 1**	**Year 2**	**Year 3**	**Year 4**	**Year 5**	**Year 6**	**Year 7**	**Year 8**	**Year 9**	**Year 10**
Low Friction Lubricants - Level 1	LUB1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Engine Friction Reduction - Level 1	EFR1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cylinder Deactivation on SOHC	DEACS	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Continuously Variable Valve Lift (CVVL)	CVVL	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cylinder Deactivation on DOHC	DEACD	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Cylinder Deactivation on OHV	DEACO	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Variable Valve Actuation - CCP and DVVL on OHV	VVA	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	$78.48	$69.69	$60.90	$52.20	$43.50	$34.80	$26.10	$17.40	$8.70	$0.00
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	$78.48	$69.69	$60.90	$52.20	$43.50	$34.80	$26.10	$17.40	$8.70	$0.00
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	$78.48	$69.69	$60.90	$52.20	$43.50	$34.80	$26.10	$17.40	$8.70	$0.00
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	$78.48	$69.69	$60.90	$52.20	$43.50	$34.80	$26.10	$17.40	$8.70	$0.00
Advanced Diesel - Small Displacement	ADSL_SD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Advanced Diesel - Medium Displacement	ADSL_MD	$73.38	$65.16	$56.93	$48.80	$40.66	$32.53	$24.40	$16.27	$8.14	$0.00
Advanced Diesel - Large Displacement	ADSL_LD	$78.48	$69.69	$60.90	$52.20	$43.50	$34.80	$26.10	$17.40	$8.70	$0.00
6-Speed Manual/Improved Internals	6MAN	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
High Efficiency Gearbox (Manual)	HETRANSM	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Improved Auto. Trans. Controls/Externals	IATC	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

6-Speed Trans with Improved Internals (Auto)	NAUTO	$79.99	$67.61	$55.23	$47.34	$39.45	$31.56	$23.67	$15.78	$7.89	$0.00
6-speed DCT	DCT	$36.18	$32.16	$28.14	$24.12	$20.10	$16.08	$12.06	$8.04	$4.02	$0.00
8-Speed Trans (Auto or DCT)	8SPD	$65.10	$56.68	$48.26	$41.36	$34.47	$27.58	$20.68	$13.79	$6.89	$0.00
High Efficiency Gearbox (Auto or DCT)	HETRANS	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Shift Optimizer	SHFTOPT	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Electric Power Steering	EPS	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Improved Accessories - Level 1	IACC1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
12V Micro-Hybrid (Stop-Start)	MHEV	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Integrated Starter Generator	ISG	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Strong Hybrid - Level 1	SHEV1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Conversion from SHEV1 to SHEV2	SHEV1_2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Strong Hybrid - Level 2	SHEV2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Plug-in Hybrid - 30 mi range	PHEV1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Plug-in Hybrid	PHEV2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Electric Vehicle (Early Adopter) - 100 mile range	EV2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Electric Vehicle (Early Adopter) - 150 mile range	EV3	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Electric Vehicle (Broad Market) - 150 mile range	EV4	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Fuel Cell Vehicle	FCV	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Mass Reduction - Level 1	MR1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Mass Reduction - Level 2	MR2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Mass Reduction - Level 3	MR3	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Mass Reduction - Level 4	MR4	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Mass Reduction - Level 5	MR5	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Low Rolling Resistance Tires - Level 1	ROLL1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Low Rolling Resistance Tires - Level 2	ROLL2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Low Rolling Resistance Tires - Level 3	ROLL3	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Low Drag Brakes	LDB	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Secondary Axle Disconnect	SAX	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Aero Drag Reduction, Level 1	AERO1	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Aero Drag Reduction, Level 2	AERO2	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -

Learning Curves

The agency uses learning curves to account for the cost reductions that manufacturers realize through experiential learning achieved through applying technologies. A complete discussion on the development and application of learning curves can be found in Chapter VII of this FRIA.

Indirect Cost Multiplier

Indirect costs were accounted for through the application of Indirect Cost Multipliers (ICMs), which were created by EPA. ICMs were applied to each technology's year-by-year direct cost to arrive at its total compliance cost, which are the costs used for modeling purposes. A full discussion of the development and application of the ICMs for purposes of this analysis can be found in Chapter VII of this FRIA.

What specific technologies did NHTSA considered for application in this rulemaking, and what are NHTSA's estimates of their incremental costs and effectiveness?

ICE Engine Technologies

What is an Internal Combustion Engine (ICE)?

Most passenger cars and light trucks in the U.S. have gasoline-fueled spark ignition internal combustion engines. These engines move the vehicle by converting the chemical energy in gasoline fuel to useful mechanical work output as shaft torque and power delivered to the transmission and to the vehicle's driving wheels. Vehicle fuel economy is directly proportional to the efficiency of the engine. Two common terms are used to define the efficiency of an engine are (1) Brake Specific Fuel Consumption (BSFC), which is the ratio of the mass of fuel used to the output mechanical energy; and (2) Brake Thermal Efficiency (BTE), which is the ratio of the fuel chemical energy, known as calorific value, to the output mechanical energy.

The efficiency of an automotive spark ignition engine varies considerably with the rotational speed and torque output demanded from the engine. The most efficient operating condition for most current engine designs occurs around medium speed (30-50 percent of the maximum allowable engine rpm) and typically between 70-85 percent of maximum torque output at that speed. At this operating condition, BTE is typically 33-36 percent. However, at lower engine speeds and torque outputs, at which the engine operates in most consumer vehicle use and on standardized drive cycles, BTE typically drops to 20-25 percent.

Spark ignition engine efficiency can be improved by reducing the energy losses that occur between the point of combustion of the fuel in the cylinders and the point where that energy reaches the output crankshaft. Reduction in this energy loss results in a greater proportion of the chemical energy of the fuel being converted into useful work. For improving engine efficiency at lighter engine load demand points, which are most relevant for CAFE fuel economy, the technologies that can be added to a given engine may be characterized by which type of energy loss is reduced. The main types of energy losses that can be reduced in gasoline engines to improve fuel economy are exhaust energy losses, engine friction losses, and gas exchange losses. Converting the gasoline engine to a diesel engine can also reduce heat losses.

How can ICE efficiency be improved?

Exhaust Energy Loss Reduction

Exhaust energy includes the kinematic and thermal energy of the exhaust gases, as well as the wasted chemical energy of unburned fuel. These losses represent approximately 32 percent of the initial fuel chemical energy and can be reduced in three ways: first, by recovering mechanical or electrical energy from the exhaust gases; second, by improving the hydrocarbon fuel conversion; and third, by improving the cycle thermodynamic efficiency. The thermodynamic efficiency can be improved by either increasing the engine's compression ratio or by operating with a lean air/fuel ratio.

Engine Friction Loss Reduction

Friction losses can represent a significant proportion of the global losses at low load. These losses are dissipated through the cooling system in the form of heat. Besides via direct reduction measures, friction can also be reduced through downsizing the engine by means of increasing the engine-specific power output.

Gas Exchange Loss Reduction

The energy expended while delivering the combustion air to the cylinders and expelling the combustion products is known as gas exchange loss, commonly referred to as pumping loss. The main source of pumping loss in a gasoline engine is the use of an inlet air throttle, which regulates engine output by controlling the pre-combustion cylinder air pressure, but which is an inefficient way to achieve this pressure control. A more efficient way of controlling the cylinder air pressure is to modify the valve timing or lift. Another way to reduce the average pumping losses is to "downsize" the engine, making it run at higher loads or higher pressures.

Several different technologies target pumping loss reduction, but the fuel consumption reduction from these technologies is not necessarily cumulative. Once most of the pumping work has been eliminated, adding further technologies that also target reduced pumping loss will have little additional effectiveness. Thus, in the decision trees used for this analysis, the effectiveness value shown for additional technologies targeting pumping loss depends on the existing technology combination already present on the engine.

What technologies can improve fuel efficiency for both gasoline and diesel ICEs?

Low Friction Lubricants (LUB)

One of the most basic methods of reducing fuel consumption in gasoline engines is the use of lower viscosity engine lubricants. More advanced multi-viscosity engine oils are available today with improved performance in a wider temperature band and with better lubricating properties. This can be accomplished by changes to the oil base stock (*e.g.*, switching engine lubricants from a Group I base oils to lower-friction, lower viscosity Group III synthetic) and through changes to lubricant additive packages (*e.g.*, friction modifiers and viscosity improvers). The use of 5W-30 motor oil is now widespread and auto manufacturers are introducing the use of even lower viscosity oils, such as 5W-20 and 0W-20, to improve cold-flow properties and reduce cold start friction. However, in some cases, changes to the crankshaft, rod and main bearings and changes to the mechanical tolerances of engine components may be required. In all cases, durability testing would be required to ensure that durability is not compromised. The shift to lower viscosity and lower friction lubricants will also improve the effectiveness of valvetrain technologies such as cylinder deactivation, which rely on a minimum oil temperature (viscosity) for operation.

Several manufacturers have previously commented confidentially, that low friction lubricants could have an effectiveness value between 0 to 1 percent. The agencies used the average effectiveness of 0.5 in the MYs 2012-2016 final rule. For purposes of this final rule, the agencies relied on the lumped parameter model and determined that the range for the effectiveness of low friction lubricant is 0.5 to 0.8 percent.

In the 2012-2016 rule, the 2010 TAR and the recent HD GHG rule, EPA and NHTSA used a direct manufacturing cost (DMC) of $3 (2007$), and considered that cost to be independent of vehicle class since the engineering work required should apply to any engine size. The agencies continue to believe that this cost is appropriate and have updated it to $3 (2010$) for this analysis[220]. No learning is applied to this technology, so the DMC remains $3 year-over-year. The agencies have used a low complexity short-term ICM of 1.24 for this technology through 2018, and a long-term ICM of 1.19 thereafter. The resultant costs are shown in Table V-32.[221]

Table V-32 Costs for Engine Modifications to Accommodate Low Friction Lubes (2010$)

Cost type	Engine type	2017	2018	2019	2020	2021	2022	2023	2024	2025

[220] The cost was updated to 2009$. However, due to rounding to the whole dollar amount it still $3.
[221] Note that the costs developed for low friction lubes for this analysis reflect the costs associated with any engine changes that would be required as well as any durability testing that may be required.

DMC	All	$3	$3	$3	$3	$3	$3	$3	$3	$3
IC	All	$1	$1	$1	$1	$1	$1	$1	$1	$1
TC	All	$4	$4	$4	$4	$4	$4	$4	$4	$4

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline engine.

Engine Friction Reduction Level I and II (EFR1and LUB2_EFR2)

In addition to low friction lubricants, manufacturers can also reduce friction and improve fuel consumption by improving the design of engine components and subsystems. Approximately 10 percent of the energy consumed by a vehicle is lost to friction, and just over half is due to frictional losses within the engine.[222] Examples include improvements in low-tension piston rings, piston skirt design, roller cam followers, improved crankshaft design and bearings, material coatings, material substitution, more optimal thermal management, and piston and cylinder surface treatments. Additionally, as computer-aided modeling software continues to improve, more opportunities for evolutionary friction reductions may become available.
All reciprocating and rotating components in the engine are potential candidates for friction reduction, and minute improvements in several components can add up to a measurable fuel economy improvement. In the MYs 2012-2016 final rule, the agencies relied on the 2002 NAS, NESCCAF and EEA reports as well as confidential manufacturer data that suggested a range of effectiveness for engine friction reduction to be between 1 to 3 percent. Because of the incremental nature of the CAFE model, NHTSA used the narrower range of 1 to 2 percent, which resulted in an average effectiveness of 1.5 percent. For this rulemaking analysis, based on the 2011 Ricardo study, the effectiveness for engine friction reduction range has been increased to 2.0 to 2.7 percent incremental to low friction lubricant 1 (LUB1).

Additionally, for this final rule, consistent with the proposal, the agencies have added a second level of incremental improvements in low friction lubricants and engine friction reduction (LUB2_EFR2). This LUB2_EFR2 includes some additional effectiveness improvements to low friction lubricant, relative to the low friction lubricant technology discussed above, based on assumptions based on manufacturer statements that further improvements will be made to low friction lubricants. The technologies for this second level of engine friction reduction and low friction lubricants are considered to be available for purposes of this analysis only after MY 2017. The effectiveness for this second level, relative to the base engine, is 3.4 to 4.8 percent based on the lumped parameter model. However, because of the incremental nature of the CAFE model, NHTSA used the effectiveness range of 0.83 to 1.37 percent incremental to the first level of engine friction reduction (EFR1) and low friction lubricants (LUB1).

[222] "Impact of Friction Reduction Technologies on Fuel Economy," Fenske, G. Presented at the March 2009 Chicago Chapter Meeting of the 'Society of Tribologists and Lubricated Engineers' Meeting, March 18th, 2009. Available at: http://www.dtic.mil/cgi-bin/GetTRDoc?Location=U2&doc=GetTRDoc.pdf&AD=ADA508227 (last accessed November 13, 2011)

In the 2012-2016 rule, the 2010 TAR and the HD GHG final rule, NHTSA and EPA used a cost estimate of $11.71 (2007$) per cylinder as the direct manufacturing cost for EFR1, which is $12 (updated to 2010$) per cylinder in this analysis. No learning is applied to this technology, so the DMC remains $12 (2010$) year-over-year. The agencies have used a low complexity ICM of 1.24 for this technology through 2018 and a long-term ICM of 1.19 thereafter. The resultant costs are shown in **Table V-33**.

Table V-33 Costs for Engine Friction Reduction – Level 1 (EFR1) (2010$)

Cost type	Engine type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	I3	$36	$36	$36	$36	$36	$36	$36	$36	$36
DMC	I4	$48	$48	$48	$48	$48	$48	$48	$48	$48
DMC	V6	$71	$71	$71	$71	$71	$71	$71	$71	$71
DMC	V8	$95	$95	$95	$95	$95	$95	$95	$95	$95
IC	I3	$9	$9	$7	$7	$7	$7	$7	$7	$7
IC	I4	$11	$11	$9	$9	$9	$9	$9	$9	$9
IC	V6	$17	$17	$14	$14	$14	$14	$14	$14	$14
IC	V8	$23	$23	$18	$18	$18	$18	$18	$18	$18
TC	I3	$44	$44	$43	$43	$43	$43	$43	$43	$43
TC	I4	$59	$59	$57	$57	$57	$57	$57	$57	$57
TC	V6	$89	$89	$85	$85	$85	$85	$85	$85	$85
TC	V8	$118	$118	$113	$113	$113	$113	$113	$113	$113

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline engine.

The agencies have estimated the DMC for the second level of friction reduction with a second level of low friction lube as double the combined DMCs of the first level of engine friction reduction and first level of low friction lube (that is, double the DMC relative to the baseline). The resultant costs of LUB2_EFR2 are as shown in Table V-34. For LUB2_EFR2 the agencies have used a low complexity ICM of 1.24 through 2024 and a long-term ICM of 1.19 thereafter.

Table V-34 Costs for Engine Friction Reduction – Level 2(LUB2_EFR2) (2010$)

Cost type	Engine type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	I3	$78	$78	$78	$78	$78	$78	$78	$78	$78
DMC	I4	$102	$102	$102	$102	$102	$102	$102	$102	$102
DMC	V6	$149	$149	$149	$149	$149	$149	$149	$149	$149
DMC	V8	$197	$197	$197	$197	$197	$197	$197	$197	$197
IC	I3	$19	$19	$19	$19	$19	$19	$19	$19	$15
IC	I4	$25	$25	$25	$25	$25	$25	$25	$25	$20
IC	V6	$36	$36	$36	$36	$36	$36	$36	$36	$29
IC	V8	$48	$48	$48	$48	$48	$48	$48	$48	$38

TC	I3	$97	$97	$97	$97	$97	$97	$97	$97	$93
TC	I4	$126	$126	$126	$126	$126	$126	$126	$126	$121
TC	V6	$185	$185	$185	$185	$185	$185	$185	$185	$178
TC	V8	$244	$244	$244	$244	$244	$244	$244	$244	$234

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline.

Gasoline Engine Technologies

Variable Valve Timing (VVT)

Variable valve timing (VVT) encompasses a family of valve-train designs that alter the timing of the intake valve, exhaust valve, or both, primarily to reduce pumping losses, increase specific power, and control the level of residual gases in the cylinder. VVT reduces pumping losses when the engine is lightly loaded by controlling valve timing closer to an optimum needed to sustain horsepower and torque. VVT can also improve volumetric efficiency at higher engine speeds and loads. Additionally, VVT can be used to alter (and optimize) the effective compression ratio where it is advantageous for certain engine operating modes (*e.g.*, in the Atkinson Cycle).

VVT has now become a widely adopted technology: in MY 2010, approximately 86 percent of all new cars and light trucks had engines with some method of variable valve timing.[223] Manufacturers are currently using many different types of variable valve timing, which have a variety of different names and methods. Manufacturers are currently using many different types of variable valve timing, which have a variety of different names and methods. Therefore, the degree of further improvement across the fleet is limited by the level of valvetrain technology already implemented on the vehicles. Information found in the 2008 baseline vehicle fleet file is used to determine the degree to which VVT technologies have already been applied to particular vehicles, to ensure that the proper level of VVT technology, if any, is applied.

Each of the three implementations of VVT uses a cam phaser to adjust the camshaft angular position relative to the crankshaft position, referred to as "camshaft phasing." The phase adjustment results in changes to the pumping work required by the engine to accomplish the gas exchange process. The majority of current cam phaser applications use hydraulically-actuated units, powered by engine oil pressure and managed by a solenoid that controls the oil pressure supplied to the phaser. The three major types of VVT are listed below.

Intake Cam Phasing (ICP)

[223] "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends - 1975 through 2009", EPA420-S-07-001, September 2007, Docket No. NHTSA-2010-0131-0147. Available at http://www.epa.gov/oms/cert/mpg/fetrends/fetrends-archive.htm (last accessed November 13, 2011).

Valvetrains with ICP, which is the simplest of the cam phasing technologies, can modify the timing of the inlet valves by phasing the intake camshaft while the exhaust valve timing remains fixed. This requires the addition of a cam phaser on each bank of intake valves on the engine. An in-line 4-cylinder engine has one bank of intake valves, while V-configured engines have two banks of intake valves.

In the MYs 2012-2016 final rule and TAR, NHTSA and EPA assumed an effectiveness range of 2 to 3 percent for ICP. Based on the 2011 Ricardo study and updated lumped-parameter model the agencies have fine-tuned the range to 2.1 to 2.7 percent.

In the 2012-2016 rule and the 2010 TAR, the agencies estimated the DMC of a cam phaser needed for ICP at $37 (2007$). This DMC becomes $39 (2010$) for this analysis and is considered applicable in the 2015 MY. This cost would be required for each cam shaft controlling intake valves; an overhead cam I4 would need one phaser, an overhead cam V6 or V8 would need two phasers, and an overhead valve V6 or V8 would need just one. This technology is considered to be on the flat-portion of the learning curve. The agencies have applied a low complexity ICM of 1.24 to this technology through 2018 and a long-term ICM of 1.19 thereafter. The resultant costs are shown in Table **V-35**.

Table V-35 Costs for Intake Cam Phasing (2010$)

Cost type	Engine type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	OHC-I4	$37	$36	$35	$35	$34	$33	$33	$32	$31
DMC	OHC-V6/V8	$74	$72	$71	$70	$68	$67	$65	$64	$63
DMC	OHV-V6/V8	$37	$36	$35	$35	$34	$33	$33	$32	$31
IC	OHC-I4	$9	$9	$7	$7	$7	$7	$7	$7	$7
IC	OHC-V6/V8	$19	$19	$15	$15	$15	$15	$15	$15	$15
IC	OHV-V6/V8	$9	$9	$7	$7	$7	$7	$7	$7	$7
TC	OHC-I4	$46	$46	$43	$42	$42	$41	$40	$40	$39
TC	OHC-V6/V8	$93	$91	$86	$84	$83	$82	$80	$79	$78
TC	OHV-V6/V8	$46	$46	$43	$42	$42	$41	$40	$40	$39

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; OHC=overhead cam; OHV=overhead valve; all costs are incremental to the baseline.

Coupled Cam Phasing (CCPS and CCPO)

Valvetrains with coupled (or coordinated) cam phasing can modify the timing of both the inlet valves and the exhaust valves an equal amount by phasing the camshaft of a single overhead cam (SOHC) engine or an overhead valve (OHV) engine. For overhead cam engines, this requires the addition of a cam phaser on each bank of the engine. Thus, an in-line 4-cylinder engine has one cam phaser, while SOHC V-engines have two cam phasers. For overhead valve (OHV) engines, which have only one camshaft to actuate both inlet and exhaust valves, CCP is the only VVT implementation option available and requires only one cam phaser.[224]

The analysis for MYs 2012-2016 final rule used an effectiveness estimate for CCP of between 1 to 4 percent. Due to the incremental nature and decision tree logic of the CAFE model, NHTSA estimated the effectiveness for coupled cam phasing on a SOHC engine to be 1 to 3 percent and 1 to 1.5 percent for coupled cam phasing on an overhead valve engine.

For this final rule, consistent with the proposal, the agencies, taking into account the additional review and the work performed for the 2011 Ricardo study, have revised the estimates for CCP. The effectiveness relative to the base engine is 4.1 to 5.5 percent based on the lumped parameter model. Because of the incremental nature of the CAFE model, NHTSA used the incremental effectiveness range of 4.14 to 5.36 percent for SOHC applications, which represents an increase over the estimates used in the MYs 2012-16 final rule and 2010 TAR. For OHV applications, CCP was paired with discrete variable valve lift (DVVL) to form a new technology descriptor called variable valve actuation (VVA). VVA is discussed later in this chapter.

The same cam phaser has been assumed for intake cam phasing as for coupled cam phasing, thus CCP cost estimates are identical to those presented in Table **V-35**.

Dual Cam Phasing (DCP)

The most flexible VVT design is dual (independent) cam phasing, where the intake and exhaust valve opening and closing events are controlled independently. This allows the option of controlling valve overlap, which can be used as an internal EGR strategy. At low engine loads, DCP creates a reduction in pumping losses, resulting in improved fuel consumption. Increased internal EGR also results in lower engine-out NO_X emissions. The amount by which fuel consumption is improved depends on the residual tolerance of the combustion system. Additional improvements are observed at idle, where low valve overlap could result in improved combustion stability, potentially reducing idle fuel consumption.

[224] We note that coaxial camshaft developments would allow other VVT options to be applied to OHV engines. However, since they would potentially be adopted on only a limited number of OHV engines, because of the complexity of these systems, NHTSA did not include them in the decision tree for this analysis.

For the 2012-2016 final rule and TAR, the agencies assumed an effectiveness range for DCP of between 3 to 5 percent relative to a base engine, or 2 to 3 relative to an engine with ICP. The agencies have updated this range, based on the updated lumped parameter model, to 4.1 to 5.5 percent relative to a base engine, or 2.0 to 2.7 percent relative to an engine with ICP.

The costs for DCP are the same per phaser as described above for ICP. However, for DCP, an additional cam phaser is required for each camshaft controlling exhaust valves. As a result, an overhead cam I4 would need two phasers, an overhead cam V6 or V8 would need four phasers, and an overhead valve V6 or V8 would need two. NHTSA believes that with DCP the exhaust valves can be closed earlier to allow some in-cylinder EGR, so we subtracted the cost of an EGR valve per bank for DCP. The EGR valve cost is $6 (2007$) in MY 2012, so the DCP cost per bank is $31 (2007$). Converting to 2010$, the DCP cost is $33. This technology is considered to be on the flat-portion of the learning curve. The agencies have applied a medium complexity ICM of 1.39 to this technology through 2018 and 1.29 thereafter. The resultant costs are shown in Table V-36.

Table V-36 Costs Per Cylinder Bank for VVT-Dual Cam Phasing (2010$)

Index	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	$32	$31	$30	$30	$29	$28	$28	$27	$27
IC	$13	$13	$10	$9	$9	$9	$9	$9	$9
TC	$45	$44	$40	$39	$38	$37	$37	$36	$36

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to base engine.

Variable Valve Lift (VVL)

Controlling the lift of the valves provides an opportunity for further efficiency improvements. By optimizing the valve-lift profile for specific engine operating regions, the pumping losses can be reduced by reducing the amount of throttling required to produce the desired engine power output. By moving the throttling losses further downstream of the throttle valve, the heat transfer losses that occur from the throttling process are directed into the fresh charge-air mixture just prior to compression, delaying the onset of knock-limited combustion processes. Variable valve lift control can also be used to induce in-cylinder mixture motion, which improves fuel-air mixing and can result in improved thermodynamic efficiency. Variable valve lift control can also potentially reduce overall valvetrain friction. At the same time, such systems may also incur increased parasitic losses associated with their actuation mechanisms. A number of manufacturers have already implemented VVL into their fleets (Toyota, Honda, and BMW), but overall this technology is still available for most of the fleet. There are two major classifications of variable valve lift, as described below.

Discrete Variable Valve Lift (DVVLS, DVVLD, DVVLO)

Discrete variable valve lift (DVVL) systems allow the selection between two or three discrete cam profiles by means of a hydraulically-actuated mechanical system. By optimizing the cam profile for specific engine operating regions, the pumping losses can be reduced by reducing the amount of throttling required to produce the desired engine power output. This increases the efficiency of the engine. These cam profiles consist of a low and a high-lift lobe, and may include an inert or blank lobe to incorporate cylinder deactivation (in the case of a 3-step DVVL system). DVVL is normally applied together with VVT control. DVVL is also known as Cam Profile Switching (CPS). DVVL is a mature technology with low technical risk.

In the MY 2012-16 final rule, based on previously-received confidential manufacturer data and the report from the Northeast States Center for a Clean Air Future (NESCCAF), the agencies estimated the effectiveness of DVVL to be between 1 to 4 percent above that realized by VVT systems. Based on the 2011 Ricardo study, NHTSA and EPA have revised the effectiveness range of DVVL systems to 2.8 to 3.9 percent above that realized by VVT systems for purposes of this analysis.

In the 2012-2016 rule and the 2010 TAR, the agencies estimated the DMC of DVVL at $116 (2007$), $169 (2007$) and $241 (2007$) for an I4, V6 and V8 engine, respectively. These DMCs become $122 (2010$), $177 (2010$) and $253 (2010$) or $30, $30 and $32 per cylinder for this analysis, all of which are considered applicable in MY 2015. Because the CAFE model uses cost per cylinder for this technology, NHTSA averaged the cost per cylinder for 4, 6 and 8 cylinder engines into a cost of $31 (2010$) per cylinder for application in the CAFE model. This technology is considered to be on the flat-portion of the learning curve and is applicable only to engines with overhead cam configurations. The agencies have applied a medium complexity ICM of 1.39 to this technology through 2018 and a long-term ICM of 1.29 thereafter. The resultant costs are shown in

Table V-37.

Table V-37 Costs Per Cylinder for Discrete Variable Valve Lift (2010$)

Index	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	$29	$28	$28	$27	$27	$26	$26	$25	$25
IC	$12	$12	$9	$9	$9	$9	$9	$9	$9
TC	$41	$40	$37	$36	$36	$35	$35	$34	$33

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to base engine.

Continuously Variable Lift (CVVL)

In CVVL systems, valve lift is varied by means of a mechanical linkage, driven by an actuator controlled by the engine control unit. The valve opening and phasing vary as the lift is changed and the relation depends on the geometry of the mechanical system. BMW has considerable production experience with CVVL systems and has sold port-injected "Valvetronic" engines since 2001. Fiat is now offering "MultiAir" engines enabling precise control over intake valve lift. CVVL allows the airflow into the engine to be regulated by means of intake valve opening reduction, which improves engine efficiency by reducing pumping losses from throttling the intake system further upstream as with a conventionally throttled engine.

Variable valve lift gives a further reduction in pumping losses compared to that which can be obtained with cam phase control only, with CVVL providing greater effectiveness than DVVL, since it can be fully optimized for all engine speeds and loads, and is not limited to a two or three step compromise. There may also be a small reduction in valvetrain friction when operating at low valve lift, resulting in improved low load fuel consumption for cam phase control with variable valve lift as compared to cam phase control only. Most of the fuel economy effectiveness is achieved with variable valve lift on the intake valves only. CVVL is only applicable to double overhead cam (DOHC) engines.

In the MYs 2012-2016 final rule, the agencies estimated the effectiveness for CVVL at 1.5 to 3.5 percent over an engine with DCP, but also recognized that it could go up as high as 5 percent above and beyond DCP to account for the implementation of more complex CVVL systems such as BMW's "Valvetronic" and Fiat "MultiAir" engines. For this rulemaking, NHTSA has increased the incremental effectiveness values for this technology, based on the updated LPM, to a range of 3.6 to 4.9 percent from 1.5 to 3.5 percent in the MYs 2012-2016 final rule.

In the MYs 2012-2016 rule and the 2010 TAR, the agencies estimated the DMC of CVVL at $174 (2007$), $320 (2007$) and $349 (2007$) for an OHC-I4, OHC-V6 and OHC-V8 engine, respectively. These DMCs become $182 (2010$), $333 (2010$) and $364 (2010$), or $45, $56 and $45 per cylinder for this analysis, all of which are considered applicable in MY 2015. Because the CAFE model uses cost per cylinder for this technology, NHTSA averaged the cost per cylinder for 4, 6 and 8 cylinder engines into a cost of $48 (2010$) per cylinder for application in the CAFE model. This technology is considered to be on the flat-portion of the learning curve. The agencies have applied a medium complexity ICM of 1.39 to this technology through 2018 and a long-term ICM of 1.29 thereafter. The resultant costs are shown in Table **V-38**.

Table V-38 Costs per Cylinder for Continuous Variable Valve Lift (2010$)

Index	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	$47	$46	$45	$44	$43	$42	$41	$41	$40

IC	$19	$19	$14	$14	$14	$14	$14	$14	$14
TC	$66	$65	$59	$58	$57	$56	$55	$55	$54

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to base engine.

Variable Valve Actuation (VVA)

For this final rule, consistent with the proposal, NHTSA has combined two valve control technologies for OHV engines; specifically, coupled cam phasing (CCPO) and discrete valve lift (DVVLO) have been combined into one technology, designated as variable valve actuation (VVA). The agency estimates the incremental effectiveness for VVA applied to an OHV engine as 2.71 to 3.59 percent. This effectiveness value is slightly lower than coupled cam phasing for overhead cam applications (CCPS), based on the assumption that VVA would be applied to an OHV engine after cylinder deactivation (DEAC). The cost for VVA is equal to the costs of CCPO and DVVLO together. However, since DEACO precedes VVA and includes the cost for lost motion devices, which enables DVVL, there is no additional cost for DVVL thus the VVA cost is equal to the CCPO cost.

Table V-39 Costs per Cylinder for Variable Valve Actuation (2010$)

Index	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	$37	$36	$35	$35	$34	$33	$33	$32	$31
IC	$15	$15	$11	$11	$11	$11	$11	$11	$11
TC	$52	$51	$46	$46	$45	$44	$43	$43	$42

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to base engine.

Cylinder Deactivation (DEACS, DEACD, DEACO)

In conventional spark-ignited engines, throttling the airflow controls engine torque output. At partial loads, efficiency can be improved by using cylinder deactivation instead of throttling. Cylinder deactivation (DEAC) can improve engine efficiency by disabling or deactivating (usually) half of the cylinders when the load is less than half of the engine's total torque capability – the valves are kept closed, and no fuel is injected – as a result, the trapped air within the deactivated cylinders is simply compressed and expanded as an air spring, with reduced friction and heat losses. The active cylinders combust at almost double the load required if all of the cylinders were operating. Pumping losses are significantly reduced as long as the engine is operated in this "part-cylinder" mode.

Cylinder deactivation control strategy relies on setting maximum manifold absolute pressures or predicted torque within which it can deactivate the cylinders. Noise and vibration issues can reduce the operating range to which cylinder deactivation is allowed, although manufacturers continue exploring vehicle changes that enable increasing the amount of time that cylinder deactivation might be suitable. Some manufacturers may choose to adopt active engine mounts and/or active noise cancellations systems to address NVH concerns and to allow a greater operating range of activation (and the agencies have estimated the costs for doing so, as noted below). Manufacturers have legitimately stated that use of DEAC on 4 cylinder engines would cause unacceptable NVH; therefore, as in the 2012-2016 rule and the TAR, the agencies are not applying cylinder deactivation to 4-cylinder engines in evaluating potential emission reductions/fuel economy improvements and attendant costs.

Cylinder deactivation has seen a recent resurgence thanks to better valvetrain designs and engine controls. General Motors and Chrysler Group have incorporated cylinder deactivation across a substantial portion of their V8-powered lineups. Honda also offers V6 models (Odyssey, Pilot) with cylinder deactivation.

Effectiveness improvements scale roughly with engine displacement-to-vehicle weight ratio: the higher displacement-to-weight vehicles, operating at lower relative loads for normal driving, have the potential to operate in part-cylinder mode more frequently.

NHTSA and EPA reviewed effectiveness estimates from MYs2012-2016 final rule, TAR, and the FRIA for the heavy-duty GHG and fuel consumption rule. Previous estimates ranged from a 6 percent reduction in CO_2 emissions depending on vehicle class for the OMEGA model, which uses technology packages. The following ranges were used in the CAFE model, due to its incremental nature, depending on the engine valvetrain configuration: for DOHC engines which are already equipped with DCP and DVVLD, only up to 0.5 percent for DEACD; for SOHC engines which have CCP and DVVLS applied, from 2.5 to 3 percent for DEACS; and for OHV engines, without VVT or VVL technologies, from 3.9 to 5.5 percent for DEACO.

For this final rule, consistent with the proposal, the agencies, taking into account the additional review and the work performed for the Ricardo study, have revised the estimates for cylinder deactivation. The effectiveness for relative to the base engine is 4.7 to 6.5 percent based on the lumped parameter model. Because of the incremental nature of the CAFE model, NHTSA used the effectiveness range of 0.44 to 0.66 percent incremental for SOHC and DOHC applications, and for OHV applications, the effectiveness was increased slightly with a range of 4.66 to 6.30 percent.

In the 2012-2016 rule and the 2010 TAR, the agencies used a DMC estimate of $140 (2007$) and $157 (2007$) for cylinder deactivation technology on V6 and V8 engines, respectively. The DMCs become $146 (2010$) and $165 (2010$) for this analysis and are considered applicable in MY 2015. This technology is considered to be on the flat-portion of the learning curve. The agencies have applied a low complexity ICM of 1.24 to this technology through 2018 and a long-term ICM of 1.19 thereafter. The resultant costs are shown in Table **V-40**.

Table V-40 Costs for Cylinder Deactivation (2010$)

Cost type	Engine type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	V6	$139	$136	$134	$131	$128	$126	$123	$121	$118
DMC	V8	$157	$153	$150	$147	$144	$142	$139	$136	$133
IC	V6	$56	$56	$42	$42	$42	$42	$42	$42	$42
IC	V8	$63	$63	$47	$47	$47	$47	$47	$47	$47
TC	V6	$196	$193	$176	$173	$170	$168	$165	$162	$160
TC	V8	$220	$217	$198	$195	$191	$189	$186	$183	$180

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline.

If lost motion devices are on the engine from the application of DVVL, the cost of DEACS and DEACD, for SOHC and DOHC engines respectively, would be $32 in MY 2017. This $32 accounts for the potential additional application of active engine mounts on SOHC and DOHC engines.[225] Further, this SOHC and DOHC engine estimate is relevant to the CAFE model only, because the OMEGA model does not apply technologies in the same incremental fashion as the CAFE model.

Stoichiometric Gasoline Direct Injection (SGDI)

Stoichiometric gasoline direct injection (SGDI), or Spark Ignition Direct injection (SIDI), engines inject fuel at high pressure directly into the combustion chamber (rather than the intake port in port fuel injection). SGDI requires changes to the injector design, an additional high pressure fuel pump, new fuel rails to handle the higher fuel pressures and changes to the cylinder head and piston crown design. Direct injection of the fuel into the cylinder improves cooling of the air/fuel charge within the cylinder, which allows for higher compression ratios and increased thermodynamic efficiency without the onset of combustion knock. Recent injector design advances, improved electronic engine management systems and the introduction of multiple injection events per cylinder firing cycle promote better mixing of the air and fuel, enhance combustion rates, increase residual exhaust gas tolerance and improve cold start emissions. SGDI engines achieve higher power density and match well with other technologies, such as boosting and variable valvetrain designs.

Several manufacturers are currently manufacturing vehicles with SGDI engines, including VW/Audi, BMW, Toyota, Ford, and General Motors among others with plans to increase the number of SGDI engines across their portfolios.

[225] The $32 cost for active engine mounts comes from the $75 (RPE) estimate used in the MY 2011 final rule that was then adjusted to account for the use of the ICM instead of the RPE. The cost is then divided by two due to the assumption that only half the applications would require active engine mounts to meet NVH targets.

NHTSA and EPA reviewed effectiveness estimates from the 2012-2016 final rule and TAR, which employed an effectiveness range for SGDI of between 2 and 3 percent. NHTSA and EPA reviewed estimates from the Alliance of Automobile Manufactures, which projects 3 percent gains in fuel efficiency and a 7 percent improvement in torque. The torque increase provides the opportunity to downsize the engine, allowing an increase in efficiency of up to 5.8 percent. NHTSA and EPA also reviewed other published literature reporting 3 percent effectiveness for SGDI.[226] Confidential manufacturer data reported an efficiency effectiveness range of 1 to 2 percent. Based on data from the recent Ricardo study and reconfiguration of the new lumped parameter model, EPA and NHTSA have revised this value to 1.5 percent[227]. Combined with other technologies (*i.e.*, boosting, downsizing, and in some cases, cooled EGR), SGDI can achieve greater reductions in fuel consumption and CO_2 emissions compared to engines of similar power output.

The NHTSA and EPA cost estimates for SGDI take into account the changes required to the engine hardware, engine electronic controls, ancillary and NVH mitigation systems. Through contacts with industry NVH suppliers, and manufacturer press releases, the agencies believe that the NVH treatments will be limited to the mitigation of fuel system noise, specifically from the injectors and the fuel lines and have included corresponding cost estimates for these NVH controls. In the 2012-2016 final rule analysis, the agencies estimated the DMC for SGDI at $213 (2007$), $321 (2007$) and $386 (2007$) for I3/I4, V6 and V8 engines, respectively. These DMCs become $222 (2010$), $334 (2010$) and $402 (2010$) or $56, $56 and $51 per cylinder for this analysis, all of which are considered applicable in MY 2012. Because the CAFE model uses cost per cylinder for this technology, NHTSA averaged the cost per cylinder for 4, 6 and 8 cylinder engines into a cost of $54 (2010$) per cylinder for application in the CAFE model. This technology is considered to be on the flat-portion of the learning curve. The agencies have applied a medium complexity ICM of 1.39 to this technology through 2018 and a long-term ICM of 1.29 thereafter. The resultant costs are shown in Table **V-41**.

Table V-41 Costs per Cylinder for Stoichiometric Gasoline Direct Injection (2010$)

Index	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	$47	$46	$45	$44	$43	$42	$41	$40	$40
IC	$20	$20	$15	$15	$15	$15	$15	$15	$15
TC	$67	$66	$60	$59	$58	$57	$56	$55	$55

[226] Paul Whitaker, Ricardo, Inc., "Gasoline Engine Performance And Emissions – Future Technologies and Optimization," ERC Symposium, Low Emission Combustion Technologies for Future IC Engines, Madison, WI, June 8-9, 2005, Docket No. NHTSA-2010-0131. Available at http://www.erc.wisc.edu/symposiums/2005_Symposium/June%208%20PM/Whitaker_Ricardo.pdf (last accessed Nov. 4, 2011).

[227] However, because GDI is a key enabler for modern, highly downsized turbocharged engines, this difference will be overshadowed by the higher effectiveness for turbocharging and downsizing when they are combined.

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to base engine.

Turbocharging and Downsizing (TRDBS)

The specific power of a naturally aspirated engine is primarily limited by the rate at which the engine is able to draw air into the combustion chambers. Turbocharging and supercharging (grouped together here as boosting) are two methods to increase the intake manifold pressure and cylinder charge-air mass above naturally aspirated levels. Boosting increases the airflow into the engine, thus increasing the specific power level, and with it the ability to reduce engine displacement while maintaining performance. This effectively reduces the pumping losses at lighter loads in comparison to a larger, naturally aspirated engine.

Almost every major manufacturer currently markets a vehicle with some form of boosting. While boosting has been a common practice for increasing performance for several decades, turbocharging has considerable potential to improve fuel economy and reduce CO_2 emissions when the engine displacement is also reduced. Specific power levels for a boosted engine often exceed 100 hp/L compared to naturally aspirated engine average power densities of approximately 70 hp/L. As a result, engines can be downsized roughly 30 percent or more while maintaining similar peak output levels.

In the last decade, improvements to turbocharger turbine and compressor design have improved their reliability and performance across the entire engine operating range. New variable geometry turbines and ball-bearing center cartridges allow faster turbocharger spool-up (virtually eliminating the once-common "turbo lag") while maintaining high flow rates for increased boost at high engine speeds. Low speed torque output has been dramatically improved for modern turbocharged engines. However, even with turbocharger improvements, maximum engine torque at very low engine speed conditions (for example, launch from standstill) is increased less than at mid and high engine speed conditions. In order to provide adequate acceleration from standstill, particularly up grades or at high altitudes, the potential to downsize engines may be less on vehicles with low displacement to vehicle mass ratios (for example, a very small displacement engine in a vehicle with significant curb weight).

Use of GDI systems with turbocharged engines and air-to-air charge air cooling also reduces the fuel octane requirements for knock limited combustion and allows the use of higher compression ratios. Ford's "Ecoboost" downsized, turbocharged GDI engines introduced on MY 2010 vehicles allow the replacement of V8 engines with V6 engines with improved in 0-60 mph acceleration and with fuel economy improvements of up to 12 percent.[228]

[228] "Development and Optimization of the Ford 3.5L V6 EcoBoost Combustion System," Yi,J., Wooldridge, S., Coulson, G., Hilditch, J. Iyer, C.O., Moilanen, P., Papaioannou, G., Reiche, D. Shelby, M., VanDerWege, B.,

Recently published data with advanced spray-guided injection systems and more aggressive engine downsizing targeted towards reduced fuel consumption and CO_2 emissions reductions indicate that the potential for reducing CO_2 emissions for turbocharged, downsized GDI engines may be as much as 15 to 30 percent relative to port-fuel-injected engines.[229] [230] [231] [232] [233] Confidential manufacturer data suggests an incremental range of fuel consumption reduction of 4.8 to 7.5 percent for turbocharging and downsizing. Other publicly-available sources suggest a fuel consumption reduction of 8 to 13 percent compared to current-production naturally-aspirated engines without friction reduction or other fuel economy technologies: a joint technical paper by Bosch and Ricardo suggests a fuel economy gain of 8 to 10 percent is possible for downsizing from a 5.7 liter port injection V8 to a 3.6 liter V6 with direct injection using a wall-guided direct injection system;[234] a Renault report suggests a 11.9 percent NEDC fuel consumption gain for downsizing from a 1.4 liter port injection in-line 4-cylinder engine to a 1.0 liter in-line 4-cylinder engine, also with wall-guided direct injection;[235] and a Robert Bosch paper suggests a 13 percent NEDC gain for downsizing to a turbocharged DI engine, again with wall-guided injection.[236] [237] These reported fuel economy benefits show a wide range depending on the SGDI technology employed.

Weaver, C. Xu, Z., Davis, G., Hinds, B. Schamel, A. SAE Technical Paper No. 2009-01-1494, 2009, Docket EPA-HQ-OAR-2009-0472-2860.

[229] Cairns et al., Lotus, "Low Cost Solutions for Improved Fuel Economy in Gasoline Engines," Global Powertrain Congress September 27-29, 2005, vol. 33. Available at http://www.gpc-icpem.org/pages/publications.html (last accessed March 15, 2010).

230 Tim Lake, John Stokes, Richard Murphy, and Richard Osborne of Ricardo and Andreas Schamel of Ford-Werke, "Turbocharging Concepts for Downsized DI Gasoline Engines," VKA/ika Aachen Colloquium 2003. Available at http://cat.inist.fr/?aModele=afficheN&cpsidt=16973598 (last accessed Nov. 9, 2011).

231 "Interim Report: New Powertrain Technologies and Their Projected Costs," October 2005, EPA420-R-05-012. Docket NHTSA-2010-0131. Available at http://www.epa.gov/otaq/technology/420r05012.pdf (last accessed November 14, 2011)

232 "Cost and Fuel Economy Comparison of Diesel and Gasoline Powertrains in Passenger Cars and Light Trucks," submitted by FEV Engine Technology, Inc., April 23, 2003, contained as Appendix I within EPA Interim Technical Report EPA420-R-04-002. Docket N0o. NHTSA-2010-0131

233 "Electric Cars: Plugged In, Batteries must be included," Deutsche Bank Global Markets Research Company, June 9, 2008. Docket NHTSA-2010-0131 or Available at http://www.inrets.fr/fileadmin/recherche/transversal/pfi/PFI_VE/pdf/deutch_bank_electric_cars.pdf (last accessed November 14, 2011)

[234] David Woldring and Tilo Landenfeld of Bosch, and Mark J. Christie of Ricardo, "DI Boost: Application of a High Performance Gasoline Direct Injection Concept," SAE 2007-01-1410. Available at http://www.sae.org/technical/papers/2007-01-1410 (last accessed August. 8, 2012)

[235] Yves Boccadoro, Loïc Kermanac'h, Laurent Siauve, and Jean-Michel Vincent, Renault Powertrain Division, "The New Renault TCE 1.2L Turbocharged Gasoline Engine," 28th Vienna Motor Symposium, April 2007.

[236] Tobias Heiter, Matthias Philipp, Robert Bosch, "Gasoline Direct Injection: Is There a Simplified, Cost-Optimal System Approach for an Attractive Future of Gasoline Engines?" AVL Engine & Environment Conference, September 2005. Docket No. NHTSA-2010-0131

[237] NEDC is the New European Driving Cycle. It was created to represent the typical driving pattern in Europe and is used in the EU emission and fuel economy certification tests. The cycle consists of the old European driving cycle (ECE15) and an Extra-Urban driving cycle (EUDC)

NHTSA and EPA reviewed estimates from MYs 2012-2016 final rule, the TAR, and existing public literature. The previous estimate from the MYs 2012-2016 assumed a 12 to 14 percent absolute effectiveness improvement, which included low friction lubricant (level one), engine friction reduction (level one), DCP, DVVL and SGDI, over a baseline fixed-valve engines, similar to the estimate for Ford's Ecoboost engine, which is already in production. Additionally, the agencies analyzed Ricardo vehicle simulation data for various turbocharged engine packages. Based on this data, and considering the widespread nature of the public estimates, the agencies believe that the effectiveness of turbocharging and downsizing is highly dependent upon implementation and degree of downsizing.

Given these variances, for this final rule, consistent with the proposal, the agencies evaluated 4 different levels of downsized and turbocharged high Brake Mean Effective Pressure (BMEP)[238] engines: 18-bar (TRBDS1), 24-bar (TRBDS2), 24-bar with cooled exhaust gas recirculation (CEGR1), and 27-bar with cooled EGR (CEGR2). All engines are assumed to include gasoline direct injection (SGDI), and thus the effectiveness values for TRBDS include the benefits of this technology. In addition, the agencies believe that in order to implement in production a 27-bar level engine, it is necessary to incorporate cooled exhaust gas recirculation (EGR), and also to require a 2-stage turbocharger as well as engine changes to increase robustness of the engine to allow the engine to operate at these higher BMEP levels. The cooled EGR technology is discussed later in this section. To mitigate potential issues with launch performance for these highly downsized engines, NHTSA does not allow the application of 24- or 27-bar engines unless the vehicle utilizes an 8-speed automatic or DCT transmission or a 6-speed manual transmission. This requirement helps to ensure that the transmission's gear ratio spread can accommodate a lower first gear, a.k.a. "granny gear", to aid in launching the vehicle from a complete stop. Table V-42 lists the possible engine downsizing options that the agencies considered in this FRM analysis.

Table V-42 Possible Engine Downsizing Options

Base Engine	18-bar Engine	24-bar Engine	27-bar Engine
I4	I4	I3	I3
V6	I4	I4	I4
V8+	V6	V6	I4

[238] Brake Mean Effective Pressure is the average amount of pressure in pounds per square inch (psi) that must be exerted on the piston to create the measured horsepower. This indicates how effective an engine is at filling the combustion chamber with an air/fuel mixture, compressing it and achieving the most power from it. A higher BMEP value contributes to higher overall efficiency.

NHTSA and EPA have revised the effectiveness estimate for TRBDS to reflect the new Ricardo work, and now assume that turbocharging and downsizing, alone, will provide a 12 to 24.6 percent absolute effectiveness improvement (depending on the degree of downsizing and boost levels) over naturally aspirated, fixed-valve engines. More specifically, 12.1 to 14.9 percent for 18-bar engines, which is equal to the boost levels evaluated in the MYs 2012-2016 final rule, assuming 33 percent downsizing; 16.4 to 20.1 percent for 24-bar engines, assuming 50 percent downsizing; 19.3 to 23.0 percent for 24-bar engines with cooled EGR, assuming 50 percent downsizing; and 20.6 to 24.6 percent for 27-bar engines with cooled EGR, assuming 56 percent downsizing. For comparison purposes, an 18-bar engine with low friction lubricant (level one), engine friction reduction (level one), DCP, DVVL and SGDI, which as stated above was assumed to yield a 12 to 14 absolute effectiveness in the MYs 2012-2016 analysis, now results in a 16.8 to 20.9 percent absolute effectiveness improvement. Coupling turbocharging and downsizing with low friction lubricant (level one and two), engine friction reductions (level one and two), DCP, DVVL and SGDI, for the MYs 2017-2025 timeframe, yields 18.0 to 22.4 percent for 18-bar engines 20.4 to 25.2 percent for 24-bar engines, 23.2 to 27.9 percent for 24-bar engine with cooled EGR, and 24.0 to 28.8 percent for 27-bar with cooled EGR over naturally aspirated, fixed-valve engines. Thus, these changes have contributed significantly to the agencies' ability to assume improvements in fuel economy during the rulemaking timeframe.

As noted above, the agencies relied on engine teardown analyses conducted by EPA, FEV and Munro to develop costs for turbocharged GDI engines.[239] Based on that work, in the 2012-2016 final rule, the agencies estimated the DMC for turbocharging to 18 bar BMEP at $404 (2007$) and $681 (2007$) for I4 and V6/V8 engines, respectively, where the higher cost for the V-configuration engines represents twin turbochargers versus the single turbocharger in the I-configuration engine. Converting to 2010$, these DMCs become $420 and $708, respectively, for this analysis. For the higher BMEP engines, in the 2010 TAR, the agencies assumed costs for 24 bar BMEP turbocharging of 1.5x the cost of the 18 bar BMEP technology, and also assumed single stage turbo for these 24 bar BMEP engine. This additional cost covered the incremental cost increase of a variable geometry turbocharger (see 2010 TAR at page B-12). Using this methodology, the DMC for 24 bar BMEP would be $630 (2010$) and $1,062 (2010$) for I-configuration and V-configuration engines, respectively. Similarly, for this final rule the agencies are assuming the DMC of the 27 bar BMEP technology is 2.5x the DMC of the 18 bar BMEP technology, or $1,050 (2010$) and $1,771 (2010$) for I-configuration and V-configuration engines, respectively. For these 27 bar BMEP engine, the agencies assumed two stage turbos would be used to reach these boost levels. All turbocharger-related DMCs are considered applicable in MY 2012. The agencies consider each turbocharger technology to be on the flat portion of the learning curve and have applied a medium complexity ICM of 1.39

[239] U.S. Environmental Protection Agency, "Draft Report – Light-Duty Technology Cost Analysis Pilot Study," Contract No. EP-C-07-069, Work Assignment 1-3, September 3, 2009, Docket No NHTSA-2010-0131.

through 2018 for 18 bar and through 2024 for 24 and 27 bar, then a long-term ICM of 1.29 to each thereafter. The resultant costs are shown in Table **V-43**.

Table V-43 Costs for Turbocharging (2010$)

Cost type	Technology (BMEP)	Engine type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	18 bar	I-engine	$365	$357	$350	$343	$336	$330	$323	$316	$310
DMC	18 bar	V-engine	$614	$602	$590	$578	$567	$555	$544	$533	$523
DMC	24 bar	I-engine	$547	$536	$525	$515	$504	$494	$484	$475	$465
DMC	24 bar	V-engine	$922	$903	$885	$867	$850	$833	$816	$800	$784
DMC	27 bar	I-engine	$911	$893	$875	$858	$841	$824	$807	$791	$775
DMC	27 bar	V-engine	$1,536	$1,505	$1,475	$1,446	$1,417	$1,389	$1,361	$1,334	$1,307
IC	18 bar	I-engine	$160	$160	$120	$119	$119	$119	$119	$118	$118
IC	18 bar	V-engine	$270	$270	$202	$201	$201	$200	$200	$200	$199
IC	24 bar	I-engine	$240	$240	$239	$239	$238	$238	$238	$237	$177
IC	24 bar	V-engine	$405	$404	$403	$403	$402	$401	$400	$400	$299
IC	27 bar	I-engine	$401	$400	$399	$398	$397	$397	$396	$395	$296
IC	27 bar	V-engine	$675	$674	$672	$671	$670	$669	$667	$666	$499
TC	18 bar	I-engine	$525	$517	$470	$462	$455	$448	$442	$435	$428
TC	18 bar	V-engine	$885	$872	$792	$779	$768	$756	$744	$733	$722
TC	24 bar	I-engine	$787	$776	$765	$754	$743	$732	$722	$712	$643
TC	24 bar	V-engine	$1,327	$1,308	$1,289	$1,270	$1,252	$1,234	$1,217	$1,200	$1,083
TC	27 bar	I-engine	$1,312	$1,293	$1,274	$1,256	$1,238	$1,220	$1,203	$1,186	$1,071
TC	27 bar	V-engine	$2,211	$2,179	$2,148	$2,117	$2,087	$2,057	$2,028	$2,000	$1,805

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline.

The cost for the downsizing portion of the turbo/downsize technology is more complex. The agencies have described those costs and how they were developed—based primarily on FEV teardowns but some were scaled to generate costs for downsizing situations that were not covered by teardowns—in both MYs 2012-2016 final rule and the TAR. The DMCs used for this analysis are identical to those used in the TAR, except that they have been updated to 2010 dollars. We note that many of the downsizing costs are negative because they result in fewer parts and less material than the engine from which they are "derived." For example, a V8 engine could be replaced by a turbocharged V6 engine having two fewer cylinders and as many as eight fewer valves (in the case of a V8 DOHC downsized to a V6 DOHC). However, the agencies' approach to calculating indirect costs results in positive indirect costs regardless of whether the DMC is positive or negative. This is done by calculating indirect costs based on the absolute value of the DMC, then adding the indirect cost to the DMC to arrive at the total cost. This way, the agencies are never making a negative DMC "more negative" when accounting for the indirect costs. This approach has been used in MYs 2012-2016 final rule and in the TAR. Given the history of the downsizing costs used by the agencies, many are considered applicable in MY 2012 and many in MY 2017.[240] All are considered to be on the flat portion of the learning curve. The agencies have applied a medium complexity ICM of 1.39 through 2018 and a long-term ICM of 1.29 thereafter. The resultant costs are shown in

Table V-44.

Table V-44 Costs for Engine Downsizing (2010$)

Cost type	Technology	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	I4 DOHC to I3	-174	-171	-167	-164	-161	-157	-154	-151	-148
DMC	I4 DOHC to I4	-77	-75	-74	-72	-71	-69	-68	-67	-65
DMC	V6 DOHC to I4	-494	-484	-474	-465	-455	-446	-437	-429	-420
DMC	V6 SOHC 2V to I4	-345	-338	-331	-325	-318	-312	-306	-300	-294
DMC	V6 OHV to I4	281	272	264	256	249	241	236	232	227
DMC	V8 DOHC to I4	-854	-828	-804	-779	-756	-733	-719	-704	-690
DMC	V8 DOHC to V6	-247	-242	-237	-233	-228	-223	-219	-215	-210
DMC	V8 SOHC 2V to I4	-656	-637	-617	-599	-581	-564	-552	-541	-530
DMC	V8 SOHC 3V to I4	-731	-709	-687	-667	-647	-627	-615	-603	-591
DMC	V8 SOHC 2V to V6	-76	-74	-73	-71	-70	-68	-67	-66	-64
DMC	V8 SOHC 3V to V6	-140	-137	-135	-132	-129	-127	-124	-122	-119
DMC	V8 OHV to I4	-242	-234	-227	-220	-214	-207	-203	-199	-195
DMC	V8 OHV to V6	328	318	308	299	290	281	276	270	265
IC	I4 DOHC to I3	77	76	57	57	57	57	57	57	57
IC	I4 DOHC to I4	34	34	25	25	25	25	25	25	25
IC	V6 DOHC to I4	217	217	162	162	161	161	161	161	160
IC	V6 SOHC 2V to I4	152	151	113	113	113	113	112	112	112

240 The engine downsizing costs based on actual FEV teardowns were considered applicable to the 2012MY, as was explained for some downsizing costs in the 2012-2016 final rule and others in the TAR. For other downsizing costs—the two changes from OHV engines to DOHC engines—the agencies did not use FEV teardowns or extrapolations from FEV teardowns, and instead used the methodology employed in the 2008 EPA Staff Report, a methodology determined to result in cost estimates more appropriate for MY 2017. The new downsizing costs—those for V8 engines downsized to I4 engines—use a combination of V8 to V6 then V6 to I4 downsizing costs and are considered applicable to MY 2017 within the context of this analysis.

IC	V6 OHV to I4	109	108	81	81	80	80	80	80	80
IC	V8 DOHC to I4	331	330	246	245	244	244	243	243	242
IC	V8 DOHC to V6	109	108	81	81	81	81	80	80	80
IC	V8 SOHC 2V to I4	254	253	189	188	188	187	187	187	186
IC	V8 SOHC 3V to I4	283	282	210	210	209	208	208	208	207
IC	V8 SOHC 2V to V6	33	33	25	25	25	25	25	25	25
IC	V8 SOHC 3V to V6	62	61	46	46	46	46	46	46	45
IC	V8 OHV to I4	94	93	70	69	69	69	69	69	69
IC	V8 OHV to V6	127	126	94	94	94	93	93	93	93
TC	I4 DOHC to I3	-98	-94	-110	-107	-104	-101	-98	-95	-92
TC	I4 DOHC to I4	-43	-41	-48	-47	-46	-44	-43	-42	-40
TC	V6 DOHC to I4	-277	-267	-312	-303	-294	-285	-277	-268	-260
TC	V6 SOHC 2V to I4	-193	-187	-218	-212	-205	-199	-193	-187	-182
TC	V6 OHV to I4	390	381	345	337	329	321	316	311	307
TC	V8 DOHC to I4	-523	-499	-558	-534	-512	-490	-476	-462	-448
TC	V8 DOHC to V6	-139	-134	-156	-152	-147	-143	-138	-134	-130
TC	V8 SOHC 2V to I4	-402	-383	-429	-411	-393	-376	-365	-355	-344
TC	V8 SOHC 3V to I4	-448	-427	-477	-457	-438	-419	-407	-395	-383
TC	V8 SOHC 2V to V6	-42	-41	-48	-46	-45	-44	-42	-41	-40
TC	V8 SOHC 3V to V6	-79	-76	-89	-86	-83	-81	-78	-76	-74
TC	V8 OHV to I4	-148	-141	-158	-151	-145	-139	-134	-131	-127
TC	V8 OHV to V6	454	444	403	393	384	375	369	363	358

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline; all resultant engines are DOHC.

The agencies note that the V8 to I4 engine downsize is new for this final rule, consistent with the proposal. This level of engine downsizing is considered for this analysis only if it also includes 27 bar BMEP turbo boost which requires the addition of cooled EGR (discussed below). As a result, any 27 bar BMEP engine in this analysis will be I4 configuration and include cooled EGR.

With the information shown in Table **V-43** and

Table V-44, the costs for any turbo/downsize change considered by the agencies can be determined. These costs are shown in Table **V-45**.

Table V-45 Total Costs for Turbo and Downsizing (2010$)

Downsize Technology	Turbo Technology (BMEP)	2017	2018	2019	2020	2021	2022	2023	2024	2025
I4 DOHC to I3	18 bar	$427	$423	$359	$356	$352	$348	$344	$340	$337
I4 DOHC to I3	24 bar	$690	$681	$654	$647	$639	$632	$624	$617	$551
I4 DOHC to I3	27 bar	$1,214	$1,199	$1,164	$1,149	$1,134	$1,120	$1,106	$1,092	$979
I4 DOHC to I4	18 bar	$482	$476	$421	$415	$410	$404	$399	$393	$388
I4 DOHC to I4	24 bar	$744	$734	$716	$707	$697	$688	$679	$670	$602
I4 DOHC to I4	27 bar	$1,269	$1,251	$1,226	$1,209	$1,192	$1,176	$1,160	$1,145	$1,031
V6 DOHC to I4	18 bar	$248	$250	$157	$159	$161	$163	$165	$167	$169
V6 DOHC to I4	24 bar	$510	$508	$452	$450	$449	$447	$445	$444	$383
V6 DOHC to I4	27 bar	$1,035	$1,026	$962	$953	$944	$935	$927	$918	$811
V6 SOHC 2V to I4	18 bar	$331	$330	$251	$251	$250	$249	$248	$248	$247
V6 SOHC 2V to I4	24 bar	$594	$589	$546	$542	$537	$533	$529	$524	$461
V6 SOHC 2V to I4	27 bar	$1,119	$1,106	$1,056	$1,044	$1,032	$1,021	$1,010	$999	$890
V6 OHV to I4	18 bar	$914	$898	$815	$799	$784	$770	$758	$746	$735
V6 OHV to I4	24 bar	$1,177	$1,156	$1,110	$1,090	$1,072	$1,053	$1,038	$1,023	$949
V6 OHV to I4	27 bar	$1,701	$1,674	$1,619	$1,593	$1,567	$1,542	$1,519	$1,498	$1,378
V8 DOHC to I4	18 bar	$1	$18	-$88	-$72	-$56	-$41	-$34	-$27	-$19
V8 DOHC to I4	24 bar	$264	$277	$207	$219	$231	$243	$246	$250	$195
V8 DOHC to I4	27 bar	$789	$794	$716	$722	$726	$731	$728	$725	$623
V8 DOHC to V6	18 bar	$746	$738	$635	$628	$620	$613	$606	$599	$592
V8 DOHC to V6	24 bar	$1,188	$1,174	$1,132	$1,118	$1,105	$1,092	$1,078	$1,066	$953
V8 DOHC to V6	27 bar	$2,073	$2,045	$1,991	$1,965	$1,940	$1,914	$1,890	$1,866	$1,675
V8 SOHC 2V to I4	18 bar	$123	$134	$41	$52	$62	$72	$76	$80	$84
V8 SOHC 2V to I4	24 bar	$385	$392	$336	$343	$350	$356	$357	$357	$298
V8 SOHC 2V to I4	27 bar	$910	$910	$846	$845	$845	$844	$838	$832	$727
V8 SOHC 3V to I4	18 bar	$77	$90	-$8	$5	$18	$29	$35	$40	$45
V8 SOHC 3V to I4	24 bar	$339	$349	$287	$296	$305	$313	$315	$317	$259
V8 SOHC 3V to I4	27 bar	$864	$866	$797	$799	$800	$801	$796	$791	$688
V8 SOHC 2V to V6	18 bar	$842	$831	$744	$733	$723	$712	$702	$692	$682
V8 SOHC 2V to V6	24 bar	$1,284	$1,267	$1,241	$1,224	$1,207	$1,191	$1,175	$1,159	$1,043
V8 SOHC 2V to V6	27 bar	$2,169	$2,138	$2,100	$2,071	$2,042	$2,014	$1,986	$1,959	$1,766
V8 SOHC 3V to V6	18 bar	$806	$796	$703	$693	$684	$675	$666	$657	$648
V8 SOHC 3V to V6	24 bar	$1,248	$1,232	$1,200	$1,184	$1,169	$1,153	$1,138	$1,124	$1,010
V8 SOHC 3V to V6	27 bar	$2,133	$2,103	$2,059	$2,031	$2,003	$1,976	$1,950	$1,924	$1,732
V8 OHV to I4	18 bar	$377	$376	$312	$311	$311	$310	$307	$304	$302
V8 OHV to I4	24 bar	$639	$635	$607	$602	$598	$594	$587	$581	$516
V8 OHV to I4	27 bar	$1,164	$1,152	$1,116	$1,105	$1,093	$1,082	$1,069	$1,056	$944
V8 OHV to V6	18 bar	$1,339	$1,316	$1,194	$1,172	$1,151	$1,131	$1,113	$1,096	$1,080
V8 OHV to V6	24 bar	$1,781	$1,752	$1,691	$1,663	$1,636	$1,609	$1,586	$1,563	$1,441
V8 OHV to V6	27 bar	$2,666	$2,623	$2,550	$2,510	$2,471	$2,432	$2,397	$2,363	$2,163

All costs are total costs (Direct manufacturing costs + Indirect costs); all costs are relative to the baseline; all resultant engines are DOHC; note that costs are shown for 27 bar BMEP engines with V6 engines. In fact, the agencies do not believe that manufacturers will employ 27 bar BMEP technology on V6 engines to comply with the final standards, instead using the additional boost to allow for downsizing V6 engines to smaller I4 engines than would be used for 18 bar BMEP or 24 bar BMEP I4 engines and/or downsizing V8 engines to I4 engines. As a result, whenever a 27 bar BMEP engine is chosen by either agency's model, the engine configuration will be an I4 and will include cooled EGR, as discussed above.

Cooled Exhaust Gas Recirculation/EGR Boost (CEGR)

Cooled exhaust gas recirculation (CEGR) or "boosted" EGR is a combustion concept that involves utilizing EGR as a charge diluent for controlling combustion temperatures and cooling the EGR prior to its introduction to the combustion system. Higher exhaust gas residual levels at part load conditions reduce pumping losses for increased fuel economy. The additional charge dilution enabled by cooled EGR reduces the incidence of knocking combustion and obviates the need for fuel enrichment or higher octane fuel at high engine power. This allows for higher boost pressure and/or compression ratio and further reduction in engine displacement and both pumping and friction losses while maintaining performance. Engines of this type use GDI and both dual cam phasing and discrete variable valve lift.

In the TAR, the agencies considered this technology as an advanced gasoline engine technology because it was considered an emerging and not yet available technology in the light-duty gasoline vehicle market. For the MYs 2012-2016 final rule and TAR, NHTSA and EPA assumed a 5 percent fuel consumption effectiveness for cooled EGR compared to a conventional downsized DI turbocharged engine. [241,242] While a cooled or "boosted" EGR technology was discussed in the MYs 2012-2016 rulemaking documents, the technology considered in this rulemaking is comparatively more advanced than the version described in the TAR. The agencies have therefore considered new costs and new effectiveness values for it. The effectiveness values used for engines with CEGR within this analysis were assumed by EPA and Ricardo to be conservative estimate of system performance at approximately 24-bar BMEP. Vehicle simulation modeling of technology packages using the more highly boosted and downsized cooled EGR engines (up to 27-bar BMEP, and utilizing EGR rates of 20-25%) with dual-stage turbocharging has been completed as part of EPA's contract with Ricardo as described in TSD Section 3.3.1.2.

For this FRM, consistent with the proposal, the agencies have updated the effectiveness of engines with CEGR using the new Ricardo vehicle simulation modeling runs. For 24-bar BMEP engines with CEGR, designated in the CAFE model inputs as CEGR1, would use a dual-loop system with both high and low pressure EGR loops and dual EGR coolers. The engines would also use single-stage, variable geometry turbocharging with higher intake boost pressure available across a broader range of engine operation than conventional turbocharged SI engines. Such a system is estimated to be capable of an additional 3 to 5 percent effectiveness relative to a turbocharged, downsized GDI engine without CEGR.[243,244] The agencies have also considered a

[241] Cairns *et al.*, Lotus, "Low Cost Solutions for Improved Fuel Economy in Gasoline Engines," Global Powertrain Congress September 27-29, 2005, vol. 33.
[242] Tim Lake, John Stokes, Richard Murphy, and Richard Osborne of Ricardo and Andreas Schamel of Ford-Werke, "Turbocharging Concepts for Downsized DI Gasoline Engines," VKA/ika Aachen Colloquium 2003. *Available at* http://cat.inist.fr/?aModele=afficheN&cpsidt=16973598 (last accessed Nov. 7, 2011).
[243] Kaiser, M., Krueger, U., Harris, R., Cruff, L. "Doing More with Less - The Fuel Economy Benefits of Cooled EGR on a Direct Injected Spark Ignited Boosted Engine," SAE Technical Paper Series, No. 2010-01-0589.

more advanced version of CEGR for 27-bar BMEP engines, designated in the CAFE model inputs as CEGR2, that employs very high combustion pressures by using dual stage turbocharging, developed by Ricardo as part of the simulation modeling work supporting this rulemaking. The agencies have considered both of these CEGR approaches for this final rule, consistent with the proposal.

Based on the data from the Ricardo and Lotus reports, NHTSA and EPA estimate the incremental reduction in fuel consumption for CEGR to be 5 percent over a turbocharged and downsized DI engine. Thus, if CEGR is applied to 24-bar engine, multiplicatively combining the 19.3 percent from the turbocharging and downsizing (TRBDS2) to the 5 percent gain from CEGR results in total fuel consumption reduction of 22.1 percent for CEGR1. This is in agreement with the range suggested in the Lotus and Ricardo reports.

In the 2010 TAR, the agencies estimated the DMC of the cooled EGR system at $240 (2007$, see 2010 TAR at page B-12). This DMC becomes $244 (updated to 2010$) for this analysis. This DMC is considered applicable in MY 2012. The agencies consider CEGR technology to be on the flat portion of the learning curve and have applied a medium complexity ICM of 1.39 through 2024 then a long-term ICM of 1.29 thereafter. The resultant costs are shown in Table V-46.

Table V-46 Costs for Cooled EGR (2010$)

Cost type	Engine type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	All	$212	$208	$204	$199	$195	$192	$188	$184	$180
IC	All	$93	$93	$93	$93	$92	$92	$92	$92	$69
TC	All	$305	$301	$296	$292	$288	$284	$280	$276	$249

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline.

Note that in the 2010 TAR, the agencies presented the CEGR system costs inclusive of turbo charging costs (see 2010 TAR, Table B2.2-1 at page B-12). For this analysis, the agencies are presenting the CEGR costs as a stand-alone technology that can be added to any turbo/downsized engine, provided sufficient boost is provided and sufficient engine robustness is accounted for in the engine design. As such, the CEGR system is considered applicable only to the 24 bar BMEP and 27 bar BMEP engines. Further, the agencies believe that 24 bar BMEP engines are capable

[244] Kapus, P.E., Fraidl, G.K., Prevedel, K., Fuerhapter, A. “GDI Turbo – The Next Steps,” JSAE Technical Paper No. 20075355, 2007.

of maintaining NO_x control without CEGR, so the models may choose 24 bar BMEP engines with and/or without CEGR, although 27 bar BMEP engines are considered to require CEGR to maintain NO_x emission control, so 27 bar BMEP technology cannot be applied in the analysis without also adding CEGR.

Advanced Diesel Engine Technologies (ADSL)

Diesel (compression ignition) engines have several characteristics that give them superior fuel efficiency compared to conventional gasoline, spark-ignited engines. Pumping losses are much lower due to lack of (or greatly reduced) throttling in a diesel engine. The diesel combustion cycle utilizes a higher compression ratio than that found in a typical gasoline engine. As a result, turbocharged light-duty diesels typically achieve much higher torque levels at lower engine speeds than equivalent-displacement naturally-aspirated gasoline engines. Future high BMEP turbocharged and downsized engines, mentioned above, are projected to improve torque levels at lower engine speeds thus reducing the diesel advantage in this area. Diesels also operate with a very lean air/fuel mixture. These attributes – reduced pumping losses, higher compression ratio and lean/air fuel mixture -- allow the engine to extract more energy from a given mass of fuel than a gasoline engine, and thus make it more efficient. Additionally, diesel fuel has higher energy content per gallon (approximately 128,700 Btu/gal (net)) than gasoline (115,400 Btu/gal (net)) fundamentally resulting from diesel fuel containing more carbon per gallon than gasoline: diesel produces 22.2 pounds of CO2 per gallon when burned, while gasoline produces 19.4 pounds of CO2 per gallon. This higher carbon content slightly offsets the GHG emissions benefit of diesel fuel relative to gasoline, however, the disbenefit is more than compensated by the greater efficiency of the diesel engine. Since diesel engines are more fuel efficient than gasoline engines, the agencies anticipate that manufacturers will evaluate and potentially invest in diesel engine production as a way to comply with more stringent CAFE standards.

However, there are two primary reasons why manufacturers might not choose to invest significantly in diesel engine technologies as a way to comply with the CAFE and GHG standards for MYs 2017-2025.

As discussed above, even though diesel has higher energy content than gasoline it also has a higher carbon density that results in higher amounts of CO_2 emitted per gallon, approximately 15 percent more than a gallon of gasoline. This is commonly referred to as the “carbon penalty” associated with using diesel fuel – a diesel vehicle yields greater fuel economy improvements compared to its CO_2 emissions reduction improvements, so a manufacturer that invests in diesel technology to meet CAFE standards may have more trouble meeting the GHG standards than if it used a different and more cost effective (from a GHG perspective) technology.

Second, diesel engines also have emissions characteristics that present challenges to meeting federal Tier 2 NOx emissions standards. By way of comparison for readers familiar with the

European on-road fleet, which contains many more diesel vehicles than the U.S. on-road fleet, U.S. Tier 2 emissions fleet average requirement of bin 5 require roughly 45 to 65 percent more NO_x reduction compared to the Euro VI standards.

Despite considerable advances by manufacturers in developing Tier 2-compliant diesel engines, it remains somewhat of a systems-engineering challenge to maintain the fuel consumption advantage of the diesel engine while meeting Tier 2 emissions regulations because some of the emissions reduction strategies can *increase* fuel consumption (relative to a Tier 1 compliant diesel engine), depending on the combination of strategies employed. A combination of combustion improvements (that reduce NO_X emissions leaving the engine) and aftertreatment (capturing NO_X emissions that have left the engine before they leave the vehicle tailpipe) are being introduced on Tier 2 compliant light-duty diesel vehicles today.

We spend time here discussing available emissions reduction technologies for diesel engines as part of this rulemaking because of the potential they have to impact fuel economy and GHG emissions for the vehicles that have them. With respect to combustion improvements, we note that several key advances in diesel engine combustion technology have made it possible to reduce emissions coming from the engine prior to aftertreatment, which reduces the need for aftertreatment. These technologies include improved fuel systems (higher injection pressure and multiple-injection capability), advanced controls and sensors to optimize combustion and emissions performance, higher EGR levels and EGR cooling to reduce NO_x, and advanced turbocharging systems. With the exception of EGR, these systems are available today and they do not adversely impact fuel efficiency. However, additional improvements in these technologies will be needed to reduce engine emissions further, should future emissions standards become more stringent. Further development may also be needed to reduce the fuel efficiency penalty associated with EGR.

With respect to aftertreatment, the traditional 3-way catalyst aftertreatment used on gasoline-powered vehicles to meet criteria pollutant regulations is ineffective due to the lean-burn combustion of a diesel, because 3-way catalysts work only with stoichiometric engines. To reduce NOx, hydrocarbons, and particulate emissions, all diesels will require a diesel particulate filter (DPF) or catalyzed diesel particulate filter (CDPF), a diesel oxidation catalyst (DOC), and some kind of NO_x reduction strategy to comply with Tier 2 emissions standards. The most common NO_x reduction strategies include the use of lean NO_x traps (LNT)[245] or selective

[245] A lean NO_x trap operates, in principle, by oxidizing NO to NO_2 in the exhaust and storing NO_2 on alkali sorbent material. When the control system determines (via mathematical model or a NO_x sensor) that the trap is saturated with NO_x, it switches the engine into a rich operating mode or may in some cases inject fuel directly into the exhaust stream to produce excess hydrocarbons that act as a reducing agent to convert the stored NO_x to N_2 and water, thereby "regenerating" the LNT and opening up more locations for NO_x to be stored. LNTs preferentially store sulfate compounds from the fuel, which can reduce catalytic performance. The system must undergo periodic

catalytic reduction (SCR).[246] A similar approach, but with greater catalyst volumes and potentially higher precious metal loading, would likely be used to meet potential and more stringent criteria emission standards. A fuel consumption penalty can be associated with some aftertreatment systems. This penalty is due to the fact that extra fuel is needed for the aftertreatment and this extra fuel is not used in the combustion process of the engine that provides torque to propel the vehicle thus reducing fuel efficiency.

Thus, both combustion improvements (for Tier 2 purposes) and aftertreatment may be associated with a fuel consumption and an emissions reduction penalty; this penalty combined with the extra cost of diesel emissions control technologies that are not necessary for gasoline engines may also make diesels less attractive to manufacturers as a technology solution for more stringent CAFE and GHG standards. However, recognizing that some manufacturers may still employ diesel technology to meet the future standards, the agencies have included diesels in our analysis as follows:

First, we sought to ensure that diesel engines would have equivalent performance to comparable gasoline engine vehicles. The purpose of this approach is to provide an adequate assessment of diesel fuel consumption performance. For the Subcompact, Compact, and Midsize Passenger Car, Performance Subcompact Car, and Small Light Truck vehicle subclasses, the agencies assumed that an I4 gasoline base engine would be replaced by an in-line 4-cylinder diesel engine with displacement varying around 2.0 liters. For the Performance Compact, Performance Midsize, Large Passenger Car, Minivan, and Midsize Truck vehicle subclasses for the CAFE model, the agencies assumed that a V6 gasoline base engine would be replaced by an in-line 4-cylinder diesel engine with displacement varying around 2.8 liters. For the Large Truck and Performance Large Car vehicle subclasses for the CAFE model, the agencies assumed that a V8 gasoline base engine would be replaced with a V6 diesel engine with displacement varying around 4.0 liters to meet vehicle performance requirements. It was also assumed that diesel engines for all of these classes would utilize SCR aftertreatment systems given recent improvements in SCR systems and system efficiency. These assumptions impacted our estimates of the costs of implementing diesel engines as compared to the base gasoline engines.

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desulfurization by operating at a net-fuel-rich condition at high temperatures in order to retain NO_x trapping efficiency.

[246] An SCR aftertreatment system uses a reductant (typically, ammonia derived from urea) that is injected into the exhaust stream ahead of the SCR catalyst. Ammonia combines with NO_x in the SCR catalyst to form N_2 and water. The hardware configuration for an SCR system is more complicated than that of an LNT, due to the onboard urea storage and delivery system (which requires a urea pump and injector to inject urea into the exhaust stream), which generally makes an SCR system cost more than an LNT system. While a rich engine-operating mode is not required for NO_x reduction, the urea is typically injected at a rate of approximately 3 percent of the fuel consumed. The agencies understand that manufacturers designing SCR systems intend to align urea tank refills with standard maintenance practices such as oil changes as more diesel vehicles are introduced into the market. For diesel vehicles currently on the market, this is generally already the practice, and represents an ongoing maintenance cost for vehicles with this technology.

Diesel engines are more costly than port-injected spark-ignition gasoline engines. These higher costs result from more costly components, more complex systems for emissions control, and other factors. The vehicle systems that are impacted include:

- Fuel systems (higher pressures and more responsive injectors);
- Controls and sensors to optimize combustion and emissions performance;
- Engine design (higher cylinder pressures require a more robust engine, but higher torque output means diesel engines can have reduced displacement);
- Turbocharger(s);
- Aftertreatment systems, which tend to be more costly for diesels;

In the MYs 2012-2016 final rule, the agencies estimated the DMC for converting a gasoline PFI engine with 3-way catalyst aftertreatment to a diesel engine with diesel aftertreatment at $1,697 (2007$), $2,399 (2007$), $1,956 (2007$) and $2,676 (2007$) for a small car, large car, medium/large MPV & small truck, and large truck, respectively (see MYs 2012-2016 final Joint TSD, Table 3-12 at page 3-44). See table V-8 of the document to convert the vehicle classes listed above and in the MYs 2012-2016 final Joint TSD to NHTSA subclasses. All of these costs were for SCR-based diesel systems, with the exception of the small car, which was a LNT-based system. For this final rule, consistent with the proposal, we are using the same methodology as used in the MYs 2012-2016 final rule, but have made four primary changes to the cost estimates as was also done in the proposal for this rule. First, the agencies have not estimated costs for a LNT-based system, and instead have estimated costs for all vehicle types assuming they will employ SCR-based systems. Second, the agencies assumed that manufacturers would meet a Tier 2 bin 2 average rather than a Tier 2 bin 5 average, assuming that more stringent levels of compliance will be required in the future. In order to estimate costs for Tier 2 bin 2 compliant vehicles, catalyst volume costs were estimated based on an assumed increase in volume of 20 percent. This was the estimated necessary increase needed to meet Tier 2, bin 2 emission level of 0.02 grams of NOx per mile. Increased catalyst volume resulted in a higher cost estimate for diesel aftertreatment than was estimated for the MYs 2012-2016 final rule. The third is to update all platinum group metal costs from the March 2009 values used in the 2012-2016 final rule to February 2011 values.[247] The February 2011 values were used for purposes of the NPRM analysis, at which time they represented the most recent monthly average prices available at the time the agencies "locked-down" all cost estimates for the purposes of moving into the modeling phase of analysis.[248] For the final rule analysis, the agencies did not

[247] As reported by Johnson-Matthey, the March 2009 monthly average costs were $1,085 per Troy ounce and $1,169 per Troy ounce for platinum (Pt) and rhodium (Rh), respectively. As also reported by Johnson-Matthey, the February 2011 monthly average costs were $1,829 per Troy ounce and $2,476 per Troy ounce for Pt and Rh, respectively. See www.platinum.matthey.com.

[248] Note that there is no good way of determining what PGM prices to use when conducting cost analyses. Spot prices are inherently dangerous to use because spot prices, like stock prices on the stock market, can vary considerably from day to day. One could argue that an average price is best, but average prices can vary

update the cost for platinum group metals. The fourth is to include an additional $50 DMC for all costs to cover costs associated with improvements to fuel and urea controls. All of the diesel costs are considered applicable to MY 2012. The agencies consider diesel technology to be on the flat portion of the learning curve and have applied a medium complexity ICM of 1.39 through 2018, and then a long-term ICM of 1.29 thereafter. The resultant costs are shown in

Table V-47.

Table V-47 Costs for Conversion to Advanced Diesel (2010$)

Cost type	NHTSA Vehicle Subclass	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	Subcompact PC, Subcompact Perf. PC, Compact PC, Midsize PC and Small LT	$2,059	$2,019	$1,979	$1,938	$1,900	$1,861	$1,825	$1,788	$1,752
DMC	Compact Perf. PC, Midsize Perf. PC, Large PC, Minivan LT and Midsize LT	$2,082	$2,040	$2,000	$1,959	$1,920	$1,882	$1,844	$1,808	$1,772
DMC	Large Perf. PC and Large LT	$2,887	$2,828	$2,771	$2,717	$2,662	$2,609	$2,556	$2,506	$2,455
IC	Subcompact PC, Subcompact Perf. PC, Compact PC, Midsize PC and Small LT	$905	$904	$676	$675	$673	$672	$671	$670	$669
IC	Compact Perf. PC, Midsize Perf. PC, Large PC, Minivan LT and Midsize LT	$915	$913	$683	$682	$681	$679	$678	$677	$676
IC	Large Perf. PC and Large LT	$1,269	$1,266	$946	$944	$943	$941	$940	$938	$936
TC	Subcompact PC, Subcompact Perf. PC, Compact PC, Midsize PC and Small LT	$2,965	$2,922	$2,653	$2,613	$2,572	$2,534	$2,496	$2,457	$2,421
TC	Compact Perf. PC, Midsize Perf. PC, Large PC, Minivan LT and Midsize LT	$2,997	$2,953	$2,683	$2,641	$2,601	$2,560	$2,522	$2,485	$2,447

considerably depending on the length of time included in the average. And if too much time is included in the average, then average prices from a time prior to PGM use in diesel engines may be included which would lead some to conclude that we had cherry picked our values. Given no good option, it seems most transparent and least selfserving to simply choose a price and report its basis. In the end, the PGM costs represent 16-23 percent of the diesel DMC in this analysis. Further, diesels play very little to no role in enabling compliance with the final standards.

TC	Large Perf. PC and Large LT	$4,155	$4,094	$3,718	$3,661	$3,606	$3,550	$3,497	$3,444	$3,392

For the MYs 2012-2016 final rule and TAR, NHTSA and EPA estimated the fuel consumption reduction of a SCR-based diesel engine to be between 20 to 25 percent over a baseline gasoline engine. NHTSA and EPA have revisited these values based on the Ricardo 2011 study, and have now estimated the absolute effectiveness of a SCR-based diesel engine to be 28.4 to 30.5 percent.

Transmission Technologies

NHTSA and EPA reviewed the transmission technology estimates used in the MYs 2012-2016 final rule and the TAR. In doing so, NHTSA and EPA considered or reconsidered all available sources and updated the estimates as appropriate. The section below describes each of the transmission technologies considered for this rulemaking. As discussed above, for the final rule NHTSA has updated the effectiveness values for advanced transmissions when coupled to naturally-aspirated engines based on the ANL simulation modeling. These changes are documented in detail in the transmission section of NHTSA's RIA Chapter V because they are specific to NHTSA's analysis only.

Improved Automatic Transmission Controls (IATC)

Calibrating the transmission shift schedule to upshift earlier and quicker, and to lock-up or partially lock-up the torque converter under a broader range of operating conditions can reduce fuel consumption. However, this operation can also result in a perceptible degradation in noise, vibration, and harshness (NVH). The degree to which NVH can be degraded before it becomes noticeable to the driver is strongly influenced by characteristics of the vehicle, and although it is somewhat subjective, it always places a limit on how much fuel consumption can be improved by transmission control changes. Aggressive Shift Logic and Early Torque Converter Lockup are best optimized simultaneously when added to an automatic transmission, due to the fact that adding both of them requires only minor modifications to the transmission mechanical components or calibration software. As a result, these two technologies are combined in the modeling when added to an automatic transmission. Since a dual clutch transmission (DCT) has no torque converter, the early torque converter lockup technology cannot be applied to DCTs.

Aggressive Shift Logic

During operation, a transmission's controller manages the operation of the transmission by scheduling the upshift or downshift, and, in automatic transmissions, locking or allowing the torque converter to slip based on a preprogrammed shift schedule. The shift schedule contains a number of lookup table functions, which define the shift points and torque converter lockup based on vehicle speed and throttle position, and other parameters such as temperature.

Aggressive shift logic (ASL) can be employed in such a way as to maximize fuel efficiency by modifying the shift schedule to upshift earlier and inhibit downshifts under some conditions, which reduces engine pumping losses and engine friction. The application of this technology does require a manufacturer to confirm that drivability, durability, and NVH are not significantly degraded.

ASL is an early upshift strategy whereby the transmission shifts to the next higher gear "earlier" (or at lower RPM during a gradual acceleration) than would occur in a traditional automatic transmission. This early upshift reduces fuel consumption by allowing the engine to operate at a lower RPM and higher load, which typically moves the engine into a more efficient operating region.

Early Torque Converter Lockup

A torque converter is a fluid coupling located between the engine and transmission in vehicles with automatic transmissions and continuously variable transmissions (CVT). This fluid coupling allows for slip so the engine can run while the vehicle is idling in gear (as at a stop light), provides for smoothness of the powertrain, and also provides for torque multiplication during acceleration, and especially launch. During light acceleration and cruising, inherent torque converter slippage between the torque converter rotor and stator increases fuel consumption. Modern automatic transmissions utilize a clutch mechanism as part of the torque converter to mechanically lock torque converter rotor and stator the preventing slippage. Fuel consumption can be further reduced by locking up the torque converter at lower vehicle speeds, provided there is sufficient power to propel the vehicle, and noise and vibration are not excessive.[249] If the torque converter cannot be fully locked up for maximum efficiency, a partial lockup strategy can be employed to reduce slippage. Early torque converter lockup is applicable to all vehicle types with automatic transmissions. Some torque converters will require upgraded clutch materials to withstand additional loading and the slipping conditions during partial lock-up. As with aggressive shift logic, confirmation of acceptable drivability, performance, durability and NVH characteristics is required to successfully implement this technology.

In the MYs 2012-2016 final rule, the agencies estimated an effectiveness improvement of 1 to 2 percent for aggressive shift logic and 0.5 percent for early torque converter lockup. This was supported by the 2002 NAS and NESCCAF reports as well as confidential manufacturer data. For this rulemaking, the agencies updated the effectiveness of ASL ranging from 1.9 to 2.7 based on the recent Ricardo study. For Early Torque Converter Lockup, MYs 2012-2016 final rule, TAR assumed an effectiveness improvement of 0.4 to 0.5 percent, and the recent Ricardo study

[249] Although only modifications to the transmission calibration software are considered as part of this technology, very aggressive early torque converter lock up may require an adjustment to damper stiffness and hysteresis inside the torque converter.

confirmed that amount. In the CAFE model, NHTSA combines ASL and early torque converter (together named Improved Automatic Transmission Control (IATC)) and assigns it an incremental effectiveness ranging from 2.3 to 3.1 percent and applicable starting in MY 2012.

In the MYs 2012-2016 rule, the agencies estimated the DMC for ASL at $26 (2007$) and for early torque converter lockup at $23 (2007$), which was considered applicable to MY 2015. These DMCs become $27 for ASL and $24 for early torque converter lockup after being converted into 2010$. NHTSA added these costs together and applied it as IATC in the CAFE model. The agency considers IATC to be on the flat portion of the learning curve and applies a medium complexity ICM of 1.39 through 2018 then a long-term ICM of 1.29 thereafter. The resultant costs are shown in Table V-48.

Table V-48 Costs for IATC (2010$)

Index	Transmission Type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	All	$50	$49	$48	$47	$46	$45	$44	$43	$42
IC	All	$13	$13	$10	$10	$10	$10	$10	$10	$10
TC	All	$62	$61	$58	$57	$56	$55	$54	$53	$52

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline.

Automatic 6-speed Transmission (NAUTO)

Manufacturers can choose to replace 4- and 5-speed transmissions with 6-, 7-, or 8-speed automatic transmissions. Additional ratios allow for further optimization of engine operation over a wider range of conditions, but this is subject to diminishing returns as the number of gear ratios increases. As additional planetary gear sets are added (which may be necessary in some cases to achieve the higher number of ratios), additional weight and friction are introduced. Also, the additional shifting of such a transmission can be perceived as bothersome to some consumers, so manufacturers need to develop strategies for smooth shifts. For the most part, manufacturers are replacing 4- and 5-speed automatics with 6-speed automatics, and 7- and 8-speed automatics are also in production. While a six speed transmission application is expected to be most prevalent for the timeframe of the 2012-2016 rulemaking, eight speed transmissions are expected to be readily available and applied in the 2017 through 2025 timeframe.

As discussed in the MY 2011 CAFE final rule, confidential manufacturer data projected that 6-speed transmissions could incrementally reduce fuel consumption by 0 to 5 percent from a baseline 4-speed automatic transmission, while an 8-speed transmission could incrementally reduce fuel consumption by up to 6 percent from a baseline 4-speed automatic transmission. GM has publicly claimed a fuel economy improvement of up to 4 percent for its 6-speed automatic transmissions.[250] The 2008 EPA Staff Technical Report found a 4.5 to 6.5 percent fuel consumption improvement for a 6-speed over a 4-speed automatic transmission.[251] Based on this information, NHTSA estimated in the MY 2011 rule, that the conversion to a 6-,7- and 8-speed transmission (NAUTO) from a 4 or 5-speed automatic transmission with IATC would have an incremental fuel consumption benefit of 1.4 percent to 3.4 percent, for all vehicle classes. From a baseline 4 or 5 speed transmission without IATC, the incremental fuel consumption benefit would be approximately 3 to 6 percent, which is consistent with the EPA Staff Report estimate. In MYs 2012-2016 final rule, NHTSA and EPA reviewed these effectiveness estimates and concluded that they remain accurate.

In this FRM analysis, consistent with the proposal, the agencies divided the improvement for this technology into two steps, first from 4- or 5- speed transmission to a 6-speed transmission (NAUTO), then from 6-speed transmission to 8 speed transmission (8SPD). The effectiveness estimates for NAUTO and 8SPD are based on the recent Ricardo study. In this section, only NAUTO is discussed. 8SPD will be discussed later in a section below.

Based on the Ricardo study, the effectiveness for a 6-speed transmission, relative to a 4-speed base transmission, ranges from 3.1 to 3.9 percent (2.1 percent for large truck with an unimproved rear axle). NHTSA incorporated this effectiveness estimate into the CAFE model as an incremental improvement over IATC ranging from 1.89 to 2.13 percent, because the Ricardo simulation-based estimates included improvements from IATC.

Based on the FEV teardown cost analysis, the DMC for 6-speed incremental to 5-speed automatic transmission is -$105.53 (2007$)—that is, a cost savings. In MYs 2012-2016 final rule, the agencies also assumed an incremental cost of moving from a 4-speed transmission to a 5-speed transmission of $91 (2007$). Adding these two values, the agency derived the cost for a 6-speed automatic transmission, incremental to a 4-speed automatic transmission, as -$14 (2007$). Due to the fact that the market has significant amounts of both 4-speed and 5-speed automatic transmission already, NHTSA used the average of incremental cost from 4-speed to 6-speed and from 5-speed to 6-speed automatic transmission to represent the incremental cost of the NAUTO technology; that is, -$60 (2007$). Converting into 2010$, this DMC is -$63, which is applicable in MY 2012. The agencies consider 6-speed automatic transmission technology to be on the flat portion of the learning curve and have applied a low complexity ICM of 1.24 through 2018 then a long-term ICM of 1.19 thereafter. The resultant costs are shown in **Table V-49**.

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[250] General Motors, news release, "From Hybrids to Six-Speeds, Direct Injection And More, GM's 2008 Global Powertrain Lineup Provides More Miles with Less Fuel" (released Mar. 6, 2007). *Available http://www.zercustoms.com/news/More-Hybrids-from-GM-in-2008.html (last accessed on Nov 3, 2011).*

[251] "EPA Staff Technical Report: Cost and Effectiveness Estimates of Technologies Used to Reduce Light-duty Vehicle Carbon Dioxide Emissions" Environmental Protection Agency, EPA420-R-08-008, March 2008, at page 17, Docket NHTSA-2010-0131.

Table V-49 Costs for 6-Speed Automatic Transmissions (2010$)

Index	Transmission Type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	All	-$54	-$53	-$52	-$51	-$50	-$49	-$48	-$47	-$46
IC	All	$15	$15	$12	$12	$12	$12	$12	$12	$12
TC	All	-$39	-$38	-$40	-$39	-$38	-$37	-$36	-$35	-$34

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to 4/5-speed transmission.

Dual Clutch Transmission (DCT)

An Automated Manual Transmission (AMT) is mechanically similar to a conventional manual transmission, but shifting and launch functions are automatically controlled by the electronics. There are two basic types of AMTs, single-clutch and dual-clutch (DCT). A single-clutch AMT is essentially a manual transmission with automated clutch control and shifting. , DCTs are emerging as more common in the U.S. primarily because of shift quality issues with single-clutch designs[252] which, at the time of this rulemaking have no widespread application plans in the U.S. Therefore, the agency's analysis focused on DCT application as the foundation of the estimates that follow.

A DCT uses separate clutches (and separate gear shafts) for the even-numbered gears and odd-numbered gears. In this way, the next expected gear is pre-selected, which allows for faster and smoother shifting. For example, if the vehicle is accelerating in third gear, the shaft with gears one, three and five has gear three engaged and is transmitting power. The shaft with gears two, four, and six is idle, but has gear four engaged. When an upshift is required, the controller disengages the odd-gear clutch while simultaneously engaging the even-gear clutch, thus making a smooth shift. If, on the other hand, the driver slows down instead of continuing to accelerate, the transmission will have to change to the next lower gear on the idling shaft to anticipate a downshift. This shift can be made quickly on the idling shaft since there is no torque being transferred on it.

In addition to the differing single-clutch and dual-clutch AMT designs, there are also wet clutch and dry clutch designs of each which are used for different types of vehicle applications. Wet clutch AMTs offer a higher torque capacity that comes from the use of a hydraulic system that can apply the clutches and, as a by-product, cools the clutches allowing for increased clutch capacity. Wet clutch systems are less efficient than the dry clutch systems due to the losses

[252] However, some U.S. DCT applications have resulted in reports of reduced consumer acceptance.

associated with hydraulic pumping. Additionally, wet AMTs have a higher cost due to the additional hydraulic hardware required.

Overall, DCTs likely offer the greatest potential for effectiveness improvements among the various transmission options considered in this analysis because they offer the inherently lower losses of a manual transmission with the efficiency and shift quality advantages of electronic controls. The lower losses stem from the elimination of the conventional lock-up torque converter, and a greatly reduced need for high pressure hydraulic circuits to hold clutches or bands to maintain gear ratios (in automatic transmissions) or hold pulleys in position to maintain gear ratio (in continuously variable transmissions). However, the lack of a torque converter will affect how the vehicle launches from rest, so a DCT will most likely be paired with an engine that offers sufficient torque at low engine speeds to allow for adequate launch performance or provide lower launch gears (higher numerically) to approximate the torque multiplication of the torque converter providing equivalent performance.

In the MYs 2012-2016 final rule, EPA and NHTSA estimated a 5.5 to 9.5 percent improvement in fuel consumption over a baseline 4/5-speed automatic transmission for a wet clutch DCT, which was assumed for all but the smallest of the vehicle subclasses, Subcompact and Compact cars and small LT. This results in an incremental effectiveness estimate of 2.7 to 4.1 percent over a 6-speed automatic transmission with IATC. For Subcompact and Compact Cars and small LT, which were assumed to use a dry clutch DCT, NHTSA estimated an 8 to 13 percent fuel consumption improvement over a baseline 4/5-speed automatic transmission, which equates to a 5.5 to 7.5 percent incremental improvement over the 6-speed transmission.
For purposes of this analysis, based on the 2011 Ricardo study, EPA and NHTSA have concluded that 8 to 13 percent effectiveness is appropriate for 6-speed DCTs compared to a baseline 4/5 speed transmission. These values include not only the DCT but also the increase in stepped gears and also a high efficiency gearbox (mentioned later). Independent of other technologies, the effectiveness for the DCT, alone, is 4 to 5 percent (for wet-clutch designs) and 5 to 6 percent (for dry-clutch designs) compared to a baseline automatic transmission of similar vintage and number of fixed gears.

In the FRM analysis, consistent with the proposal, NHTSA applied an incremental effectiveness of 4 percent for a 6-speed dry DCT and 3.4 to 3.8 percent for a wet DCT compared to a 6-speed automatic transmission with IATC based on the lumped parameter model. This effectiveness value also includes the accompanied 7 percent transmission efficiency improvement for MY 2010 and after transmissions. This translates to an effectiveness range of 7.4 to 8.6 percent compared to a 4 speed automatic transmission for dry clutch design and 7.4 to 7.9 percent for a wet clutch design. NHTSA did not apply DCTs to vehicles with towing requirements, such as Minivan LT, Midsize LT and Large LT.

Chapter 3 of the 2012-2016 final joint TSD referenced DCT costs of -$147 (2007$ and incremental to a 6-speed automatic transmission) based on an FEV tear-down study that assumed 450,000 units of production, but because the agencies did not consider there to be sufficient U.S. capacity in the 2012-2016 timeframe to produce 450,000 units, the tear-down values were adjusted accordingly. In contrast, the TAR timeframe for consideration was 2017-2025, so in that analysis the agencies assumed that production capacity would exist and that therefore the FEV tear-down results were valid without adjustment. We continue to believe that to be the case for purposes of this analysis. In the final joint TSD supporting MYs 2012-2016 rule the agencies also noted that the negative tear-down estimates found by FEV were not surprising when considering the relative simplicity of a dual-clutch transmission compared to an automatic transmission. Again, the agencies continue to consider this to be true.

For this analysis, then, the FEV teardown cost was employed for DCT. As stated in the MYs 2012-2016 final rule, the 6-speed wet DCT incremental to 6-speed automatic transmission is -$147 (2007$), and the incremental cost from a dry DCT to a wet DCT is $67 (2007$). The agency derived the 6-speed dry DCT cost incremental to 6-speed automatic transmission cost as -$147-$67 = -$214 (2007$). Converting to 2010$, the incremental cost from a 6-speed automatic transmission to 6-speed dry DCT is -$226 and the incremental cost from a 6-speed automatic transmission to 6-speed wet DCT is -$155. These costs are applicable in MY 2012. The agencies consider the 6 speed DCT technology to be on the flat portion of the learning curve and have applied a medium complexity ICM of 1.39 through 2018 then a long-term ICM of 1.29 thereafter. The resultant costs are shown in

Table V-50.

Table V-50 Costs for 6-Speed Dual Clutch Transmissions (2010$)

Index	Transmission Type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	Dry DCT	-$194	-$190	-$187	-$183	-$179	-$176	-$172	-$169	-$166
IC	Dry DCT	$85	$85	$64	$64	$64	$64	$64	$63	$63
TC	Dry DCT	-$109	-$105	-$123	-$119	-$115	-$112	-$109	-$105	-$102
DMC	Wet DCT	-$133	-$130	-$128	-$125	-$123	-$120	-$118	-$115	-$113
IC	Wet DCT	$59	$59	$43	$43	$43	$43	$43	$43	$43
TC	Wet DCT	-$75	-$72	-$84	-$82	-$80	-$77	-$75	-$73	-$70

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to 6-speed automatic transmission.

Automatic and Dual Clutch 8-Speed Transmission (8SPD)

As stated in the previous section under NAUTO, the agencies separated 8-speed transmission from NAUTO in consideration of the fact that an 8-speed transmission is more effective in reducing fuel consumption than 6-speed transmission, and more 8-speed automatic transmissions are beginning to enter the market.

In this FRM analysis, consistent with the proposal, the agencies assumed that 8-speed transmissions will not become available until MY 2017. NHTSA applied 8-speed automatic transmissions succeeding 6-speed automatic transmission to vehicles with towing requirements, such as minivans, midsize light trucks and large light trucks; all other vehicle subclasses use 8-speed DCT to succeed 6-speed DCT.

NHTSA derived effectiveness values from EPA's lumped parameter model, updated with values from the recent Ricardo study, for an 8-speed DCT relative to a 4-speed automatic transmission ranging from 11.1 to 13.1 percent for subclasses except Minivan LT, Midsize LT and Large LT, which assume an 8-speed automatic transmission relative to 4-speed automatic transmission ranging from 8.7 to 9.2 percent. This translates into effectiveness values appropriate for the CAFE model in the range of 3.85 to 4.57 percent for an 8-speed DCT relative to a 6-speed DCT and 4.9 to 5.34 percent for 8-speed automatic transmission relative to 6-speed automatic transmission.

For the cost of an 8-speed automatic transmission, the agencies have relied on a tear-down study completed by FEV since publication of the TAR.[253] In that study, the 8-speed automatic transmission was found to have an incremental cost of $62 (2007$) compared to the 6-speed automatic transmission. Converting to 2010$, this DMC becomes $65 for this analysis. The agencies consider this DMC to be applicable to MY 2012, although, as stated, the technology will not be available for application until MY 2017. The agencies consider the 8-speed transmission technology to be on the flat portion of the learning curve and have applied a medium complexity ICM of 1.39 through MY 2018 then a long-term ICM of 1.29 thereafter.[254] Note that the cost for the 8-speed automatic transmission relative to the 6-speed automatic transmission is lower here than that used in the recent heavy-duty rulemaking analysis. In that rule, we remained consistent with the proposal for that rule which carried an estimated DMC of $210 (2008$). That DMC was based on an estimation derived by NAS (see NAS 2010, Table 7-

[253] FEV Inc., "Light-Duty Technology Cost Analysis: Advanced 8-speed Transmissions", Contract No. EP-C-07-069, Work Assignment 3-3, EPA-420-R-11-015, November 2011, Docket NHTSA-2010-0131.

[254] This ICM would be applied to the 6 speed to 8 speed increment of $64 (2009$) applicable in 2012. The 4 speed to 6 speed increment would carry the low complexity ICM.

10).[255] For this final rule, consistent with the proposal, we have chosen to use a DMC based on the more recent FEV tear-down analysis.

New for this analysis is costing for an 8-speed DCT. For the cost of this technology, the agencies have relied on a tear-down study completed by FEV since publication of the TAR.256 In that study, the 8-speed DCT was found to have an incremental cost of $198 (2007$) compared to the 6-speed DCT. Converting to 2010$, this DMC increment becomes $206 for this analysis. The agencies consider this DMC to be applicable to MY 2012. The agencies consider the 8-speed DCT technology to be on the flat portion of the learning curve and have applied a medium complexity ICM of 1.39 through MY 2024 then a long-term ICM of 1.29 thereafter. The 8-speed DCT has a later switch to long term ICMs because it is a newer technology that is not currently implemented in the fleet. The resultant costs for both 8-speed automatic transmission and 8-speed DCTs incremental to 6-speed transmission with same transmission type are shown in

Table **V-50**.

Table V-51 Costs for 8-Speed Automatic and Dual Clutch Transmissions (2010$)

Index	Transmission Type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	Auto	$56	$55	$54	$53	$52	$51	$49	$48	$47
IC	Auto	$24	$24	$18	$18	$18	$18	$18	$18	$18
TC	Auto	$81	$79	$72	$71	$70	$69	$68	$67	$66
DMC	DCT	$179	$176	$172	$169	$166	$162	$159	$156	$153
IC	DCT	$79	$79	$59	$59	$59	$59	$59	$59	$59
TC	DCT	$258	$254	$230	$227	$223	$220	$217	$214	$210

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to 6-speed transmission of same type.

[255] National Academy of Sciences, "Assessment of Fuel Economy Technologies for Light-Duty Vehicles" Available at http://www.nap.edu/catalog.php?record_id=12924 (last accessed: November 15, 2011).
[256] FEV Inc., "Light-Duty Technology Cost Analysis: Advanced 8-speed Transmissions", Contract No. EP-C-07-069, Work Assignment 3-3, EPA-420-R-11-015, November 2011 Docket NHTSA-2010-0131.

High Efficiency Gear Box for Automatic, DCT and Manual Transmission (HETRANS and HETRANSM)

For this rule, a high efficiency gearbox refers to some or all of a suite of incremental gearbox improvement technologies that should be available within the 2017 to 2025 timeframe. The majority of these improvements address mechanical friction within the gearbox. These improvements include, but are not limited to, shifting clutch technology improvements (especially for smaller vehicle classes); improved kinematic design; dry sump lubrication systems; more efficient seals, bearings and clutches (reducing drag); component superfinishing; and improved transmission lubricants. More detailed description can be found in the 2011 Ricardo report.[257] The high efficiency gearbox technology is applicable to any type of transmission.

EPA analyzed detailed transmission efficiency input data provided by Ricardo and implemented it directly into the lumped parameter model. Based on the LPM effectiveness, resulting from these inputs, the agencies estimate that a high efficiency gearbox can provide a fuel consumption reduction in the range of 3.8 to 5.7 percent (3.8 percent for 4WD trucks with an unimproved rear axle) over a baseline transmission in MY 2017 and beyond.

The agencies estimated the DMC of the high efficiency gearbox at $200 (2009$). We have based this on the DMC for engine friction reduction in a V8 engine which, as presented in Table V-34, is $197 (2010$). In the proposal, we rounded this value up to $200 (2009$) which becomes $202 (2010$) for this final analysis. This DMC is considered applicable for MY 2017. The agencies consider high efficiency gearbox technology to be on the flat portion of the learning curve and have applied a low complexity ICM of 1.24 through 2024 then a long-term ICM of 1.19 thereafter. The resultant costs are shown in Table **V-52**.

Table V-52 Costs for High Efficiency Gearbox (2010$)

Index	Transmission Type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	All	$202	$196	$190	$184	$179	$173	$170	$167	$163
IC	All	$49	$49	$49	$49	$49	$49	$48	$48	$39
TC	All	$251	$245	$239	$233	$227	$222	$218	$215	$202

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline.

Shift Optimization (SHFTOPT)

[257] U.S. EPA, "Computer Simulation of Light-Duty Vehicle Technologies for Greenhouse Gas Emission Reduction in the 2020-2025 Timeframe", Contract No. EP-C-11-007, Work Assignment 0-12 Docket NHTSA-2010-0131.

In this FRM analysis, consistent with the proposal, the agencies introduced another level of aggressive shift logic based on the shift optimization algorithm employed in the recent Ricardo study. NHTSA named this technology Shift Optimization (SHFTOPT) in the CAFE model. As described in the 2011 Ricardo report, shift optimization is a strategy whereby the engine and/or transmission controller(s) continuously evaluate all possible gear options that would provide the necessary tractive power (while limiting the adverse effects on driveline NVH) and select the gear that lets the engine run in the most efficient operating zone. Thus, shift optimization tries to keep the engine operating near its most efficient point for a give power demand. The shift controller emulates a traditional CVT by selecting the best gear ratio for fuel economy at a given required vehicle power level to take full advantage of high BMEP engines.[258]

Ricardo acknowledged in its report that the shift optimization currently causes significant implications for drivability and hence affects consumer acceptability. However, Ricardo recommended the inclusion of this technology for the 2020-2025 time frame based on the assumption that manufacturers will develop a means of yielding the fuel economy benefit without adversely affecting driver acceptability. The agencies believe these drivability challenges could include shift busyness – that is, more frequent shifting compared to current vehicles as perceived by the customers. The agencies note that in confidential discussions with two major transmission suppliers, the suppliers described transmission advances which reduce shifting time and provide smoother torque transitions than today's designs, making the shifting event less apparent to the driver; however, these improvements will not influence the customer's perception of shift busyness related to the changes in engine speed.

In addition, the agencies note that several auto companies and transmission firms have announced future introduction of transmissions into the U.S. market with even a higher number of gears than were included in the Ricardo simulation and in the agencies' feasibility assessment for this final rule (which is 8 forward speeds). These announcements include both 9 and 10 speed transmissions which may present further challenges with shift busyness, given the availability of one or two additional gears. At the same time, the associated closer gear spacing will generally result in smaller engine speed changes during shifting that may be less noticeable to the driver.

The agencies are including shift optimization in the analysis under the premise that manufacturers are developing means to mitigate these drivability issues by MY 2017, as assumed in the 2011 Ricardo study (more information on Ricardo's treatment of the optimized shift strategy is described in Section 6.4 of the 2011 Ricardo report). If manufacturers are not able to solve these drivability issues, the assumed effectiveness could be lower and the cost could be higher or both. NHTSA sought comment on the feasibility of the shift optimization strategy

[258] In this analysis, the agencies have assumed that shift optimization is applicable to all vehicles, consistent with the proposal.

described above and the likelihood that and manner in which manufacturers will be able to overcome the drivability issues. No specific comment was given on shift optimization, but the Alliance emphasized that the agencies should examine the progress in the development of powertrain improvements as part of the mid-term evaluation and determine if researchers are making the kind of breakthroughs anticipated by the agencies for technologies like high-efficiency transmissions.

The effectiveness from the LPM for SHFTOPT ranges from 5.1 to 7.0 percent improvement over a transmission with non-optimized shift logic. In the CAFE model, an incremental effectiveness relative to IATC ranging from 3.27 to 4.31 percent is applied.

The agencies are estimating the DMC for SHFTOPT to be equivalent to ASL's cost of $27 (2010$) in relative to baseline transmission. Essentially this yield a nearly negligible incremental cost of $1 for SHFTOPT over IATC, which, combined with its effectiveness, makes it a very attractive technology for the model to apply in the analysis. This cost for SHFTOPT is considered applicable to MY 2017. The timing of SHFTOPT is different from that for ASL because SHFTOPT is newer and not yet being implemented in the fleet. The agencies consider SHFTOPT technology to be on the flat portion of the learning curve and have applied a medium complexity ICM of 1.39 through 2024 then a long-term ICM of 1.29 thereafter.

Table V-53 Cost for Shift Optimization (2010$)

Index	Transmission Type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	All	$1.0	$1.0	$0.9	$0.9	$0.9	$0.9	$0.8	$0.8	$0.8
IC	All	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2	$0.2
TC	All	$1.2	$1.2	$1.2	$1.2	$1.1	$1.1	$1.1	$1.1	$1.0

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; cost incremental to IATC.

6-Speed Manual Transmissions (6MAN)

Manual transmissions depend entirely upon driver input to shift gears: the driver selects when to perform the shift and which gear to select. This is the most efficient transfer of energy of all transmission layouts, because it has the lowest internal gear losses, with a minimal hydraulic system, and the driver provides the energy to actuate the clutch. From a systems viewpoint, however, vehicles with manual transmissions have the drawback that the driver may not always select the optimum gear ratio for fuel economy. Nonetheless, increasing the number of available ratios in a manual transmission can improve fuel economy by allowing the driver to select a ratio that optimizes engine operation more often. Typically, this is achieved through adding overdrive ratios to reduce engine speed at cruising velocities (which saves fuel through reduced engine pumping losses) and pushing the torque required of the engine towards the optimum level. However, if the gear ratio steps are not properly designed, this may require the driver to change gears more often in city driving, resulting in customer dissatisfaction. Additionally, if gear ratios are selected to achieve improved launch performance instead of to improve fuel economy, then no fuel saving effectiveness is realized.

The MY 2012-2016 final rule assumed an effectiveness increase of 0.5 percent for replacing a 5-speed manual with a 6-speed manual transmission, which was derived from confidential manufacturer data. Based on the updated LPM for this 2017-2025 rule, NHTSA has found that an effectiveness increase of 2.0 to 2.5 percent is possible when moving from a 5-speed to a 6-speed manual transmission with improved internals.

NHTSA updated costs from MYs 2012-2016 final rule to reflect the ICM low complexity markup of 1.11, which resulted in an incremental compliance cost of $250 as compared to $338 for MY 2012. This represents a DMC of $225 (2007$) which becomes $234 (2010$) for this analysis, applicable in MY 2012. NHTSA continues to consider a 6 speed manual transmission to be on the flat portion of the learning curve and has applied a low complexity ICM of 1.24 through 2018 then a long-term ICM of 1.19 thereafter. NHTSA's resultant costs for a 6 speed manual transmission are shown in Table V-54.

Table V-54 Costs for 6 Speed Manual Transmission (2010$)

Index	Transmission Type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	Manual	$204	$199	$196	$192	$188	$184	$181	$177	$173
IC	Manual	$57	$57	$45	$44	$44	$44	$44	$44	$44
TC	Manual	$260	$256	$240	$236	$232	$229	$225	$221	$218

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost; all costs are incremental to the baseline.

Vehicle Accessory, Hybridization and Electrification Technologies

Electrical Power Steering (EPS) and Electrohydraulic Power Steering (EHPS)

Electric power steering (EPS) and Electro-hydraulic power steering (EHPS) provide a potential reduction in fuel consumption over hydraulic power steering because of reduced overall accessory loads. This eliminates the parasitic losses associated with belt-driven power steering pumps which consistently draw load from the engine to pump hydraulic fluid through the steering actuation systems even when the wheels are not being turned. EPS is an enabler for all vehicle hybridization technologies since it provides power steering when the engine is off. EPS may be implemented on most vehicles with a standard 12V system. Some heavier vehicles may require a higher voltage system or EHPS, which may add cost and complexity.

In the 2012-2016 final rule, EPA and NHTSA estimated a 1 to 2 percent effectiveness for EPS based on the 2002 NAS report, Sierra Research Report and confidential OEM data. The 2010 Ricardo study also confirmed this estimate. The agencies continue to believe that these effectiveness estimates are accurate for the rulemaking timeframe, thus they have been retained for this final rule. For large pickup trucks the agencies used EHPS due to the utility requirement of these vehicles. The effectiveness of EHPS is estimated to be 0.8 percent based on the updated LPM results.

In the MY 2012-2016 final rule, the agencies estimated the DMC at $88 (2007$). Converting to 2010$, this DMC becomes $92 for this analysis, consistent with the recent heavy-duty GHG rule, and is considered applicable in MY 2015. The agencies use the same DMC for EPS as for EHPS. Technically, EHPS is less costly than EPS. However, we believe that EHPS is likely to be used, if at all, only on the largest trucks and utility vehicles. As such, it would probably need to be heavier-duty than typical EPS systems and the agencies consider the net effect to place EHPS on par with EPS in terms of costs. The agencies consider EPS/EHPS technology to be on the flat portion of the learning curve and have applied a low complexity ICM of 1.24 through 2018 then a long-term ICM of 1.19 thereafter. The resultant costs are shown in Table **V-55**.

Table V-55 Costs of Electrical/Electro-hydraulic Power Steering (2010$)

Cost type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	$87	$86	$84	$82	$80	$79	$77	$76	$74
IC	$22	$22	$18	$18	$18	$18	$18	$18	$18
TC	$109	$108	$101	$100	$98	$96	$95	$93	$92

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost

Improved Accessories Level 1 and Level 2(IACC1 and IACC2)

The accessories on an engine, including the alternator, coolant, and oil pumps, are traditionally mechanically-driven. A reduction in fuel consumption can be realized by driving them electrically, and only when needed ("on-demand").

Electric water pumps and electric fans can provide better control of engine cooling. For example, coolant flow from an electric water pump can be reduced and the radiator fan can be shut off during engine warm-up or cold ambient temperature conditions which will reduce warm-up time, reduce warm-up fuel enrichment, and reduce parasitic losses.

Indirect benefit may also be obtained by reducing the flow from the water pump electrically during the engine warm-up period, allowing the engine to heat more rapidly and thereby reducing the fuel enrichment needed during cold starting of the engine. Further benefit may be obtained when electrification is combined with an improved, higher efficiency engine alternator. Intelligent cooling can more easily be applied to vehicles that do not typically carry heavy payloads, so larger vehicles with towing capacity present a challenge, as these vehicles have high cooling fan loads.

The agencies considered whether to include electric oil pump technology for the rulemaking. Because it is necessary to operate the oil pump any time the engine is running, electric oil pump technology has an insignificant effect on efficiency. Therefore, the agencies decided to not include electric oil pump technology for this final rule, consistent with the proposal.

In MYs 2012-2016 final rule, the agencies used an effectiveness value in the range of 1 to 2 percent based on the technologies discussed above. NHTSA did not apply this technology to large pickup trucks due to the utility requirement concern for this vehicle subclass.

For this final rule, consistent with the proposal, the agencies considered two levels of improved accessories. For level one of this technology (IACC1), NHTSA now incorporates a high efficiency alternator (70 percent efficient). The second level of improved accessories (IACC2) adds the higher efficiency alternator and incorporates a mild regenerative alternator strategy, as well as intelligent cooling. NHTSA and EPA jointly reviewed the estimates of 1 to 2 percent effectiveness used in the 2012-2016 final rule and TAR for level IACC1. For this final rule, the agencies used an effectiveness value in 1.2 to 1.8 percent range varying based on different vehicle subclasses. For IACC1, NHTSA assumes an incremental effectiveness for this technology relative to EPS in the CAFE model of 0.91 to 1.61 percent, and an incremental effectiveness for IACC2 relative to IACC1 ranging from 1.74 to 2.55 percent.

In the 2012-2016 rule, the agencies estimated the DMC of IACC1 at $71 (2007$). Converting to 2010$, this DMC becomes $75 for this analysis, applicable in MY 2015, and consistent with the heavy-duty rule. The agencies consider IACC1 technology to be on the flat portion of the learning curve and have applied a low complexity ICM of 1.24 through 2018 then a long-term ICM of 1.19 thereafter.

The assumed cost is higher for IACC2 due to the inclusion of a higher efficiency alternator and a mild level of regeneration. The agencies estimate the DMC of the higher efficiency alternator and the regeneration strategy at $45 (2010$) incremental to IACC1, applicable in MY 2015.

Including the costs for IACC1 results in a DMC for IACC2 of $120 (2010$) relative to the baseline case, and applicable in MY 2015. The agencies consider the IACC2 technology to be on the flat portion of the learning curve. The agencies have applied a low complexity ICM of 1.24 through 2018 then a long-term ICM of 1.19 thereafter. The resultant costs are shown in **Table V-56**.

Table V-56 Costs for Improved Accessory Technology – Levels 1 & 2 (2010$)

Cost type	IACC Technology	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	Level 1	$71	$70	$68	$67	$65	$64	$63	$62	$60
DMC	Level 2	$114	$112	$110	$107	$105	$103	$101	$99	$97
IC	Level 1	$18	$18	$14	$14	$14	$14	$14	$14	$14
IC	Level 2	$29	$29	$23	$23	$23	$23	$23	$23	$23
TC	Level 1	$89	$88	$82	$81	$80	$78	$77	$76	$75
TC	Level 2	$143	$141	$133	$131	$128	$126	$124	$122	$120

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost
Note that both levels of IACC technology are incremental to EPS in the CAFE model.

Air Conditioner Systems

Air conditioning (A/C) use places excess load on an engine, which results in additional fuel consumption and GHG emissions. A number of methods related only to the A/C system components and their controls can be used to improve A/C systems. The A/C improving technologies considered for this final rule focus primarily, but not exclusively, on the compressor, electric motor controls, and system controls which reduce load on the A/C system (*e.g.*, reduced 'reheat' of the cooled air and increased of use re-circulated cabin air). Technologies that reduce A/C related fuel consumption include internal heat exchanger, blower motor control, default to recirculated air, and reduced reheat with externally controlled with fixed or variable displacement compressor. Technologies that reduce air conditioning leakage or reduce the GWP of air conditioning refrigerant were not considered and are only included in the EPA GHG program. For purposes of this final rule, a detailed description of the A/C program can be found in Chapter 5 of the joint TSD. The reader is directed to that chapter to learn the specifics of the program, the fuel consumption improvement values involved, and details behind the costs that have been estimated. Table **V-57** is a copy of Table 5-17 from that chapter of the TSD, showing the total costs for A/C controls used in this final rule, consistent with the proposal.

Table V-57 Costs of A/C Controls Carried Over into the Final Rule (2010$)

Car/ Truck	Cost type	Rule	2017	2018	2019	2020	2021	2022	2023	2024	2025
Car	TC	Reference	$76	$75	$70	$69	$68	$67	$66	$65	$64
	TC	Control	$25	$40	$57	$65	$79	$77	$72	$71	$69
	TC	Both	$101	$115	$127	$134	$147	$144	$138	$135	$133
Truck	TC	Reference	$58	$57	$54	$53	$52	$51	$50	$49	$49

	TC	Control	$2	$46	$73	$82	$95	$93	$88	$86	$84
	TC	Both	$60	$103	$127	$134	$147	$144	$138	$135	$133
Fleet	TC	Both	$86	$111	$127	$134	$147	$144	$138	$135	$133

12 volt Micro Hybrid or Stop-Start (MHEV)

The stop-start technology we consider for this final rule, consistent with the proposal—also known as idle-stop or 12-volt micro-hybrid—is the most basic hybrid system that facilitates idle-stop capability. When the vehicle comes to a stop, the system will automatically shut down the internal combustion engine and restart the engine when vehicle starts to move again. This is especially beneficial to reduce fuel consumption when vehicles spend significant amount of time stopped in traffic. Along with other enablers, this system typically replaces the standard 12-volt starter with an improved unit capable of higher power and increased cycle life. These systems typically incorporate an improved battery to prevent voltage-droop on restart. Different from MYs 2012-2016 rule, for this analysis this technology is applied to all vehicle classes, including large pickup trucks.

In the MYs 2012-2016 final rule, the effectiveness NHTSA used in the CAFE model ranged from 2 to 4 percent, depending on whether the vehicle was equipped with a 4-, 6- or 8-cylinder engine, with the 4-cylinder engine having the lowest range and the 8-cylinder having the highest. In this FRM analysis, consistent with the proposal, when combining IACC1, IACC2 and 12V stop-start system, the estimated effectiveness based on 2010 Ricardo study ranges from 4.8 percent to 5.9 percent. For CAFE modeling, the incremental effectiveness for 12V stop-start relative to IACC2 is 1.68 to 2.2 percent. Importantly, the effectiveness values presented here represent two-cycle effectiveness. Because stop-start technology provides additional off-cycle benefits, both agencies apply a credit value to the technology. Off-cycle credits are discussed in Chapter 5 of the Joint TSD.

In the MYs 2012-2016 final rule, the agencies estimated the DMC at $282 (2007$) to $350 (2007$) for small cars through large trucks, respectively. Converting to 2010$, these DMCs become $295 (2010$) through $367 (2010$) for this analysis, and are considered applicable in MY 2015. The agencies consider 12V stop-start technology to be on the steep portion of the learning curve in the 2012-2016 timeframe and flat thereafter, and have applied a medium complexity ICM of 1.39 through 2018 then a long-term ICM of 1.29 thereafter. The resultant costs are shown in Table **V-58**.

Table V-58 Costs for 12V Micro Hybrid (2010$)

Cost type	NHTSA Vehicle Class	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	Subcompact PC/Perf PC	$232	$225	$219	$212	$206	$200	$194	$188	$182

DMC	Compact PC/Perf PC	$251	$244	$236	$229	$222	$216	$209	$203	$197
DMC	Midsize PC/Perf PC	$276	$268	$260	$253	$244	$237	$230	$223	$216
DMC	Large PC/Perf PC	$297	$288	$279	$271	$263	$255	$247	$239	$232
DMC	Minivan	$297	$288	$279	$271	$263	$255	$247	$239	$232
DMC	Midsize LT	$304	$295	$286	$278	$269	$261	$254	$245	$238
DMC	Small LT	$263	$255	$246	$239	$232	$225	$218	$212	$206
DMC	Large LT	$343	$333	$323	$313	$304	$295	$286	$278	$270
IC	Subcompact PC/Perf PC	$93	$92	$69	$69	$69	$69	$68	$68	$68
IC	Compact PC/Perf PC	$100	$100	$75	$74	$74	$74	$74	$74	$73
IC	Midsize PC/Perf PC	$110	$109	$82	$82	$81	$81	$81	$81	$81
IC	Large PC/Perf PC	$118	$117	$88	$88	$87	$87	$87	$87	$86
IC	Minivan	$118	$117	$88	$88	$87	$87	$87	$87	$86
IC	Midsize LT	$121	$120	$90	$90	$89	$89	$89	$89	$89
IC	Small LT	$104	$104	$78	$78	$77	$77	$77	$77	$77
IC	Large LT	$136	$136	$102	$101	$101	$101	$101	$100	$100
TC	Subcompact PC/Perf PC	$325	$318	$288	$281	$275	$268	$262	$256	$249
TC	Compact PC/Perf PC	$351	$343	$311	$304	$297	$290	$283	$277	$271
TC	Midsize PC/Perf PC	$386	$378	$341	$333	$325	$318	$311	$304	$297
TC	Large PC/Perf PC	$415	$405	$367	$359	$349	$341	$334	$326	$319
TC	Minivan	$415	$405	$367	$359	$349	$341	$334	$326	$319
TC	Midsize LT	$425	$415	$376	$367	$359	$350	$342	$334	$326
TC	Small LT	$367	$359	$324	$317	$309	$302	$295	$289	$282
TC	Large LT	$481	$470	$425	$415	$405	$396	$387	$378	$370

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost

High Voltage Stop-Start/Belt Integrated Starter Generator (ISG)

Higher Voltage Stop-Start and Belt Mounted Integrated Starter Generator (BISG) systems are similar to a micro-hybrid system, offering idle-stop functionality, except that they utilize larger electric machine and a higher capacity battery, typically 42 volts or above, thus enabling a limited level of regenerative braking unavailable for a MHEV. The larger electric machine and battery also enables a limited degree of power assist, which MHEV cannot provide. However, because of the limited torque capacity of the belt-driven design, these systems have a smaller electric machine, and thus less capability than crank-integrated or stronger hybrid systems. These systems replace the conventional alternator with a belt-driven starter/alternator and may add electric power steering and an auxiliary automatic transmission pump. The limited electrical requirements of these systems allow the use of lead-acid batteries or super-capacitors for energy storage, or the use of a small lithium-ion battery pack, as is modeled in this analysis. While the mild hybrid system was not applied in the NPRM analysis because the agencies judged it was not cost-effective at that time, the agencies have decided to make the technology available for the final rule because credits are available for mild hybrid pickup trucks. The simulation modeling and cost estimation results show that the mild hybrid system could be a cost effective technology on the vehicle electrification technology path.

For the BISG technology the agencies sized the system using a 15 kW starter/generator and 0.25 kWh Li-ion battery pack, which is similar to General Motors' eAssist BISG, which is available in MY 2012 Buick LaCrosse, Buick Regal, and Chevrolet Malibu vehicles. The agencies made this size system available to all vehicle subclasses, believing that manufacturers might use a similar strategy to control component complexity across the subclasses. As mentioned above, estimates were developed by ANL using Autonomie full vehicle simulation software. The absolute effectiveness for the CAFE analysis ranged from 8.5 to 11.6 percent depending on vehicle subclass. The effectiveness values include technologies that would be expected to incorporated with BISG which are stop/start (MHEV) and improved accessories (IACC1 and IACC2), however the effectiveness values do not include electric power steering (EPS).

The costs for the mild hybrid technology are all new for this final rule and were developed in a manner consistent with costs generated for strong hybrids. The ISG costs are shown in Table V-59.

Table V-59 Costs for ISG Hybrid (2010$)

Cost type	NHTSA Vehicle Class	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	All	$1,093	$1,065	$1,039	$1,013	$987	$963	$939	$915	$892
IC	All	$1,642	$1,613	$1,527	$1,499	$1,472	$1,447	$1,421	$1,397	$1,255
TC	All	$550	$548	$488	$487	$485	$484	$483	$482	$362

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost

Integrated Motor Assist (IMA)/Crank Integrated Starter Generator

IMA is a system developed and marketed by Honda[259] and is similar to CISG. They both utilize a thin axial electric motor bolted to the engine's crankshaft and connected to the transmission through a torque converter or clutch. The axial motor is motor/generator that typically operates above 100 volts (but lower than the stronger hybrid systems discussed below, which typically operate at around 300 volts) and can provide sufficient torque for launch as well as generate sufficient current to provide significant levels of brake energy recovery. The motor/generator also acts as the starter for the engine and can replace a typical accessory-driven alternator. Current IMA/CISG systems typically do not launch the vehicle on electric power alone, although some commercially available systems can cruise on electric power and dual-clutch IMA/CISG systems capable of all-electric drive are under development. IMA and CISG could be applied to

[259] http://automobiles.honda.com/insight-hybrid/features.aspx?Feature=ima (last accessed on November 14, 2011)

all classes of vehicles. IMA technology is not included as an enabling technology in this analysis, although it is included as a baseline technology because it exists in the 2008 baseline fleet. Neither NHTSA nor EPA used this technology as an enabling technology in this FRM analysis.

Batteries for MHEV, ISG, HEV, PHEV and EV Applications

The design of battery secondary cells can vary considerably between MHEV, ISG, HEV, PHEV and EV applications.

MHEV batteries: Due to their lower voltage (12-42 VDC) and reduced power and energy requirements, MHEV systems may continue to use lead-acid batteries even long term (2017 model year and later). MHEV battery designs differ from those of current starved-electrolyte (typical maintenance free batteries) or flooded-electrolyte (the older style lead-acid batteries requiring water "top-off") batteries used for starting, lighting and ignition (SLI) in automotive applications. Standard SLI batteries are primarily designed to provide high-current for engine start-up and then recharge immediately after startup via the vehicle's charging system. Deeply discharging a standard SLI battery will greatly shorten its life. MHEV applications are expected to use:

- Extended-cycle-life flooded (ELF) lead-acid batteries
- Absorptive glass matt, valve-regulated lead-acid (AGM/VRLA) batteries –or –
- Asymmetric lead-acid battery/capacitor hybrids (*e.g.*, flooded ultra-batteries)

MHEV systems using electrolytic double-layer capacitors are also under development and may provide improved performance and reduced cost in the post-2017 timeframe.

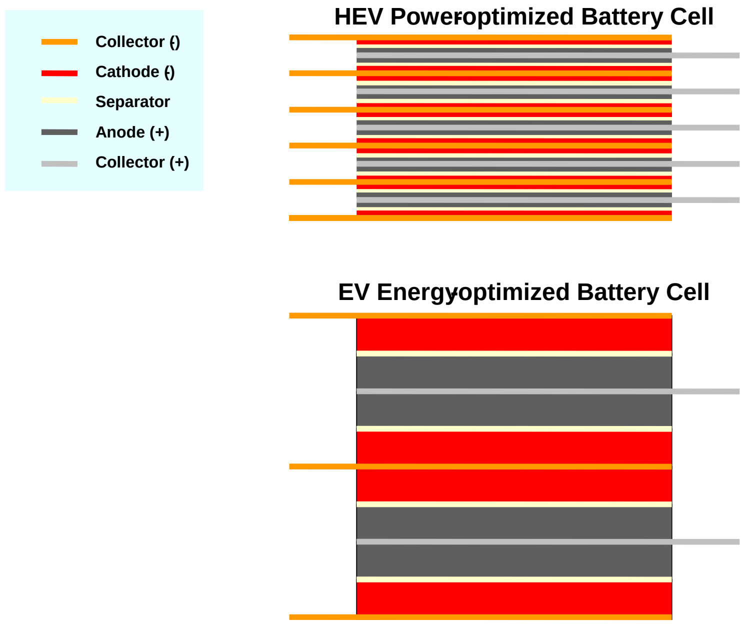
ISG and HEV batteries: ISG and HEV applications operate in a narrow, short-cycling, charge-sustaining state of charge (SOC). Energy capacity in ISG and HEV applications is somewhat limited by the ability of the battery and power electronics to accept charge and by space and weight constraints within the vehicle design. ISG and HEV battery designs tend to be optimized for high power density rather than high energy density, with thinner cathode and anode layers and more numerous current collectors and separators (Figure V-33).

EV batteries: EV batteries tend to be optimized for high energy density and are considerably larger and heavier than HEV batteries in order to provide sufficient energy capacity. EV battery cells tend to have thicker cathode and anode layers and fewer collectors and separators than HEV cells. This reduced the specific cost on a per-kWh basis for EV battery cells relative to HEV battery cells.

PHEV batteries: PHEV battery designs are intermediate between power-optimized HEV and energy-optimized EV battery cell designs. PHEV batteries must provide both charge depleting operation similar to an EV and charge sustaining operation similar to an HEV. Unlike HEV applications, charge-sustaining operation with PHEVs occurs at a relatively low battery

SOC, which can pose a significant challenge with respect to attaining acceptable battery cycle life. In the case of the GM Volt, this limits charge depleting operation to a minimum SOC of approximately 30 percent.[260] An alternative approach for PHEV applications that has potential to allow extension of charge depletion to a lower battery SOC is using energy-optimized lithium-ion batteries for charge depleting operation in combination with the use of supercapacitors for charge sustaining operation.[261]

Figure V-33: Schematic representation of power and energy optimized prismatic-layered battery cells



Power-split hybrid vehicles from Toyota, Ford and Nissan (which uses the Toyota system under license), integrated motor assist hybrid vehicles from Honda and the GM 2-mode hybrid vehicles currently use nickel-metal hydride (NiMH) batteries. Lithium-ion (Li-ion) batteries offer the potential to approximately double both the energy and power density relative to current NiMH batteries, enabling much more electrical-energy-intensive automotive applications such as PHEVs and EVs.

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[260] "Latest Chevrolet Volt Battery Pack and Generator Details and Clarifications." Lyle Dennis interview of Rob Peterson (GM) regarding the all-electric drive range of the GM Volt, August 29, 2007. Accessed on the Internet on November 14, 2011 at http://gm-volt.com/2007/08/29/latest-chevy-volt-battery-pack-and-generator-details-and-clarifications/

[261] "Active Combination of Ultracapacitors and Batteries for PHEV ESS." Bohn, T. U.S. Department of Energy 2009 Vehicle Technologies Merit Review, May 20, 2009, Docket No. NHTSA-2010-0131 or available at http://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2009/vehicles_and_systems_simulation/vss_15_bohn.pdf (last accessed November 14, 2011)

Li-ion batteries for high-volume automotive applications differ substantially from those used in consumer electronics applications with respect to cathode chemistry, construction and cell size. Li-ion battery designs currently in production by CPI (LG-Chem) for the GM Volt PHEV and by AESC and GS-Yuasa (respectively) for the Nissan Leaf and Mitsubishi iMiEV use large-format, layered-prismatic cells assembled into battery modules. The modules are then combined into battery packs.

Two families of cathode chemistries are used in large-format, automotive Li-ion batteries currently in production – $LiMn_2O_4$-spinel (CPI, GS-Yuasa, AESC) and LiFePO4 (A123 Systems). Current production batteries typically use graphite anodes. Automotive Li-ion batteries using lithium nickel manganese cobalt (NMC) oxide cathodes with graphite anodes are in advanced stages of development for PHEV and EV applications. The agencies expect large-format Li-ion batteries to completely replace NiMH batteries for post-2017 HEV applications. We also expect that large-format stacked and/or folded prismatic Li-ion cell designs will continue to be used for PHEV and EV applications and that NMC/graphite Li-ion batteries will be a mature technology for 2017-2025 light-duty vehicle applications. Another more distant future option may be lithium-sulfur batteries, but we have not accounted for them in this rulemaking analysis due to the need to resolve certain safety concerns and the potential for loss of polysulfides from the dilithium crystals to the electrolyte, leading to fading of battery capacity over time.[262]

HEV, PHEV and EV System Sizing and Cost Estimating Methodology

Battery packs are (and will continue to be) one of the most expensive components for EVs, PHEVs and HEVs. To obtain reasonable cost estimates for electrified vehicles, it is important to establish a reliable approach for determining battery attributes for each vehicle and class. Both battery energy content ("size") and power rating are key inputs used to establish costs per ANL's battery costing model. For EVs and PHEVs in particular, battery size and weight are closely related, and so battery weight must be known as well. The following section details the steps taken to size a battery and how battery costs are derived by EPA using ANL's BatPaC model.

Battery Pack Sizing and Hybrid System Sizing

Calculation of required battery pack energy requirements for EVs and PHEVs is not straightforward. Because vehicle energy consumption is strongly dependent on weight, and battery packs are very heavy, the weight of the battery pack itself can change the energy required to move the vehicle. As vehicle energy consumption increases, the battery size must increase for

[262] *See* http://www-ssrl.slac.stanford.edu/content/sites/default/files/documents/science-highlights/pdf/lis.pdf (last accessed Aug. 5, 2012).

a given range (in the case of EVs and PHEVs) – as a result, vehicle weight increases, and per-mile energy consumption increases as well, increasing the battery size, and so on.

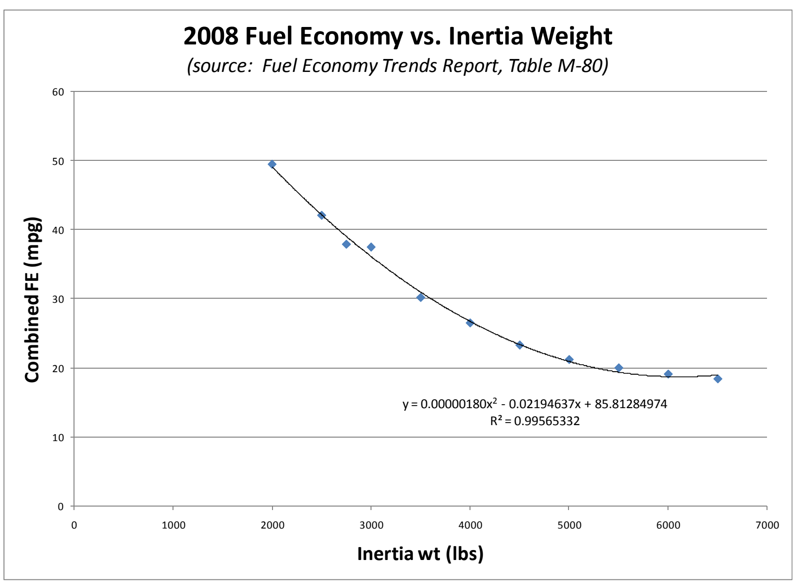
EPA built spreadsheets to estimate the required battery size for each vehicle and class. Listed below are the steps EPA has taken in these spreadsheets to estimate not only battery size, but associated weight for EVs and PHEVs of varying ranges and designs.

1. Establish baseline FE/energy consumption
2. Assume nominal weight of electrified vehicle (based on weight reduction target)
3. Calculate vehicle energy demand at this target weight
4. Calculate required battery energy
5. Calculate actual battery and vehicle weight
6. Do vehicle weight and battery size match estimated values?

Steps 2-6 were iterated until assumed weight reduction target (and nominal vehicle weight) reconciled with required battery size and the calculated weight of each vehicle.

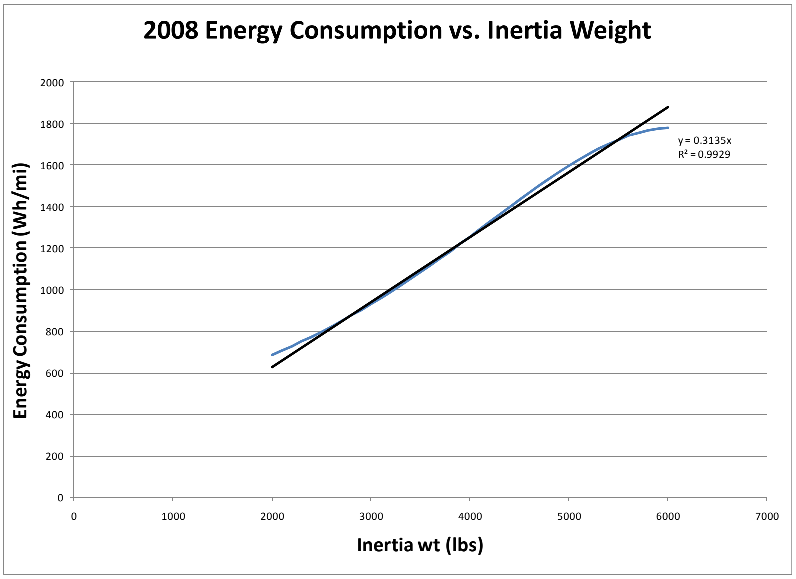
Vehicle energy consumption is estimated based on a fitted trendline for fuel economy versus inertia weight, or estimated test weight (ETW) (from FE Trends data for 2008 MY vehicles, table M-80) and converting to Wh/mi. This is shown in Figure V-34.

Figure V-34 Average fuel economy based on inertia weight (ETW) from FE Trends data



Then, fuel economy was converted into energy consumption (assuming 33,700 Wh energy in 1 gallon of gasoline) and used to populate a range of test weights between 2,000 and 6,000 lbs. A linear trend line was used to fit this curve and then applied to estimate generic energy consumption for baseline vehicles of a given ETW, shown below in Figure V-35.

Figure V-35 Equivalent energy consumption (in Wh/mi) for baseline vehicles



To calculate battery pack size, the electrified vehicle weight must first be known; to calculate vehicle weight, the battery pack size must first be known. This circular reference required an iterative solution. EPA assumed a target vehicle glider (a rolling chassis with no powertrain) weight reduction and applied that to the baseline curb weight. The resulting nominal vehicle weight was then used to calculate the vehicle energy demand. To calculate the energy demand (efficiency) of an electric vehicle in Wh/mi, the following information was needed:

- Baseline energy consumption / mpg
- Efficiency (η) improvement of electric vehicle
- Change in road loads

In Table **V-60** below, the following definitions apply:

- Brake eff (brake efficiency) – the % amount of chemical fuel energy converted to energy at the engine crankshaft (or, for batteries, the amount of stored electrical energy converted to shaft energy entering the transmission)
- D/L eff (driveline efficiency) – the % of the brake energy entering the transmission delivered through the driveline to the wheels
- Wheel eff (wheel efficiency) – the product of brake and driveline efficiency
- Cycle eff (cycle efficiency) – the % of energy delivered to the wheels used to overcome road loads and power the vehicle (it does not include energy lost as braking heat)
- Vehicle efficiency – the product of wheel and cycle efficiency
- Road loads – the amount of resistant energy the vehicle must overcome during a city/highway test. Composed of vehicle weight (inertia), aerodynamic drag and rolling resistance

- Vehicle efficiency – the product of wheel and cycle efficiency
- Road loads – the amount of resistant energy the vehicle must overcome during a city/highway test. Composed of vehicle weight (inertia), aerodynamic drag and rolling resistance.

Table V-60: EV100 efficiency and energy demand calculations, 20% appl. weight reduction

Vehicle Class	Brake eff	D/L eff	Wheel eff	Cycle eff	Vehicle eff	Road loads	Energy reduction	Energy eff increase	IW-based, base ICE nominal mpgge	Base fuel energy req'd Wh/mi	FTP fuel energy req'd Wh/mi	Onroad fuel energy req'd Wh/mi
Baseline gas ICE	24%	81%	20%	77%	15%	100%						
Sub/Compact PC	85%	93%	79%	97%	77%	88%	83%	478%	37	912	158	225
Midsize PC	85%	93%	79%	97%	77%	88%	83%	478%	30	1122	194	277
Large PC	85%	93%	79%	97%	77%	88%	83%	478%	25	1332	230	329
Small LT	85%	93%	79%	97%	77%	89%	83%	475%	29	1180	205	293
Midsize LT	85%	93%	79%	97%	77%	89%	83%	475%	23	1497	260	372
Large LT	85%	93%	79%	97%	77%	88%	83%	482%	20	1727	297	424

The energy efficiency of a baseline vehicle (around 15 percent), as indicated in the table above, was estimated using efficiency terms derived from EPA's lumped parameter model (engine/battery brake efficiency, driveline efficiency, cycle efficiency and road load ratio to baseline). To calculate the energy consumption of an EV (or PHEV in charge-depleting mode), the following assumptions were made:

- "Brake" efficiency (for an EV, the efficiency of converting battery energy to tractive energy at the transmission input shaft) was estimated at 85% - assuming, roughly a 95% efficiency for the battery, motor, and power electronics, respectively.
- The driveline efficiency (including the transmission) was comparable to the value calculated by the lumped parameter model for an advanced 6-speed dual-clutch transmission at 93%.
- The cycle efficiency assumes regenerative braking where 97% recoverable braking energy is recaptured. As a result, most of the energy delivered to the wheels is used to overcome road loads.
- The road loads were based on the weight reduction of the vehicle. In the case of a 100 mile EV with a 20% weight reduction, road loads (as calculated by the LP model) are reduced to 88-89% of the baseline vehicle.[263]

The energy consumption of the EV includes ratio of the road loads of the EV to the baseline vehicle, and the ratio of the efficiency of the EV compared to the baseline vehicle. It is expressed mathematically as shown below in Equation V-1.

[263] Included in this example road load calculation is a 10% reduction in rolling resistance and aerodynamic drag.

Equation V-4: EV energy consumption

$$E_{EV\_FTP}(Wh/mi) = E_{baseline\_FTP} * \left(\frac{\%Roadload_{new}}{\%Roadload_{old}} * \frac{\eta_{vehicle\_old}}{\eta_{vehicle\_new}}\right)$$

In Table **V-60**, the baseline energy required (in Wh/mi) is in the column labeled "Base fuel energy reqd." The energy required for each vehicle class EV over the FTP is in the column "FTP fuel energy reqd Wh/mi" and incorporates the equation above. This energy rate refers to the laboratory or unadjusted test cycle value, as opposed to a real-world "on-road" value. EPA assumes a 30% fuel economy shortfall, based loosely on the 5-cycle Fuel Economy Labeling Rule from 2006 which is directionally correct for electrified vehicles. This corresponds to an increase in fuel consumption of 43%. Applying this 43% increase gives the onroad energy consumption values for EVs as shown in the far right column of the previous table. From this value, one can determine an appropriate battery pack size for the vehicle.

The required battery energy for EVs equals the on-road energy consumption, multiplied by the desired range, divided by the useful state-of-charge window of the battery. It is calculated as follows in
Equation **V-5**.

Equation V-5: Required battery pack energy (size) for EVs

$$BP(kWh) = \frac{E_{onroad}(\frac{Wh}{mi}) \times range(mi)}{SOC\%}$$

Assumed usable SOC windows were 80% for EVs (10-90%) and 70% for PHEVs (15%-85%). The battery pack sizes are listed in orange in Table V-61 for the 100-mile EV case and show both the on-road energy consumption ("EV adj Wh/mi" column) and the nominal battery energy content or "battery pack size."

Table V-61: Battery pack sizes for 100-mile EV based on inertia weight, 20% applied weight reduction

Class	Baseline curb wt (lb)	Inertia wt (lb)	EV unadj (Wh/mi)	EV adj (Wh/mi)	100 mile batt pack size (kWh)
2008 Baseline					
Small car	2633	2933	158	225	28.2
Std car	3306	3606	194	277	34.7
Large car	3897	4197	230	329	41.1
Small MPV	3474	3774	205	293	36.7
Large MPV	4351	4651	260	372	46.5
Truck	5108	5408	297	424	53.0
2010 Baseline					
Small car	2753	3053	164	234	29.2
Std car	3387	3687	200	286	35.7
Large car	4035	4335	241	344	43.0
Small MPV	3528	3828	209	298	37.3
Large MPV	4313	4613	257	367	45.8
Truck	5346	5646	307	439	54.8

EPA used Equation V-3 to determine weight of an EV:

Equation V-6: EV weight calculation

$$W_{EV} = W_{base} - WR_{glider} - W_{ICE\_powertrain} + W_{electric\_drive}$$

Any weight reduction technology was applied only to the glider (baseline vehicle absent powertrain) as defined in Equation V-4:

Equation V-7: Weight reduction of the glider

$$WR_{glider} = \%WR * (W_{base} - W_{ICE\_powertrain})$$

In the case of PHEVs, it was assumed that the base ICE powertrain remains so it is not deducted; the proper equation for PHEVs is shown in equation V-5**:**

Equation V-5: Weight calculation for PHEV

$$W_{PHEV} = W_{base} - WR_{glider} + W_{electric\_drive}$$

Listed in Table V-62 are the assumed baseline ICE-powertrain weights, by vehicle class:

Table V-62: Baseline ICE-powertrain weight assumptions, by class

Vehicle Class	Engine	Trans (diff not included)	Fuel sys (50% fill)	Engine mounts/ NVH treatments	Exhaust	12V batt	Total ICE powertrain weight
Sub/Compact PC	250	125	50	25	20	25	495
Midsize PC	300	150	60	25	25	30	590
Large PC	375	175	70	25	30	35	710
Small LT	300	150	60	25	25	30	590
Midsize LT	400	200	80	25	30	40	775
Large LT	550	200	100	25	40	50	965

EPA then estimated the weight of the electric drive subsystem using the energy content of the battery pack as an input. EPA scaled the weight by applying a specific energy for the electric drive subsystem, including the battery pack, drive motor, wiring, power electronics, etc., of 120 Wh/kg (or 18.33 lb/kWh). This specific energy value is based on adding components to an assumed battery pack specific energy of 150 Wh/kg.[264] Then, the gearbox (the only subsystem excluded from the electric drive scaling) was added to the weight of the electric drive subsystem; this total was included into the electric vehicle weight calculation as $W_{electric\_drive}$.[265] A summary table of electric drive weights for 100-mile EVs is shown in **Table V-63**:

Table V-63: Total electric drive weights for 100-mile EVs

Class	Batt pack size (kWh)	2020 electric content (lbs)	Gearbox (power-split or other)	2020 EV powertrain total
2008 Baseline				
Sub/Compact PC	28.2	517	50	567
Midsize PC	34.7	635	60	695
Large PC	41.1	754	70	824
Small LT	36.7	672	60	732
Midsize LT	46.5	853	80	933
Large LT	53.0	972	100	1072
2010 Baseline				
Sub/Compact PC	29.2	536	50	586
Midsize PC	35.7	655	60	715
Large PC	43.0	788	70	858
Small LT	37.3	683	60	743
Midsize LT	45.8	840	80	920
Large LT	54.8	1005	100	1105

The difference between the actual weight and the predicted or nominal weight should be zero. However, if not then a revised weight reduction was used for another iteration of steps 2-6 until the two vehicle weights match. Spreadsheet tools such as "solver" in MS Excel were used for automating this iterative process.

[264] 150 Wh/kg is a conservative estimate for year 2017 and beyond: outputs from ANL's battery cost model show specific energy values of 160- 180 Wh/kg for a similar timeframe.
[265] Applies only to the EV. Because the baseline ICE powertrain weight (which includes gearbox weight) was not deducted from the PHEV, it is not added back in for the PHEV.

Table **V-64** shows example results for 100-mile range EVs; in this case a 20% applied glider weight reduction for a variety of vehicle classes.

Table V-64: Sample calculation sheet for 100-mile EVs for the 2008 baseline

Class	Base curb wt (lb)	Base power/wt ratio	Powertrain weight (lb)	Base glider wt (lb)	WR of glider	New EV wt (nominal lb)	Energy cons adjusted (Wh/mi)	Batt pack size (kWh)	Electric drive wt (lb)	New EV weight (lb)	Error	% WR from curb	% RL vs base
Sub/Compact PC	2633	0.0486	495	2138	428	2205	225	28.2	567	2277	0	13.5 %	88 %
Midsize PC	3306	0.0575	590	2716	543	2763	277	34.7	695	2868	0	13.2 %	88 %
Large PC	3897	0.0872	710	3187	637	3260	329	41.1	824	3374	0	13.4 %	88 %
Small LT	3474	0.0463	590	2884	577	2897	293	36.7	732	3039	0	12.5 %	89 %
Midsize LT	4351	0.0565	775	3576	715	3636	372	46.5	933	3794	0	12.8 %	89 %
Large LT	5108	0.0617	965	4143	829	4279	424	53.0	1072	4387	0	14.1 %	88 %

Table **V-65** shows the effect on net electric vehicle weight reduction after 20% glider weight reduction was applied to EVs and PHEVs. As battery pack size increases for larger-range EVs and PHEVs, the overall realized vehicle weight reduction decreases (because it requires more energy to carry the extra battery weight). In this example, EVs with a 150 mile range require almost 20% weight reduction to the glider to make up for the additional weight of the electric drive and battery pack compared to a conventional ICE-based powertrain.

Table V-65: Actual weight reduction percentages for EVs and PHEVs with 20% weight reduction applied to glider

	75 Mile EV Actual %WR vs. base vehicle	100 Mile EV Actual %WR vs. base vehicle	150 Mile EV Actual %WR vs. base vehicle	20 Mile PHEV Actual %WR vs. base vehicle	40 Mile PHEV Actual %WR vs. base vehicle
2008 Baseline					
Sub/Compact PC	19%	14%	2%	12%	7%
Midsize PC	18%	13%	2%	12%	7%
Large PC	19%	13%	2%	12%	7%
Small LT	18%	13%	1%	12%	7%
Midsize LT	18%	13%	1%	12%	7%
Large LT	19%	14%	3%	11%	6%
2010 Baseline					
Sub/Compact PC	18%	13%	1%	12%	7%
Midsize PC	18%	13%	1%	12%	7%
Large PC	18%	13%	1%	12%	7%
Small LT	18%	12%	1%	12%	8%
Midsize LT	18%	13%	1%	12%	7%
Large LT	19%	14%	3%	11%	6%

Because there is no "all-electric range" requirement for HEVs, battery pack sizes were relatively consistent for a given weight class. Furthermore, because battery pack sizes are at least an order of magnitude smaller for HEVs than for all-electric vehicles, the sensitivity of HEV vehicle weight (and hence energy consumption) to battery pack size is rather insignificant. For these reasons, a more direct approach (rather than an iterative process) works for battery sizing of HEVs. HEV batteries were scaled similar to the 2010 Fusion Hybrid based on nominal battery energy per lb ETW (equivalent test weight), at 0.37 Wh/lb. A higher usable SOC window of 40% (compared to 30% for Fusion Hybrid) reduced the required Li-Ion battery size to 75% of the Fusion Hybrid's NiMH battery. This resulted in a 0.28 Wh/lb ETW ratio. In comparing anecdotal data for HEVs, the agencies assumed a slight weight increase of 4-5% for HEVs compared to baseline non-hybridized vehicles. The added weight of the Li-ion pack, motor and other electric hardware were offset partially by the reduced size of the base engine.

HEV, PHEV and EV Battery Pack Cost Analysis using the ANL BatPac Model

The U.S. Department of Energy (DOE) has established long term industry goals and targets for advanced battery systems as it does for many energy efficient technologies. Argonne National Laboratory (ANL) was funded by DOE to provide an independent assessment of Li-ion battery costs because of their expertise in the field as one of the primary DOE National Laboratories responsible for basic and applied battery energy storage technologies for future HEV, PHEV and EV applications. A basic description of the ANL Li-ion battery cost model and initial modeling results for PHEV applications were published in a peer-reviewed technical paper presented at

EVS-24.[266] ANL has extended modeling inputs and pack design criteria within the battery cost model to include analysis of manufacturing costs for EVs and HEVs as well as PHEVs.[267] In early 2011, ANL issued a draft report detailing the methodology, inputs and outputs of their Battery Performance and Cost (BatPac) model.[268] A complete independent peer-review of the BatPac model and its inputs and results for HEV, PHEV and EV applications has been completed.[269] ANL recently provided the agencies with an updated report documenting the BatPac model that addresses many of the issues raised within the peer review.[270] Based on the feedback from peer-reviewers, ANL updated the model in the following areas:

1. Battery pack cost is adjusted upward. This adjustment is based on the feedback from several peer-reviewers, and changes are related to limiting electrode thickness to 100 microns, changing allocation of overhead cost to more closely represent a Tier 1 auto supplier, increasing cost of tabs, changing capital cost of material preparation, etc;
2. Battery management system cost is increased to represent the complete monitoring and control needs for proper battery operation and safety as shown in Table 5.3 in the report;
3. Battery automatic and manual disconnect unit cost is added based on safety considerations as shown in Table 5.3 in the report;
4. Liquid thermal management system is added. ANL stated in the report that the liquid-cooled closure design it uses in the model would not have sufficient surface area and cell spacing to be cooled by air effectively as shown in Table 5.3 in the report.

Subsequently, the agencies requested that an option be added to select between liquid or air thermal management and that adequate surface area and cell spacing be determined accordingly. Also, the agencies requested a feature to allow battery packs to be configured as subpacks in parallel or modules in parallel, as additional options for staying within voltage and cell size limits for large packs.

ANL added these features in a version of the model distributed March 1, 2012. This version of the model is used for the battery cost estimates in the final rule. This model and the peer review report are available in the public dockets for this rulemaking.

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[266] Nelson, P.A., Santini, D.J., Barnes, J. "Factors Determining the Manufacturing Costs of Lithium-Ion Batteries for PHEVs," 24th World Battery, Hybrid and Fuel Cell Electric Vehicle Symposium and Exposition EVS-24, Stavenger, Norway, May 13-16, 2009 Docket No. NHTSA-2010-0131 or Available at http://www.transportation.anl.gov/pdfs/B/624.PDF (last accessed November 14, 2011).

[267] Santini, D.J., Gallagher, K.G., and Nelson, P.A. "Modeling of Manufacturing Costs of Lithium-Ion Batteries for HEVs, PHEVs, and EVs," Paper to be presented at the 25th World Battery, Hybrid and Fuel Cell Electric Vehicle Symposium and Exposition, EVS-25, Shenzhen, China, November 5-9, 2010. Available at http://www.docin.com/p-99138808.html (last accessed November 14, 2011).

[268] The ANL draft report can be found at Docket No. NHTSA-2010-0131.

[269] The ANL peer review can be found in at Docket No. NHTSA-2010-0131.

[270] The ANL final report on BatPac can be found at Docket No. NHTSA-2010-0131.

NHTSA and EPA decided to use the ANL BatPaC model, for estimating large-format lithium-ion batteries for this final rule, consistent with the proposal, for the following reasons. First, the ANL model has been described and presented in the public domain and does not rely upon confidential business information (which would therefore not be reviewable by the public). The model was developed by scientists at ANL who have significant experience in this area. The model uses a bill of materials methodology which the agencies believe is the preferred method for developing cost estimates. The ANL model appropriately considers the vehicle applications power and energy requirements, which are two of the fundamental parameters when designing a lithium-ion battery for an HEV, PHEV, or EV. The ANL model can estimate *high volume* production costs, which the agencies believe is appropriate for the 2025 time frame. Finally, the ANL model's cost estimates, while generally lower than the estimates we received from the OEMs, is consistent with some of the supplier cost estimates the agencies received from large-format lithium-ion battery pack manufacturers. A portion of those data was received from on-site visits to vehicle manufacturers and battery suppliers done by the EPA in 2008.

The ANL battery cost model is based on a bill of materials approach in addition to specific design criteria for the intended application of a battery pack. The costs include materials, manufacturing processes, the cost of capital equipment, plant area, and labor for each manufacturing step as well as the design criteria include a vehicle application's power and energy storage capacity requirements, the battery's cathode and anode chemistry, and the number of cells per module and modules per battery pack. The model assumes use of a laminated multi-layer prismatic cell and battery modules consisting of double-seamed rigid containers. The model also assumes that the battery modules are liquid-cooled. The model takes into consideration the cost of capital equipment, plant area and labor for each step in the manufacturing process for battery packs and places relevant limits on electrode coating thicknesses and other processes limited by existing and near-term manufacturing processes. The ANL model also takes into consideration annual pack production volume and economies of scale for high-volume production.

Basic user inputs to BatPaC include performance goals (power and energy capacity), choice of battery chemistry (of five predefined chemistries), the vehicle type for which the battery is intended (HEV, PHEV, or EV), the desired number of cells and modules, and the volume of production. BatPaC then designs the cells, modules, and battery pack, and provides an itemized cost breakdown at the specified production volume.

BatPaC provides default values for engineering properties and material costs that allow the model to operate without requiring the user to supply detailed technical or experimental data. In general, the default properties and costs represent what the model authors consider to be reasonable values representing the state of the art expected to be available to large battery manufacturers in the year 2020. Users are encouraged to change these defaults as necessary to represent their own expectations or their own proprietary data.

In using BatPaC, it is extremely important that the user monitor certain properties of the cells, modules, and packs that it generates, to ensure that they stay within practical design guidelines, adjusting related inputs if necessary. In particular, pack voltage and individual cell capacity should be limited to appropriate ranges for the application. These design guidelines are not rigidly defined but approximate ranges are beginning to emerge in the industry.

Also inherent in BatPaC are certain modeling assumptions that are still open to some uncertainty or debate in the industry. For some, such as the available portion of total battery energy (aka "SOC window") for a PHEV/EV/HEV, the user can easily modify a single parameter to represent a value other than the default. For others, such as specific unit costs for thermal management or battery monitoring components, changes can often be made by replacing the relevant components of the model outputs.

The cost outputs used by the agencies to determine 2025 HEV, PHEV and EV battery costs were based on the following inputs and assumptions:

EPA selected basic user inputs as follows. For performance goals, EPA used the power and energy requirements derived from the scaling analysis described in the previous section. Specifically, these covered each of the six classes of vehicles (Small Car, Standard Car, Large Car, Small MPV, Large MPV, and Truck) under each of the five weight reduction scenarios (0%, 2%, 7.5%, 10%, and 20%). The chosen battery chemistries were NMC441-G (for EVs and PHEV40) and LMO-G (for P2 HEVs and PHEV20). Vehicle types were EV75, EV100, EV150 (using the BatPaC "EV" setting); PHEV20 and PHEV40 (using the "PHEV" setting), and P2 HEV (using the "HEV-HP" setting). All modules were composed of 32 cells, with each pack having a varying number of modules. Cost outputs were generated for annual production volumes of 50K, 125K, 250K, and 450K packs. The cost outputs for the 450K production volume are used in the FRM analysis, consistent with the proposal, as being applicable in MY 2017 (HEV) and MY 2025 (EVs and PHEVs).

For engineering properties and material costs, and for other parameters not identified below, EPA used the defaults provided in the model. For design guidelines regarding pack voltage and cell capacity, EPA chose guidelines based on knowledge of current practices and developing trends of battery manufacturers and OEMs, supplemented by discussions with the BatPaC authors. Specifically: (1) allowable pack voltage was targeted to approximately 120V for HEVs and approximately 350-400V for EVs and PHEVs (with some EV150 packs for larger vehicles allowed to about 460-600V); (2) allowable cell capacity was limited to less than approximately 80 A-hr.

EPA made several modeling assumptions that differed from the default model: (1) The SOC window for HEVs was increased to 40% rather than the default 25%. (2) HEV packs were modeled as air cooled instead of liquid cooled (except for Truck and MPV with Towing, which are modeled as liquid-cooled). EPA replaced the model's projected costs for air cooling components (blower motor, ducting, and temperature feedback) with costs derived from FEV's teardown studies, which may be more representative of volume production than the default values provided in the model.

Additionally, EPA did not include warranty costs computed by BatPaC in the total battery cost because these are accounted for elsewhere in the agencies' rulemaking analysis by means of indirect cost multipliers (ICMs).

Table V-66 Summary of Inputs and Assumptions Used with BatPaC

Category of input/Assumptions	BatPaC Default or Suggested Values	Agency Inputs for FRM Analysis
Annual production volume	n/a	450,000
Battery chemistry	n/a	for HEV, PHEV20: LMO-G for PHEV40, EV: NMC441-G
Allowable pack voltage	for HEV: 160-260 V for PHEV, EV: 290-360 V	for HEV: ~ 120 V for PHEV, EV: ~ 360-600 V
Allowable cell capacity	< 60 A-hr	< 80 A-hr
Cells per module	16-32	32
SOC window for HEVs	25%	40%
Thermal management	Liquid	Air, for small/medium HEVs Liquid for all others

The cost projections produced by BatPaC are sensitive to the inputs and assumptions the user provides. Significant uncertainty remains regarding which will best represent manufacturer practice in the year 2020. The battery pack cost projection from BatPaC model ranges from \$160/kWh for EV150 for large truck to \$306/kWh for PHEV40 for large passenger car with NMC as chemistry and to \$376/kWh for PHEV20 for large passenger car using LMO as shown in Table V-68. The agencies note that costs used in the analysis are lower than the costs generally reported in stakeholder meetings, which ranged from \$300/kW-hour to \$400/kW-hour range for 2020 and \$250 to \$300/kW-hour range for 2025. A comparison of BatPaC modeling results to the costs used in MYs 2012-2016 final rule and to cost estimates compiled by EPA from battery suppliers and auto OEMs is shown in Table V-67 Table from ANL Recommendation

.

In the comments for NPRM, ICCT commented that future versions of the BatPac model should include the option to select either air or liquid cooling.[271] Tesla commented that that while it thought the BatPac model was helpful, Tesla rather "supports a more comprehensive approach to assessing battery cost," *i.e.*, by "factor[ing] in all the costs of the battery and attendant systems including cell management, thermal management and the disconnect unit."[272] Tesla stated that the battery systems in its Model S would cost only $350/kWh at production levels of 25,000/year, and that it expected its costs to come down in the future.[273] Porsche, in contrast, argued that the battery costs used in the NPRM were significantly underestimated, which "inflates the apparent cost-effectiveness" of the standards.[274] As stated above, for the final rulemaking the agencies' requested ANL to update the BatPaC model to allow for either air or liquid cooling. This option was used in the final rule analysis. Additionally, the agencies are accounting for the costs of cell management, thermal management, and battery disconnect.

The agencies also reviewed publically available PHEV and EV battery cost literature including reports from Anderman[275], Frost & Sullivan[276], TIAX[277], Boston Consulting Group[278], and NRC[279]. Due to the uncertainties inherent in estimating battery costs through the 2025 model year, a sensitivity analysis will be provided in each agency's RIA using a range of costs estimated by DOE technical experts to represent a reasonable outer bound to the results from the BatPaC model. In a recent report to NHTSA and EPA, DOE and ANL suggested the following range for the sensitivity study with 95% confidence interval after analyzing the confidence bound using the BatPaC model. NHTSA incorporated the BatPaC sensitivity ranges suggested by ANL, below, while EPA used bounds described in Chapter 3 of their final RIA.

Table V-67 Table from ANL Recommendation[280]

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[271] ICCT, Docket No. NHTSA-2010-0131-0258, at 21-22.

[272] Tesla, Docket No. NHTSA-2010-0131-0259, at 5.

[273] *Id*.

[274] Porsche, Docket No. NHTSA-2010-0131-0224, at 6.

[275] Anderman, M. (2010) Feedback on ARB's Zero-Emission Vehicle Staff Technical Report of 11/25/2009 including attachment A: Status of EV Technology Commercialization, Advanced Automotive Batteries, January 6, 2010. NHTSA Docket: NHTSA-2010-0131.

[276] Frost & Sullivan (2009b) World Hybrid Electric and Electric Vehicle Lithium-ion Battery Market, N6BF-27, Sep 2009.

[277] Barnett, B. (2009) "PHEV Battery Cost Assessment" TIAX LLC presentation at U.S. DOE/EERE 2009 Vehicle Technologies Program Annual Merit Review, May 19, 2009. Accessed on the Internet on Aug 3, 2012 at: http://www1.eere.energy.gov/vehiclesandfuels/pdfs/merit_review_2009/energy_storage/es_02_barnett.pdf. NHTSA Docket: NHTSA-2010-0131.

[278] Boston Consulting Group (2010) Batteries for Electric Cars – Challenges, Opportunities, and the Outlook to 2020. *Available* at http://electricdrive.org/index.php?ht=a/GetDocumentAction/id/27906 (Accessed on Aug 14, 2012). Docket: NHTSA-2010-0131.

[279] National Research Council (2010) Transitions to Alternative Transportation Technologies--Plug-in Hybrid Electric Vehicles. *Available at* https://download.nap.edu/catalog.php?record_id=12826 (Accessed on Aug 14, 2012). Docket: NHTSA-2010-0131.

[280] K. G. Gallagher, P. A. Nelson, (2010) "An Initial BatPac Variation Study" in Docket: NHTSA-2010-0131.

Suggested confidence bounds as percentage of the calculated point estimate for a graphite based Li-ion battery using the default inputs in BatPaC			
		Confidence Interval	
Battery type	**Cathodes**	**lower**	**upper**
HEV	LMO, LFP, NCA, NMC	-10%	10%
PHEV, EV	NMC, NCA	-10%	20%
PHEV, EV	LMO, LFP	-20%	35%

While it is expected that other Li-ion battery chemistries with higher energy density, higher power density and lower cost will likely be available in the 2017-2025 timeframe, the specific chemistries used for the cost analysis were chosen due to their known characteristics and to be consistent with both public available information on current and near term HEV, PHEV and EV product offerings from Hyundai, GM and Nissan as well as confidential business information on future products currently under development.[281,282,283,284] The specific cost outputs from the BatPaC model used by NHTSA in this analysis pre-consideration of mass reduction are shown in Table V-68.

Table V-68 MY2017 Direct Manufacturing Costs (2010$) for P2 HEV, PHEVs and EVs at 0% Net Vehicle Mass Reduction

NHTSA Vehicle Class	P2 HEV (LMO) @ 450K/yr volume		PHEV20 (LMO) @ 450K/yr volume		PHEV40 (NMC) @ 450K/yr volume		EV75 (NMC) @ 450K/yr volume		EV100 (NMC) @ 450K/yr volume		EV150 (NMC) @ 450K/yr volume	
2008 Baseline												
	Pack	$/kWh	Pack	$/kWh	Pack	$/kWh	Pack	$/kWh	Pack	$/kWh	Pack	$/kWh

281 "Hyundai ups tech ante with Sonata Hybrid," Automotive News, August 2, 2010. Available at http://www.autonews.com/apps/pbcs.dll/article?AID=/20100802/RETAIL03/308029942/1186 (last accessed November 14, 2011).

282 "Chevrolet Stands Behind Volt With Standard Eight-Year, 100,000-Mile Battery Warranty," GM Press release available at http://media.gm.com/content/media/us/en/news/news_detail.brand_gm.html/content/Pages/news/us/en/2010/July/0714_volt_battery (last accessed: November 14, 2011).

283 "Nissan's new 2012 hybrid system aims for 1.8-L efficiency with a 3.5-L V6," SAE Automotive Engineering Online, February 15, 2010. Available at http://ev.sae.org/article/7651 (last accessed November 14, 2011)

284 "Lithium-ion Battery," Nissan Global Technology Information Available at http://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/li_ion_ev.html (last accessed November 14, 2011).

Subcompact PC/Perf. PC Compact PC/Perf. PC	$726	$896	$2,531	$364	$3,644	$262	$5,115	$224	$6,105	$201	$8,080	$177
Midsize PC/Perf. PC	$801	$804	$2,962	$347	$4,390	$257	$6,021	$215	$7,054	$189	$9,753	$174
Large PC/Perf. PC	$938	$809	$3,734	$368	$6,006	$296	$7,724	$232	$8,630	$195	$11,120	$167
Small LT	$779	$747	$2,835	$316	$4,247	$236	$5,995	$203	$7,293	$186	$10,109	$171
Minivan/Midsize LT	$876	$682	$3,424	$300	$5,269	$231	$7,310	$195	$8,641	$173	$12,114	$162
Large LT	$1,010	$676	$3,874	$295	$6,122	$233	$8,332	$193	$9,962	$173	$13,878	$161
2010 Baseline												
	Pack	$/kWh	Pack	$/kWh	Pack	$/kWh	Pack	$/kWh	Pack	$/kWh	Pack	$/kWh
Subcompact PC/Perf. PC Compact PC/Perf. PC	$732	$904	$2,572	$370	$3,722	$268	$5,232	$221	$6,255	$198	$8,298	$175
Midsize PC/Perf. PC	$809	$813	$3,019	$353	$4,494	$263	$6,152	$214	$7,173	$187	$9,928	$173
Large PC/Perf. PC	$950	$819	$3,813	$376	$6,158	$304	$7,923	$229	$8,863	$192	$11,432	$166
Small LT	$788	$756	$2,933	$326	$4,351	$242	$6,070	$203	$7,375	$185	$10,228	$171
Minivan/Midsize LT	$878	$683	$3,434	$301	$5,286	$232	$7,312	$197	$8,586	$174	$12,032	$162
Large LT	$1,019	$682	$3,922	$298	$6,215	$236	$8,472	$191	$10,158	$172	$14,166	$160

Due to the weight increases of adding electrification system such as battery pack, and the weight decreases by applying smaller or no conventional internal combustion system for HEVs, PHEVs and EVs, the net mass reduction for HEV, PHEV and EV varies for different electrification packages and vehicle classes. The agencies estimated vehicle mass reduction offsets for different electrification packages as shown in Table **V-69**. These mass reduction offsets can be positive or negative depending on whether the added electrification system is heavier or lighter than the mass change due to the downsized conventional powertrain or even the elimination of the conventional internal combustion system. For example, for a 20-mile range subcompact PHEV shown in Table **V-69**, a 7% mass reduction of the glider (vehicle systems not including powertrain) is offset by the additional weight of the electrification system, and therefore 7% mass reduction is needed to achieve a net 0% overall vehicle mass reduction. On the other hand, for a 75-mile range large electric passenger car, because a conventional engine and transmission weigh more than the addition of the electrification systems, a net mass reduction of 1 percent can be achieved by simply switching from conventional gasoline powered vehicle to EV75 without applying any mass reduction to the glider. The agencies differentiate between “applied” mass reduction and "net" mass reduction in this analysis. The applied mass reduction is the mass reduction applied to a vehicle to achieve the net mass reduction after considering the interaction between mass reduction and electrification system, *i.e.*, the applied mass reduction includes all the offsets shown in **Table V-69**.

Table V-69 Mass reduction Offset Associated with Electrification Technologies

Vehicle Class	P2 HEV	PHEV20	PHEV40	EV75	EV100	EV150
2008 Baseline						
Subcompact/Compact	5%	7%	13%	0%	6%	18%
Midsize car	5%	7%	12%	0%	6%	18%
Large car	5%	8%	14%	-1%	5%	17%
Small LT	5%	7%	12%	0%	6%	18%
Midsize LT	4%	7%	12%	1%	7%	19%
Large truck	5%	7%	13%	0%	6%	18%
2010 Baseline						
Subcompact/Compact	5%	7%	12%	0%	6%	19%
Midsize car	5%	7%	12%	1%	7%	19%
Large car	5%	8%	13%	0%	6%	17%
Small LT	5%	7%	12%	1%	7%	19%
Midsize LT	5%	7%	12%	1%	7%	19%
Large LT	4%	7%	12%	0%	6%	19%

Using the ANL model outputs, the agencies calculated battery system costs for HEVs, PHEVs and EVs for different vehicle classes with different level of mass reduction. These results are summarized in Table **V-70** to Table V-75. NHTSA assumes that all minivans and midsize light trucks will maintain current towing capability so that consumers will not lose that functionality when moving to electrified vehicles.

Table V-70 MY2017 Direct Manufacturing Costs for P2 HEV packages at different levels of applied vehicle mass reduction (2010 dollars, markups not included)

P2 HEV (LMO) @ 450K/yr volume		0% mass reduction		2% mass reduction		7.5% mass reduction		10% mass reduction		20% mass reduction	
EPA Vehicle Class	**NHTSA Vehicle Class**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**
2008 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$726	$896	$722	$909	$712	$950	$708	$970	$700	$1,008
Standard Car	Midsize PC/Perf. PC	$801	$804	$796	$815	$783	$849	$777	$866	$765	$901
Large Car	Large PC/Perf. PC	$938	$809	$929	$817	$909	$848	$900	$862	$882	$894
Small MPV	Small LT	$779	$747	$775	$758	$762	$790	$757	$806	$746	$839
Large MPV	Minivan	$876	$682	$870	$691	$853	$718	$846	$731	$830	$760

	Midsize LT										
Truck	Large LT	$1,010	$676	$1,003	$685	$983	$711	$974	$724	$957	$747
2010 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$732	$904	$729	$918	$718	$958	$714	$978	$705	$1,017
Standard Car	Midsize PC/Perf. PC	$809	$813	$805	$824	$791	$858	$785	$875	$773	$909
Large Car	Large PC/Perf. PC	$950	$819	$943	$830	$920	$858	$911	$873	$893	$904
Small MPV	Small LT	$788	$756	$784	$767	$771	$800	$765	$816	$754	$848
Large MPV	Minivan Midsize LT	$878	$683	$872	$692	$855	$720	$847	$733	$832	$762
Truck	Large LT	$1,019	$682	$1,012	$691	$992	$718	$983	$731	$967	$754

Table V-71 MY2025 Direct Manufacturing Costs for PHEV20 packages at different levels of applied vehicle mass reduction (2010 dollars, markups not included)

PHEV20 (LMO) @ 450K/yr volume		0% mass reduction		2% mass reduction		7.5% mass reduction		10% mass reduction		20% mass reduction	
EPA Vehicle Class	**NHTSA Vehicle Class**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**
2008 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$2,531	$364	$2,517	$364	$2,469	$370	$2,447	$371	$2,431	$373
Standard Car	Midsize PC/Perf. PC	$2,962	$347	$2,938	$348	$2,835	$345	$2,808	$346	$2,784	$347
Large Car	Large PC/Perf. PC	$3,734	$368	$3,696	$369	$3,592	$369	$3,546	$368	$3,510	$369
Small MPV	Small LT	$2,835	$316	$2,813	$317	$2,754	$319	$2,730	$320	$2,703	$323
Large MPV	Minivan Midsize LT	$3,424	$300	$3,393	$301	$3,309	$302	$3,274	$303	$3,244	$303
Truck	Large LT	$3,874	$295	$3,834	$295	$3,732	$295	$3,681	$297	$3,671	$296
2010 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$2,572	$370	$2,554	$370	$2,507	$376	$2,487	$377	$2,468	$379
Standard Car	Midsize PC/Perf. PC	$3,019	$353	$2,992	$354	$2,927	$357	$2,858	$352	$2,829	$353
Large Car	Large PC/Perf. PC	$3,813	$376	$3,773	$376	$3,668	$376	$3,621	$376	$3,575	$376
Small MPV	Small LT	$2,933	$326	$2,911	$328	$2,811	$326	$2,783	$326	$2,754	$329
Large MPV	Minivan Midsize LT	$3,434	$301	$3,403	$302	$3,319	$303	$3,282	$303	$3,253	$304
Truck	Large LT	$3,922	$298	$3,881	$298	$3,778	$299	$3,732	$301	$3,706	$298

Table V-72 MY2025 Direct Manufacturing Costs for PHEV40 packages at different levels of applied vehicle mass reduction (2010 dollars, markups not included)

PHEV40 (NMC) @ 450K/yr volume		0% mass reduction		2% mass reduction		7.5% mass reduction		10% mass reduction		20% mass reduction	
EPA Vehicle Class	**NHTSA Vehicle Class**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**
2008 Baseline											
Small Car	Subcompact PC/Perf. PC	$3,644	$262	$3,619	$262	$3,542	$264	$3,542	$264	$3,542	$264

	Compact PC/Perf. PC										
Standard Car	Midsize PC/Perf. PC	$4,390	$257	$4,343	$257	$4,228	$258	$4,228	$258	$4,228	$258
Large Car	Large PC/Perf. PC	$6,006	$296	$5,921	$295	$5,671	$291	$5,671	$291	$5,671	$291
Small MPV	Small LT	$4,247	$236	$4,207	$237	$4,101	$238	$4,100	$237	$4,100	$237
Large MPV	Minivan Midsize LT	$5,269	$231	$5,212	$231	$5,065	$231	$5,065	$231	$5,065	$231
Truck	Large LT	$6,122	$233	$6,050	$233	$5,900	$232	$5,900	$232	$5,900	$232
2010 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$3,722	$268	$3,690	$267	$3,606	$269	$3,606	$269	$3,606	$269
Standard Car	Midsize PC/Perf. PC	$4,494	$263	$4,447	$263	$4,324	$263	$4,324	$263	$4,324	$263
Large Car	Large PC/Perf. PC	$6,158	$304	$6,073	$303	$5,850	$300	$5,850	$300	$5,850	$300
Small MPV	Small LT	$4,351	$242	$4,309	$243	$4,198	$243	$4,198	$243	$4,198	$243
Large MPV	Minivan Midsize LT	$5,286	$232	$5,228	$232	$5,080	$232	$5,080	$232	$5,080	$232
Truck	Large LT	$6,215	$236	$6,142	$236	$5,980	$235	$5,980	$235	$5,980	$235

Table V-73 MY2025 Direct Manufacturing Costs for EV75 packages at different levels of applied vehicle mass reduction (2010 dollars, markups not included)

EV75 (NMC) @ 450K/yr volume		0% mass reduction		2% mass reduction		7.5% mass reduction		10% mass reduction		20% mass reduction	
EPA Vehicle Class	**NHTSA Vehicle Class**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**
2008 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$5,115	$224	$5,098	$225	$4,996	$228	$4,962	$229	$4,768	$233
Standard Car	Midsize PC/Perf. PC	$6,021	$215	$5,965	$215	$5,818	$216	$5,755	$216	$5,509	$219
Large Car	Large PC/Perf. PC	$7,724	$232	$7,635	$232	$7,397	$231	$7,295	$231	$6,907	$231
Small MPV	Small LT	$5,995	$203	$5,952	$204	$5,843	$206	$5,800	$207	$5,625	$211
Large MPV	Minivan Midsize LT	$7,310	$195	$7,237	$196	$7,045	$196	$6,963	$196	$6,610	$197
Truck	Large LT	$8,332	$193	$8,242	$193	$8,005	$193	$7,883	$194	$7,474	$194
2010 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$5,232	$221	$5,195	$222	$5,106	$225	$5,071	$226	$4,912	$231
Standard Car	Midsize PC/Perf. PC	$6,152	$214	$6,092	$214	$5,940	$215	$5,874	$215	$5,624	$218
Large Car	Large PC/Perf. PC	$7,923	$229	$7,832	$229	$7,586	$229	$7,479	$228	$7,092	$228
Small MPV	Small LT	$6,070	$203	$6,016	$203	$5,904	$205	$5,860	$206	$5,684	$210
Large MPV	Minivan Midsize LT	$7,312	$197	$7,238	$198	$7,046	$198	$6,962	$198	$6,605	$198
Truck	Large LT	$8,472	$191	$8,380	$191	$8,141	$191	$8,036	$191	$7,629	$191

Table V-74 MY2025 Direct Manufacturing Costs for EV100 packages at different levels of applied vehicle mass reduction (2010 dollars, markups not included)

EV100 (NMC) @ 450K/yr volume		0% mass reduction		2% mass reduction		7.5% mass reduction		10% mass reduction		20% mass reduction	
EPA Vehicle Class	**NHTSA Vehicle Class**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**
2008 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$6,105	$201	$6,083	$201	$5,950	$204	$5,906	$205	$5,817	$206
Standard Car	Midsize PC/Perf. PC	$7,054	$189	$7,001	$189	$6,826	$190	$6,770	$191	$6,662	$192

Large Car	Large PC/Perf. PC	$8,630	$195	$8,535	$195	$8,283	$194	$8,175	$194	$7,999	$194
Small MPV	Small LT	$7,293	$186	$7,237	$186	$7,096	$188	$7,039	$189	$6,953	$190
Large MPV	Minivan Midsize LT	$8,641	$173	$8,571	$174	$8,392	$175	$8,321	$176	$8,215	$177
Truck	Large LT	$9,962	$173	$9,879	$174	$9,676	$175	$9,554	$176	$9,392	$177
2010 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$6,255	$198	$6,209	$199	$6,094	$201	$6,048	$202	$5,956	$204
Standard Car	Midsize PC/Perf. PC	$7,173	$187	$7,118	$188	$6,980	$190	$6,884	$189	$6,802	$190
Large Car	Large PC/Perf. PC	$8,863	$192	$8,765	$192	$8,504	$192	$8,393	$192	$8,251	$192
Small MPV	Small LT	$7,375	$185	$7,318	$185	$7,174	$187	$7,117	$188	$7,031	$189
Large MPV	Minivan Midsize LT	$8,586	$174	$8,516	$174	$8,338	$176	$8,268	$176	$8,128	$177
Truck	Large LT	$10,158	$172	$10,075	$172	$9,865	$174	$9,782	$174	$9,615	$175

Table V-75 MY2025 Direct Manufacturing Costs for EV150 packages at different levels of applied vehicle mass reduction (2010 dollars, markups not included)

EV150 (NMC) @ 450K/yr volume		0% mass reduction		2% mass reduction		7.5% mass reduction		10% mass reduction		20% mass reduction	
EPA Vehicle Class	**NHTSA Vehicle Class**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**	**Pack**	**$/kWh**
2008 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$8,080	$177	$8,048	$178	$8,048	$178	$8,048	$178	$8,048	$178
Standard Car	Midsize PC/Perf. PC	$9,753	$174	$9,714	$174	$9,714	$174	$9,714	$174	$9,714	$174
Large Car	Large PC/Perf. PC	$11,120	$167	$11,073	$167	$11,073	$167	$11,073	$167	$11,073	$167
Small MPV	Small LT	$10,109	$171	$10,109	$171	$10,109	$171	$10,109	$171	$10,109	$171
Large MPV	Minivan Midsize LT	$12,114	$162	$12,112	$162	$12,112	$162	$12,112	$162	$12,112	$162
Truck	Large LT	$13,878	$161	$13,818	$161	$13,759	$161	$13,759	$161	$13,759	$161
2010 Baseline											
Small Car	Subcompact PC/Perf. PC Compact PC/Perf. PC	$8,298	$175	$8,265	$176	$8,265	$176	$8,265	$176	$8,265	$176
Standard Car	Midsize PC/Perf. PC	$9,928	$173	$9,888	$173	$9,888	$173	$9,888	$173	$9,888	$173
Large Car	Large PC/Perf. PC	$11,432	$166	$11,384	$166	$11,384	$166	$11,384	$166	$11,384	$166
Small MPV	Small LT	$10,228	$171	$10,228	$171	$10,228	$171	$10,228	$171	$10,228	$171
Large MPV	Minivan Midsize LT	$12,032	$162	$11,981	$163	$11,981	$163	$11,981	$163	$11,981	$163
Truck	Large LT	$14,166	$160	$14,045	$160	$14,044	$160	$14,044	$160	$14,044	$160

The agencies then generated linear regressions of battery pack costs against percentage net mass reduction using the costs shown in Table V-68. The regression results are shown in Table V-76. These regression results are used to account for the cost reduction from using a smaller battery due to down-weighting of the vehicle. Detailed discussion of how these results are used can be found in section 0 of this chapter. For P2 HEV battery packs, the direct manufacturing costs shown in Table V-76 are considered applicable to MY 2017. The agencies consider the P2 battery packs technology to be on the flat portion of the learning curve during the 2017-2025 timeframe. The agencies have applied a "high1" complexity ICM of 1.56 through 2024 then a long-term ICM of 1.35 thereafter. For PHEV and EV battery packs, the direct manufacturing costs shown in Table V-76 are considered applicable to MY2025 because more development work is needed for this technology to have a high penetration in the U.S. market, including research in battery material, safety systems, etc. For the PHEV and EV battery packs, the agencies have applied the learning curve discussed in learning section of this chapter. The agencies have applied a "high2" complexity ICM of 1.77 through 2024 then a long-term ICM of 1.50 thereafter.

Table V-76 Linear Regressions of Battery Pack Direct Manufacturing Costs vs Net Mass reduction (2010$)

EPA Vehicle Class	NHSTA Vehicle Class	P2 HEV @MY2017	PHEV20 @MY2025	PHEV40 @MY2025	EV75 @MY2025	EV100 @MY2025	EV150 @MY2025
2008 Baseline							
Small car	Subcompact PC/Perf. PC Compact PC/Perf. PC	-$181x+$726	-$861x+$2,533	-$1,517x+$3,646	-$1,859x+$5,131	-$2,168x+$6,115	-$2,045x+$8,080
Standard car	Midsize PC/Perf. PC	-$240x+$801	-$1,543x+$2,962	-$2,195x+$4,389	-$2,754x+$6,023	-$2,958x+$7,056	-$2,552x+$9,753
Large car	Large PC/Perf. PC	-$369x+$937	-$1,881x+$3,734	-$4,700x+$6,010	-$4,356x+$7,725	-$4,647x+$8,630	-$2,840x+$11,120
Small MPV	Small LT	-$240x+$801	-$1,543x+$2,962	-$2,195x+$4,389	-$2,754x+$6,023	-$2,958x+$7,056	-$2,552x+$9,753
Large MPV	Minivan Midsize LT	-$303x+$876					
Truck	Large LT	-$367x+$1,010					
2010 Baseline							
Small car	Subcompact PC/Perf. PC Compact PC/Perf. PC	-$188x+$733	-$866x+$2,572	-$1,612x+$3,722	-$1,717x+$5,233	-$2,209x+$6,256	-$2,700x+$8,298
Standard car	Midsize PC/Perf. PC	-$248x+$810	-$1,573x+$3,024	-$2,291x+$4,494	-$2,887x+$6,154	-$2,883x+$7,178	-$3,242x+$9,928
Large car	Large PC/Perf. PC	-$387x+$950	-$1,957x+$3,813	-$4,217x+$6,158	-$4,543x+$7,925	-$4,744x+$8,862	-$4,250x+$11,432
Small MPV	Small LT	-$233x+$789	-$1,516x+$2,934	-$2,022x+$4,350	-$2,155x+$6,067	-$2,706x+$7,375	-$21x+$10,228
Large MPV	Minivan Midsize LT	-$305x+$878					
Truck	Large LT	-$364x+$1,019					

Notes:
"x" in the equations represents the net mass reduction as a percentage, so a subcompact P2 HEV with a 20% applied weight reduction and, therefore, a 15% net weight reduction would cost (-$181)x(15%)+$726=$698.
The small MPV EV150 regression has no slope since the net weight reduction is always 0 due to the 19.1% weight reduction required for the base vehicle.
The agencies did not regress PHEV or EV costs for the minivan, midsize LT and large truck vehicle classes since we do not believe these vehicle classes would use the technologies.

For Mild HEV batteries, the agencies used a similar approach to estimating the cost of the battery pack but used a different approach to determining its size. Our Mild HEV system used in the analyses is based, largely, on the Buick eAssist system.[285] According to the press releases, it includes a 15 kW motor and a 15 kW/0.5kWh/115 Volt two-module battery. For the agencies' analyses, a 15kW/0.25kWh/110 Volt single-module battery was selected for several reasons. First, the Buick system uses a 20% state-of-charge (SOC) swing for the battery. We believe that, in the 2017-2025 timeframe, a 40% SOC swing is reasonable. As such, the energy capacity of the battery can be halved (from 0.5 to 0.25 kWh).[286] The 110V system used in the analysis is essentially the same as Buick's 115V system. The voltage change is due to our use of a 28 cell single-module battery pack rather than the 32 cell double-module battery pack which is used in the eAssist system. Such changes are consistent with our expectation that cells will increase in size allowing for fewer cells and fewer modules. Further, for the Mild HEV technology, the agencies are using the same system regardless of vehicle class or subclass. In other words, the Mild HEV system is a stand-alone technology that can be applied to any subclass without unique modifications for each class or subclass. As such, it adds more weight as a percentage to a smaller vehicle than to a larger vehicle but it provides more effectiveness to a smaller vehicle than to a larger vehicle. Since the same system is used regardless of vehicle class or subclass, the costs are identical regardless of vehicle class or subclass. Using the ANL BatPaC model, the Mild HEV battery DMC was calculated as $553 and is considered applicable to the MY 2017. The agencies derived the Mild HEV battery pack cost using the same methodology that was used for the P2 HEV battery pack, and consider cost to be on the flat portion of the learning curve during the 2017-2025 timeframe. The agencies have applied a high1 complexity ICM of 1.56 through 2024 then 1.35 thereafter. The resultant Mild HEV battery pack costs are as shown in **Table V-77**.

Table V-77 Costs for Mild Hybrid Battery Packs for both 2008 and 2010 Baselines (2010$)

Cost type	Vehicle class	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	All	$553	$536	$520	$505	$490	$475	$461	$447	$433
IC	All	$312	$311	$310	$309	$308	$307	$306	$305	$187
TC	All	$865	$847	$830	$813	$797	$782	$766	$752	$621

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost

[285] "eAssist" is a Buick (or General Motors) term and is not a generic term for this technology, hence our use of the term mild hybrid.

[286] Note that projected battery cost is relatively insensitive to kWh capacity at the high power-to-energy ratio of these batteries. A 0.5 kWh battery could alternatively be specified at a similar cost.

Table V-78 NHTSA Weight Reduction Offset Associated with Mild HEVs for both the 2008 and 2010 Baselines (2010$)

EPA Vehicle Class	NHTSA Vehicle Class	Weight Penalty
Small car	Subcompact PC / Perf. Subcompact PC / Compact PC / Perf. Compact PC	3.5%
Standard car	Midsize PC/Perf. PC	3.0%
Large car	Large PC/Perf. PC	2.5%
Small MPV	Small LT	2.5%
Large MPV	Minivan Midsize LT	2.5%
Truck	Large LT	2.0%

Non-battery System Costs for MHEVs, HEVs, PHEVs and EVs

This section addresses the costs of non-battery components which are required for electric drive vehicles. Some of these components are not found in every electric-drive vehicle (*e.g.*, an HEV does not have an on-board battery charger as found in a PHEV or EV). Others are found in all electric drive vehicles and must be scaled to the vehicle type or class to properly represent the cost. As discussed in the TAR and NPRM, the agencies derived the costs of these components from the FEV teardown study. Where appropriate, costs were scaled to vehicle class and in the case of the motor and inverter the sizing methodology used for battery sizing was applied.

The electric drive motor and inverter provide the motive power for any electric-drive vehicle by converting electrical energy from the battery into kinetic energy for propulsion. In an electric-drive vehicle, energy stored in the battery is routed to the inverter which converts it to a voltage and wave form that can be used by the motor.

In many cases, such as HEVs, the combined cost of the motor and inverter exceed the battery cost. As batteries become larger in PHEVs and EVs, the battery cost grows faster than motor and inverter cost. For this analysis, the agencies used the vehicle power requirement calculation discussed in Section *"HEV, PHEV and EV System Sizing and Cost Estimating Methodology"* to calculate the required motor and inverter size for each vehicle class at each weight reduction point. Then, for the HEVs and PHEVs, a regression was created from the FEV teardown data for motors and inverters and this regression was used to calculate the motor and inverter cost for each combination of vehicle class and weight reduction. This regression for use with the 2008 baseline was $13.78x(motor size in kW)+$781.50 (values in 2010$), and for use with the 2010 baseline was $14.13x(motor size in kW)+$771.21 (values in 2010$). The results are shown as the "Motor assembly" line items in Table V-79 through Table V-90, which show our scaled

DMC for P2 HEV, PHEV20 and PHEV40 for both 2008 and 2010 baselines. NHTSA averaged the cost of PHEV20 and PHEV40 for the cost of a PHEV30 used in the FRM analysis.

For EVs, the agencies used the motor and inverter cost regression from the 2010 TAR (see 2010 TAR at page B-21) and we used that regression for both the 2008 and 2010 baselines. Since the FEV teardown was conducted on an HEV Ford Fusion, the agencies believe the technology for an EV is different enough to warrant using the TAR regression. The regression presented in the TAR showed the DMC being equal to \$8.45x(motor size in kW)+\$185.05. The results are presented as separate line items for "Motor inverter" and "Motor assembly" in Table V-85 through Table V-90 which show our scaled DMC for EV75, EV100 and EV150, for both 2008 and 2010 baselines.

In addition to electric drive motors and inverters, there are several other components in electric drive vehicles that are required. These components include the following:

- *Body Modifications* required on HEVs and PHEVs include changes to sheet metal to accommodate electric drive components and the addition of fasteners to secure components such as electric cables. These costs come from the FEV teardown and are scaled by vehicle class. For EVs, these costs are assumed to be included in the base vehicle because they are less likely to be adapted from conventional vehicles.

- *Brake System* changes include the addition of a braking system that can control the vehicle's regenerative braking system—a key enabler of electric drive vehicle efficiency. The brake system costs are from the FEV teardown and are scaled to vehicle class.

- *Climate Control System* includes components such as an electric air conditioning compressor that enables operation while the engine is off for HEVs and PHEVs as well as for an EV which has no engine. Climate control system costs come from the FEV teardown and are scaled to vehicle class.

- *Conventional vehicle battery and alternator* are deleted in these vehicles, for a cost savings, replaced by the DC-DC converter which converts the high-voltage traction battery to a nominal 12V DC to operate the vehicle's accessories. This comes from the FEV teardown study and is scaled to vehicle class.

- *DC-DC converter* converts the high-voltage battery voltage to a nominal 12V battery voltage to run vehicle accessories such as the radio, lights and wipers. This cost comes from the FEV teardown study and is scaled to vehicle class.

- *Power distribution and Control* consists of those components which route electricity to the motor, inverter and contains the controllers to operate and monitor the electric drive system. This cost applies to HEVs and PHEVs and comes from the FEV teardown study. It is scaled to vehicle class.

- *On-Vehicle Charger* consists of the components necessary to charge a PHEV or EV from an outlet. It includes the charging port, wiring and electronics necessary to convert a

120V or 240V AC input to the high-voltage DC power necessary to charge the battery. Because the FEV teardown study subject vehicle did not have an on-vehicle charger, the costs from the TAR were used for this item. It is not scaled to vehicle class; however the EV charger is assumed to cost twice the amount of the PHEV charger to account for a higher current capacity. This cost does not include off-vehicle charger components which are discussed below.

- *Supplemental heating* is required for passenger comfort on PHEVs and EVs which may operate for long periods with no engine heat available. This cost comes from the FEV teardown study and is scaled to vehicle class. The supplemental heater on the EV is assumed to be three times more costly than the PHEV because the entire cabin comfort is dependent on the supplemental heater. In a PHEV, it is assumed that in extreme conditions, the internal combustion engine will start to provide additional cabin heat and defrost functions.

- *High Voltage Wiring* is an item used on EVs only. It includes the high voltage cabling from the battery to the inverter and motor as well as control components. It is equivalent to the power distribution and control used on HEVs and PHEVs and comes from the FEV teardown study. It is scaled to vehicle class.

- *Delete Internal Combustion Engine and Transmission* For EVs, the engine and transmission are deleted and a credit is applied. These credits come from work done in support of the 2010 TAR and are scaled to vehicle class.

- *Battery Discharge System* For HEVs, PHEVs and EVs, it is expected that manufacturers will provide the means to safely discharge battery packs following a vehicle crash. The agencies have assumed that this would include dedicated DC terminals, an access panel for the terminals, and a diagnostics port. The estimated cost of this capability is the same for all vehicle classes, but is different for HEVs than for PHEVs and EVs.

The results of the scaling exercise applied to non-battery components are presented in Table V-79 through Table V-90 for P2 HEVs, PHEV20, PHEV40, EV75, EV100 and EV150, for the 2008 and 2010 baselines, respectively.

Table V-79 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for P2 HEV for the 2008 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV	Large MPV	Truck
0% WR						
Body system	$6	$6	$6	$6	$6	$6
Brake system	$221	$228	$231	$225	$233	$240
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$162	$152	$152	$177
Power Distr & control	$196	$201	$204	$200	$206	$220

Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,045	$1,172	$1,480	$1,112	$1,287	$1,429
Total	$1,675	$1,857	$2,175	$1,777	$2,052	$2,169
2% WR						
Body system	$6	$6	$6	$6	$6	$6
Brake system	$221	$228	$231	$225	$233	$240
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$162	$152	$152	$177
Power Distr & control	$196	$201	$204	$200	$206	$220
Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,039	$1,164	$1,467	$1,106	$1,277	$1,416
Total	$1,670	$1,849	$2,161	$1,771	$2,042	$2,156
7.5% WR						
Body system	$6	$6	$6	$6	$6	$6
Brake system	$221	$228	$231	$225	$233	$240
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$162	$152	$152	$177
Power Distr & control	$196	$201	$204	$200	$206	$220
Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,025	$1,143	$1,428	$1,088	$1,249	$1,381
Total	$1,655	$1,828	$2,123	$1,752	$2,014	$2,121
10% WR						
Body system	$6	$6	$6	$6	$6	$6
Brake system	$221	$228	$231	$225	$233	$240
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$162	$152	$152	$177
Power Distr & control	$196	$201	$204	$200	$206	$220
Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,018	$1,133	$1,411	$1,079	$1,237	$1,364
Total	$1,649	$1,818	$2,105	$1,744	$2,002	$2,104
20% WR						
Body system	$6	$6	$6	$6	$6	$6
Brake system	$221	$228	$231	$225	$233	$240
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$162	$152	$152	$177
Power Distr & control	$196	$201	$204	$200	$206	$220

Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,007	$1,115	$1,377	$1,064	$1,212	$1,337
Total	$1,637	$1,800	$2,071	$1,729	$1,977	$2,077

Table V-80 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for P2 HEV for the 2010 baseline (2010$)

System	Small Car	Std Car	Large Car	Small MPV	Large MPV	Truck
0% WR						
Body system	$6	$6	$6	$6	$6	$6
Brake system	$223	$229	$232	$225	$232	$242
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$177	$162	$162	$177
Power Distr & control	$197	$202	$205	$201	$206	$221
Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,051	$1,191	$1,512	$1,134	$1,299	$1,445
Total	$1,683	$1,878	$2,224	$1,811	$2,073	$2,188
2% WR						
Body system	$6	$6	$6	$6	$6	$6
Brake system	$223	$229	$232	$225	$232	$242
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$177	$162	$162	$177
Power Distr & control	$197	$202	$205	$201	$206	$221
Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,045	$1,183	$1,497	$1,127	$1,288	$1,432
Total	$1,677	$1,869	$2,210	$1,804	$2,063	$2,175
7.5% WR						
Body system	$6	$6	$6	$6	$6	$6
Brake system	$223	$229	$232	$225	$232	$242
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$177	$162	$162	$177
Power Distr & control	$197	$202	$205	$201	$206	$221
Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,030	$1,159	$1,457	$1,107	$1,259	$1,395
Total	$1,662	$1,846	$2,169	$1,784	$2,034	$2,138
10% WR						

Body system	$6	$6	$6	$6	$6	$6
Brake system	$223	$229	$232	$225	$232	$242
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$177	$162	$162	$177
Power Distr & control	$197	$202	$205	$201	$206	$221
Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,023	$1,149	$1,438	$1,098	$1,246	$1,378
Total	$1,655	$1,836	$2,150	$1,775	$2,021	$2,121
20% WR						
Body system	$6	$6	$6	$6	$6	$6
Brake system	$223	$229	$232	$225	$232	$242
Climate controls	$140	$157	$168	$164	$250	$186
Delete electrical	($60)	($65)	($82)	($86)	($86)	($94)
DC-DC converter	$121	$152	$177	$162	$162	$177
Power Distr & control	$197	$202	$205	$201	$206	$221
Battery discharge system	$6	$6	$6	$6	$6	$6
Motor assembly	$1,010	$1,129	$1,402	$1,081	$1,220	$1,350
Total	$1,642	$1,816	$2,114	$1,757	$1,994	$2,093

Table V-81 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for PHEV20 for the 2008 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Body system	$6	$6	$6	$6
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
Power Distr & control	$196	$201	$204	$200
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,097	$2,735	$4,276	$2,436
Battery discharge system	$13	$13	$13	$13
Total	$2,878	$3,575	$5,129	$3,258
2% WR				
Body system	$6	$6	$6	$6
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152

Power Distr & control	$196	$201	$204	$200
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,071	$2,695	$4,207	$2,403
Battery discharge system	$13	$13	$13	$13
Total	$2,852	$3,536	$5,059	$3,225
7.5% WR				
Body system	$6	$6	$6	$6
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
Power Distr & control	$196	$201	$204	$200
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$1,999	$2,588	$4,014	$2,312
Battery discharge system	$13	$13	$13	$13
Total	$2,780	$3,428	$4,867	$3,134
10% WR				
Body system	$6	$6	$6	$6
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
Power Distr & control	$196	$201	$204	$200
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$1,966	$2,539	$3,927	$2,271
Battery discharge system	$13	$13	$13	$13
Total	$2,747	$3,379	$4,780	$3,093
20% WR				
Body system	$6	$6	$6	$6
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
Power Distr & control	$196	$201	$204	$200
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$1,943	$2,500	$3,861	$2,235
Battery discharge system	$13	$13	$13	$13

Total	$2,724	$3,341	$4,714	$3,057

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Table V-82 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for PHEV20 for the 2010 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Body system	$6	$6	$6	$6
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
Power Distr & control	$197	$202	$205	$201
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,169	$2,870	$4,476	$2,586
Battery discharge system	$13	$13	$13	$13
Total	$2,951	$3,712	$5,347	$3,419
2% WR				
Body system	$6	$6	$6	$6
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
Power Distr & control	$197	$202	$205	$201
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,141	$2,828	$4,402	$2,549
Battery discharge system	$13	$13	$13	$13
Total	$2,924	$3,670	$5,272	$3,383
7.5% WR				
Body system	$6	$6	$6	$6
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
Power Distr & control	$197	$202	$205	$201
On vehicle charger	$105	$105	$105	$105

Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,064	$2,712	$4,198	$2,450
Battery discharge system	$13	$13	$13	$13
Total	$2,847	$3,554	$5,069	$3,283
10% WR				
Body system	$6	$6	$6	$6
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
Power Distr & control	$197	$202	$205	$201
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,029	$2,660	$4,106	$2,404
Battery discharge system	$13	$13	$13	$13
Total	$2,812	$3,502	$4,976	$3,238
20% WR				
Body system	$6	$6	$6	$6
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
Power Distr & control	$197	$202	$205	$201
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,002	$2,616	$4,031	$2,364
Battery discharge system	$13	$13	$13	$13
Total	$2,785	$3,458	$4,901	$3,197

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Table V-83 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for PHEV40 for the 2008 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Body system	$6	$6	$6	$6
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)

DC-DC converter	$121	$152	$162	$152
Power Distr & control	$196	$201	$204	$200
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,097	$2,735	$4,276	$2,436
Battery discharge system	$13	$13	$13	$13
Total	$2,878	$3,575	$5,129	$3,258
2% WR				
Body system	$6	$6	$6	$6
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
Power Distr & control	$196	$201	$204	$200
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,071	$2,695	$4,207	$2,403
Battery discharge system	$13	$13	$13	$13
Total	$2,852	$3,536	$5,059	$3,225
7.5% WR				
Body system	$6	$6	$6	$6
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
Power Distr & control	$196	$201	$204	$200
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,007	$2,591	$4,025	$2,313
Battery discharge system	$13	$13	$13	$13
Total	$2,788	$3,432	$4,878	$3,135
10% WR				
Body system	$6	$6	$6	$6
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
Power Distr & control	$196	$201	$204	$200
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,007	$2,591	$4,025	$2,312

Battery discharge system	\$13	\$13	\$13	\$13
Total	\$2,788	\$3,432	\$4,878	\$3,134
20% WR				
Body system	\$6	\$6	\$6	\$6
Brake system	\$221	\$228	\$231	\$225
Climate controls	\$140	\$157	\$168	\$164
Delete electrical	(\$60)	(\$65)	(\$82)	(\$86)
DC-DC converter	\$121	\$152	\$162	\$152
Power Distr & control	\$196	\$201	\$204	\$200
On vehicle charger	\$105	\$105	\$105	\$105
Supplemental heater	\$38	\$43	\$45	\$44
Motor assembly	\$2,007	\$2,591	\$4,025	\$2,312
Battery discharge system	\$13	\$13	\$13	\$13
Total	\$2,788	\$3,432	\$4,878	\$3,134

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Table V-84 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for PHEV40 for the 2010 baseline (2010\$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Body system	\$6	\$6	\$6	\$6
Brake system	\$223	\$229	\$232	\$225
Climate controls	\$140	\$157	\$168	\$164
Delete electrical	(\$60)	(\$65)	(\$82)	(\$86)
DC-DC converter	\$121	\$152	\$177	\$162
Power Distr & control	\$197	\$202	\$205	\$201
On vehicle charger	\$105	\$105	\$105	\$105
Supplemental heater	\$38	\$43	\$45	\$44
Motor assembly	\$2,169	\$2,870	\$4,476	\$2,586
Battery discharge system	\$13	\$13	\$13	\$13
Total	\$2,951	\$3,712	\$5,347	\$3,419
2% WR				
Body system	\$6	\$6	\$6	\$6
Brake system	\$223	\$229	\$232	\$225
Climate controls	\$140	\$157	\$168	\$164
Delete electrical	(\$60)	(\$65)	(\$82)	(\$86)
DC-DC converter	\$121	\$152	\$177	\$162
Power Distr & control	\$197	\$202	\$205	\$201

On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,141	$2,828	$4,402	$2,549
Battery discharge system	$13	$13	$13	$13
Total	$2,924	$3,670	$5,272	$3,383
7.5% WR				
Body system	$6	$6	$6	$6
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
Power Distr & control	$197	$202	$205	$201
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,068	$2,714	$4,206	$2,450
Battery discharge system	$13	$13	$13	$13
Total	$2,851	$3,556	$5,076	$3,283
10% WR				
Body system	$6	$6	$6	$6
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
Power Distr & control	$197	$202	$205	$201
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,068	$2,714	$4,206	$2,449
Battery discharge system	$13	$13	$13	$13
Total	$2,851	$3,556	$5,076	$3,283
20% WR				
Body system	$6	$6	$6	$6
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
Power Distr & control	$197	$202	$205	$201
On vehicle charger	$105	$105	$105	$105
Supplemental heater	$38	$43	$45	$44
Motor assembly	$2,068	$2,714	$4,206	$2,449
Battery discharge system	$13	$13	$13	$13
Total	$2,851	$3,556	$5,076	$3,283

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Table V-85 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for EV75 for the 2008 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$703	$1,044	$1,868	$885
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$992	$1,383	$2,329	$1,200
Battery discharge system	$13	$13	$13	$13
Total	$350	$1,145	$2,060	($12)
2% WR				
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$689	$1,023	$1,831	$867
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$976	$1,359	$2,286	$1,180
Battery discharge system	$13	$13	$13	$13
Total	$320	$1,100	$1,979	($50)
7.5% WR				
Brake system	$221	$228	$231	$225

Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$650	$966	$1,728	$818
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$932	$1,293	$2,168	$1,124
Battery discharge system	$13	$13	$13	$13
Total	$237	$977	$1,759	($154)
10% WR				
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$633	$939	$1,681	$796
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$911	$1,263	$2,114	$1,099
Battery discharge system	$13	$13	$13	$13
Total	$199	$921	$1,659	($202)
20% WR				
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$571	$851	$1,519	$727
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$840	$1,162	$1,928	$1,020

Battery discharge system	$13	$13	$13	$13
Total	$65	$731	$1,309	($350)

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Table V-86 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for EV75 for the 2010 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$729	$1,094	$1,932	$946
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$1,021	$1,441	$2,402	$1,271
Battery discharge system	$13	$13	$13	$13
Total	$406	$1,255	$2,214	$132
2% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$714	$1,072	$1,893	$927
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$1,004	$1,416	$2,358	$1,249
Battery discharge system	$13	$13	$13	$13
Total	$375	$1,208	$2,131	$92
7.5% WR				

Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$674	$1,012	$1,787	$875
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$958	$1,347	$2,236	$1,189
Battery discharge system	$13	$13	$13	$13
Total	$289	$1,079	$1,903	($20)
10% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$656	$985	$1,739	$851
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$938	$1,315	$2,180	$1,162
Battery discharge system	$13	$13	$13	$13
Total	$250	$1,020	$1,799	($71)
20% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$595	$895	$1,580	$780
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)

Motor assembly	$867	$1,212	$1,998	$1,080
Battery discharge system	$13	$13	$13	$13
Total	$118	$828	$1,458	($225)

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Table V-87 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for EV100 for the 2008 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$703	$1,044	$1,868	$885
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$992	$1,383	$2,329	$1,200
Battery discharge system	$13	$13	$13	$13
Total	$350	$1,145	$2,060	($12)
2% WR				
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$689	$1,023	$1,831	$867
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$976	$1,359	$2,286	$1,180
Battery discharge system	$13	$13	$13	$13
Total	$320	$1,100	$1,979	($50)
7.5% WR				

Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$650	$966	$1,728	$818
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$932	$1,293	$2,168	$1,124
Battery discharge system	$13	$13	$13	$13
Total	$237	$977	$1,759	($154)
10% WR				
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$633	$939	$1,681	$796
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$911	$1,263	$2,114	$1,099
Battery discharge system	$13	$13	$13	$13
Total	$199	$921	$1,659	($202)
20% WR				
Brake system	$221	$228	$231	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$608	$906	$1,617	$774
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)

Motor assembly	$883	$1,224	$2,041	$1,073
Battery discharge system	$13	$13	$13	$13
Total	$146	$848	$1,521	($249)

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Table V-88 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for EV100 for the 2010 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$729	$1,094	$1,932	$946
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$1,021	$1,441	$2,402	$1,271
Battery discharge system	$13	$13	$13	$13
Total	$406	$1,255	$2,214	$132
2% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$714	$1,072	$1,893	$927
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$1,004	$1,416	$2,358	$1,249
Battery discharge system	$13	$13	$13	$13
Total	$375	$1,208	$2,131	$92
7.5% WR				

Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$674	$1,012	$1,787	$875
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$958	$1,347	$2,236	$1,189
Battery discharge system	$13	$13	$13	$13
Total	$289	$1,079	$1,903	($20)
10% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$656	$985	$1,739	$851
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$938	$1,315	$2,180	$1,162
Battery discharge system	$13	$13	$13	$13
Total	$250	$1,020	$1,799	($71)
20% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$633	$954	$1,684	$829
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)

Motor assembly	$912	$1,280	$2,118	$1,137
Battery discharge system	$13	$13	$13	$13
Total	$201	$954	$1,682	($118)

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Table V-89 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for EV100 for the 2008 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$703	$1,044	$1,868	$885
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$992	$1,383	$2,329	$1,200
Battery discharge system	$13	$13	$13	$13
Total	$351	$1,146	$2,061	($11)
2% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$692	$1,028	$1,837	$878
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$979	$1,364	$2,293	$1,193
Battery discharge system	$13	$13	$13	$13
Total	$328	$1,111	$1,995	($26)
7.5% WR				

Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$692	$1,028	$1,837	$878
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$979	$1,364	$2,293	$1,193
Battery discharge system	$13	$13	$13	$13
Total	$328	$1,111	$1,995	($26)
10% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$692	$1,028	$1,837	$878
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$979	$1,364	$2,293	$1,193
Battery discharge system	$13	$13	$13	$13
Total	$328	$1,111	$1,995	($26)
20% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$162	$152
High voltage wiring	$196	$201	$204	$200
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$692	$1,028	$1,837	$878
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)

Motor assembly	$979	$1,364	$2,293	$1,193
Battery discharge system	$13	$13	$13	$13
Total	$328	$1,111	$1,995	($26)

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Table V-90 Scaled Non-battery DMC by Applied Vehicle Weight Reduction for EV100 for the 2010 baseline (2010$)

System	Small car	Standard car	Large car	Small MPV
0% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$729	$1,094	$1,932	$946
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$1,021	$1,441	$2,402	$1,271
Battery discharge system	$13	$13	$13	$13
Total	$406	$1,255	$2,214	$132
2% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$720	$1,081	$1,910	$941
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$1,011	$1,425	$2,377	$1,265
Battery discharge system	$13	$13	$13	$13
Total	$387	$1,226	$2,167	$121
7.5% WR				

Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$720	$1,081	$1,910	$941
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$1,011	$1,425	$2,377	$1,265
Battery discharge system	$13	$13	$13	$13
Total	$387	$1,226	$2,167	$121
10% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$720	$1,081	$1,910	$941
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)
Motor assembly	$1,011	$1,425	$2,377	$1,265
Battery discharge system	$13	$13	$13	$13
Total	$387	$1,226	$2,167	$121
20% WR				
Brake system	$223	$229	$232	$225
Climate controls	$140	$157	$168	$164
Delete electrical	($60)	($65)	($82)	($86)
DC-DC converter	$121	$152	$177	$162
High voltage wiring	$197	$202	$205	$201
Supplemental heater	$76	$85	$91	$89
On vehicle charger	$316	$316	$316	$316
Motor inverter	$720	$1,081	$1,910	$941
Controls	$121	$121	$121	$121
Delete IC engine	($1,596)	($1,596)	($2,466)	($2,394)
Delete transmission	($894)	($894)	($894)	($894)

Motor assembly	$1,011	$1,425	$2,377	$1,265
Battery discharge system	$13	$13	$13	$13
Total	$387	$1,226	$2,167	$121

a The agencies have not estimated PHEV or EV costs for the large MPV and truck vehicle classes since we do not believe these vehicle classes would use the technologies.

Similar to the approach taken for battery pack costs, the agencies generated linear regressions of non-battery system costs against percent of net mass reduction and the results are shown in Table **V-91**. This was done using the same weight reduction offsets as used for battery packs as presented in Table **V-69**. These regression results are used to account for the cost reduction from using a smaller battery due to down-weighting of the vehicle. Detailed discussion of how these results are used can be found in the next section of this chapter. The agencies separated battery pack costs from the remainder of the systems for each type of electrified vehicle. The advantage of separating the battery pack costs from other system costs is that it allows each to carry unique indirect cost multipliers and learning effects which are important given that battery technology is an emerging technology, while electric motors and inverters are more stable technologies.

Table V-91 Linear Regressions of Non-Battery System Direct Manufacturing Costs vs Net Mass reduction (2010$)

EPA Vehicle Class	NHTSA Vehicle Class	P2 HEV @MY2017	PHEV20 @MY2025	PHEV40 @MY2025	EV75 @MY2025	EV100 @MY2025	EV150 @MY2025
2008 Baseline							
Small car	Subcompact PC/Perf. PC Compact PC/Perf. PC	-$263x+$1,675	-$1,316x+$2,878	-$1,316x+$2,878	-$1,510x+$350	-$1,510x+$350	-$1,510x+$351
Standard car	Midsize PC/Perf. PC	-$391x+$1,857	-$1,953x+$3,575	-$1,953x+$3,575	-$2,242x+$1,145	-$2,242x+$1,145	-$2,242x+$1,146
Large car	Large PC/Perf. PC	-$699x+$2,175	-$3,495x+$5,129	-$3,495x+$5,129	-$4,012x+$2,060	-$4,012x+$2,060	-$4,012x+$2,061
Small MPV	Small LT	-$331x+$1,777	-$1,655x+$3,258	-$1,655x+$3,258	-$1,900x+-$12	-$1,900x+-$12	-$1,900x+-$11
Large MPV	Minivan Midsize LT	-$506x+$2,052					
Truck	Large LT	-$648x+$2,169					
2008 Baseline							
Small car	Subcompact PC/Perf. PC Compact PC/Perf. PC	-$279x+$1,683	-$1,397x+$2,951	-$1,397x+$2,951	-$1,565x+$406	-$1,565x+$406	-$1,565x+$406
Standard car	Midsize PC/Perf. PC	-$420x+$1,878	-$2,099x+$3,712	-$2,099x+$3,712	-$2,350x+$1,255	-$2,350x+$1,255	-$2,350x+$1,255
Large car	Large PC/Perf. PC	-$741x+$2,224	-$3,705x+$5,347	-$3,705x+$5,347	-$4,149x+$2,214	-$4,149x+$2,214	-$4,149x+$2,214
Small MPV	Small LT	-$363x+$1,811	-$1,814x+$3,419	-$1,814x+$3,419	-$2,032x+$132	-$2,032x+$132	-$2,032x+$132
Large MPV	Minivan Midsize LT	-$528x+$2,073					

Truck	Large LT	-$674x+$2,188					

Notes:
"x" in the equations represents the net mass reduction as a percentage, so a small car P2 HEV (2008 baseline) with a 20% applied weight reduction and, therefore, a 15% net weight reduction would cost (-$263)x(15%)+$1,675=$1,635.
The small MPV EV150 regression has no slope since the net weight reduction is always 0 due to the 19.1% weight reduction required for the base vehicle.
The agencies did not regress PHEV or EV costs for the minivan, midsize LT and large truck vehicle classes since we do not believe these vehicle classes would use the technologies.

For P2 HEV non-battery components, the direct manufacturing costs shown in Table **V-91** are considered applicable to MY 2017. The agencies consider the P2 and PHEV non-battery component technologies to be on the flat portion of the learning curve during the 2017-2025 timeframe. The agencies have applied a high1 complexity ICM of 1.56 through 2018 then a long-term ICM of 1.35 thereafter. For EV non-battery components, the direct manufacturing costs shown in Table **V-91** are considered applicable to MY 2025. The agencies consider the PHEV and EV non-battery component technologies to be on the flat portion of the learning curve during the 2017-2025 timeframe. The agencies have applied a high2 complexity ICM of 1.77 through 2024 then a long-term ICM of 1.50 thereafter.

For Mild HEV non-battery components, the agencies have used a combination of cost sources which include the FEV teardown of a Saturn Vue along with estimates used for P2 HEVs as described above. For the electrical power distribution and control system and the DC-DC converter, estimates presented in the FRM for subcompacts were used with a presumed 20% weight reduction because those systems were estimated to include a 16 kW motor (essentially the same as the 15 kW motor assumed for the Mild HEV technology). These costs and the FEV Saturn Vue teardown costs we used are shown in Table V-92.

Table V-92 FEV Teardown Results & P2 HEV Values used for MHEV Non-Battery Direct Manufacturing Cost Estimates

System	Teardown result (2007$)	P2 HEV (2009$)[a]	2010$
Cooling subsystem (including water pumps)	$88.71		$92.37
Accessory drive subsystem	$30.75		$32.02
Body system	$14.83		$15.44
Brake system	$42.30		$44.05
Climate control system	$0		$0
Transmission oil pump and filter subsystem	$53.86		$56.09
Generator/alternator and regulatory subsystem	$51.94		$54.09
Electrical power distribution & control system		$203.22	$205.25
DC-DC converter		$115.33	$116.48
Total			$615.79
[a]See the joint TSD, Table 3-80, 20% WR (EPA-420-D-11-901, November 2011).			

For Mild HEV non-battery components, the direct manufacturing costs shown in Table V-92 are considered applicable MY 2012. The agencies consider the Mild HEV non-battery component technologies to be on the flat portion of the learning curve during the 2017-2025 timeframe. The agencies have applied a medium complexity ICM of 1.39 through 2018 then 1.29 thereafter. The resultant costs used in this final analysis are shown in Table V-93.

Table V-93 Costs for Mild HEV Non-Battery Components for both the 2008 and 2010 Baselines (2010$)

Cost type	Vehicle class	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	All	$534	$524	$513	$503	$493	$483	$473	$464	$455
IC	All	$235	$234	$175	$175	$175	$174	$174	$174	$173
TC	All	$769	$758	$688	$678	$667	$657	$647	$637	$628

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost

How Did NHTSA Account for the Cost Synergy between Mass Reduction and Electrification System in CAFE Model?

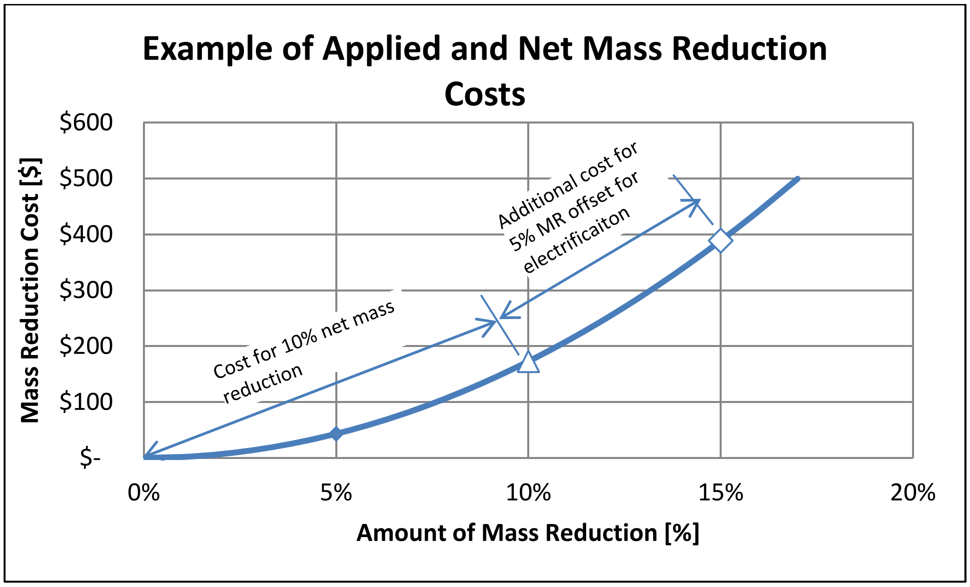
The CAFE model does not use pre-built packages and applies technologies incrementally as necessary to meet the fuel consumption reduction requirement, so the cost interaction between any particular technology and other technologies (cost synergies) must be defined. This allows flexibility so that when a technology is picked, the model will automatically look through the cost synergy defined in a table and apply cost adjustments accordingly. The total cost for mass reduction and electrification is composed of the following four parts:

(1) Cost of net mass reduction;
(2) Cost of electrification with zero mass reduction;
(3) Mass reduction cost synergy for increased or decreased amount of mass reduction due to switching from conventional powertrain to electrification systems, as defined in Table **V-69**. For example, if a midsize passenger car needs both 10 percent net mass reduction and P2 hybrid to meet the CAFE target, the model will need to find the cost of additional 5 percent of mass reduction to consider the vehicle weight increase due to switching from conventional powertrain system to P2 electrification packages. This additional 5 percent of mass reduction is calculated starting from 10 percent mass reduction, not zero as shown in Figure **V-36** because mass reduction cost versus mass reduction percent is not a linear function. The cost increases faster as the amount of mass reduction becomes higher.
(4) Electrification system cost synergies (battery and non-battery components) due to mass reduction as defined in Table V-76 and Table **V-91**: Continuing the example in the steps above, if a midsize passenger car needs both 10 percent net mass reduction and P2 hybrid to meet the CAFE target, after calculating the costs above, the model will need to find the cost of electrification systems, including battery system and non-battery system, with the required net amount of mass reduction using the equations in Table V-76 and Table **V-91**. Then the delta cost between this cost and the cost calculated in step (2), i.e., electrification system

cost with zero applied mass reduction is calculated and treated as a cost synergy. These cost deltas are normally negative, i.e., a cost reduction, due to the downsizing of the electrification system resulting from mass reduction.

The sum of item (3) and (4) in the above list are calculated as cost synergy and stored in the cost synergy table as defined ”*Synergies*” section earlier in this Chapter.

Figure V-36 Mass Reduction Cost Example for Applied and Net Mass Reduction



Hardware Costs for Charging Grid-Connected Vehicles

Grid-connected vehicles such as EVs and PHEVs require a means to charge their on-board batteries to enable their electric range capabilities. These vehicles require certain hardware to charge, both on-vehicle and off-vehicle. The agencies' September 2010 Technical Assessment Report contains an in-depth analysis of the topic of charging and infrastructure. The TAR analysis and assumptions did not receive any significant comment on this issue, and a review of the current state of the industry indicates the assumptions in the TAR are still valid. Therefore, the assumptions for the cost of Electric Vehicle Support Equipment (EVSE) are unchanged. Additionally, while some of the characteristics of the modeled grid-connected vehicles such as battery size and energy demand have changed somewhat due to further analysis, the application of Level 1 and Level 2 charging by vehicle type based on charge time has not changed.

Three charging levels are currently under consideration. Level 1 charging uses a standard 120 volt (V), 15-20 amps (A) rated (12-16 A usable) circuit and is available in standard residential and commercial buildings. Level 2 charging uses a single phase, 240 V, 20-80 A circuit and allows much shorter charge times. Level 3 charging—sometimes colloquially called “quick” or “fast” charging—uses a 480 V, three-phase circuit, available in mainly industrial areas, typically providing 60-150 kW of off-board charging power. It is expected that 97 to 99% of charging will take place at home, so a cost for a home charger, appropriate to the duty cycle of the vehicle, is added to the vehicle cost. Level 3 charging is available to commercial users and vehicles that charge at Level 3 stations will be assumed to pay at the charge station for the convenience of fast charging. Therefore Level 3 charger costs are not included in overall vehicle cost.

The specific equipment required for charging a grid-connected vehicle consists of the following:

Charger: A charger that converts electricity from alternating current (AC) from the electricity source to direct current (DC) required for the battery, and also converts the incoming 120 or 240 volt current to 300 or higher volts. Grid-connected vehicles carry an on-board charger capable of accepting AC current from a wall plug (Level 1 circuit) or, from a Level 2 charging station. On-board charger power capability ranges from 1.4 to 10 kW and is usually proportional to the vehicle’s battery capacity. The lowest charging power, 1.4 kW, is expected only when grid-connected vehicles are connected to 120 volt (Level 1) outlets, and all currently known PHEV and EV on-board chargers are expected to provide at least 3.3 kW charging when connected to a Level 2 (220 volt, 20+ A) charging station. The latest SAE connection recommended practice, J1772, allows for delivery of up to ~19 kW to an on-board vehicle charger. For higher capacity charging under Level 3, a charging station that delivers DC current directly to the vehicle’s battery is incorporated off-board in the wall or pedestal mounted.

Charging Station: The charging station needed to safely deliver energy from the electric circuit to the vehicle, called electric vehicle support equipment (EVSE). The EVSE may at a minimum, be a specialized cordset that connects a household Level 1/120V socket to the vehicle; otherwise, the EVSE will include a cordset and a charging station (a wall or pedestal mounted box incorporating a charger and other equipment). Charging stations may include optional advanced features such as timers to delay charging until off-peak hours, communications equipment to allow the utility to regulate charging, or even electricity metering capabilities. Stakeholders are working on which features are best located on the EVSE or on the vehicle itself, and it is possible that redundant capabilities and features may be present in both the vehicle and EVSEs in the near future until these issues are worked out. EVSE and vehicle manufacturers are also working to ensure that current SAE-compliant “basic” EVSEs are charge-compatible with future grid-connected vehicles.

Dedicated Circuit: A Level 1 circuit is standard household current, 120V AC, rated at 15 or 20 A (12 or 16 A usable). A Level 2 circuit is rated at 208 to 240V and up to 80 A and is similar to the type of circuit that powers electric stoves (up to 50 A) and dryers (usually 30 A). Generally, Level 1 and 2 circuits used for electric vehicle recharging must be dedicated circuits, i.e., there cannot be other appliances on that circuit. For a Level 2 circuit, the homeowner or other user must install a charging station and will need a permit. A homeowner may choose to install the charger on a separately-metered circuit to take advantage of special electrical rates for off-peak charging, where available.

In addition to the costs of purchasing and installing charging equipment, charging station installation may include the costs of upgrading existing electrical panels and installing the electrical connection from the panel to the desired station location. These costs may be dramatically lowered if new construction incorporates the panel box and wiring required for charging stations, or even includes charging stations or outlets for charging stations as standard equipment.

The current costs of charging stations are highly variable depending on the level of service (and alternative power capabilities within these categories), location (individual residence, grouped residences, retail or business, parking lot or garage), level of sophistication of the station, and installation requirements, including electrical upgrading requirements. Estimated costs for charging stations are included in Table V-94 below.

Table V-94: Estimated Costs for Charging Stations Used in the 2010 TAR (2008$)

Level	Location	Equipment	Installation
1	Single Residence	$30- $200 (charge cord only, included at no cost to consumer with EV/PHEV) when an accessible household plug (e.g., in a garage or adjacent to a driveway) with a ground fault interrupter is already available	$400-$1000+ may be necessary depending on difficulty of installing a new circuit at the desired location, but in most cases, owners with sufficient panel capacity would opt for a more capable 220 VAC Level 2 installation instead of a Level 1 dedicated circuit because the additional installation cost is only marginally higher
2	Residential, Apartment Complex, or Fleet Depot[b]	3.3 kW EVSE (each): $300-$4,000 6.6 kW EVSE (each): $400-$4,000	3.3- 6.6 kW installation cost: $400-$2,300 without wiring/service panel upgrade, or $2,000-$5,000 with panel upgrade

refs: 287,288, 289, 290
[a] Detailed information on charger cost for each charging level and location and specific sources for cost estimates are available in the TAR, Appendix G.
[b] Level 2 EVSE installation costs vary considerably for single-family residences, multi-family residences, and fleet depots, depending upon the need for wiring and service panel upgrades. The range depicted here reflects the anticipated variability of these costs. However, EPRI estimates that the typical residential Level 2 installation costs to be approximately $1,500. See the TAR, Appendix G for additional information.

Application of Charging Level by Vehicle Type

The home charging availability for a specific consumer will need to be differentiated among EV/PHEVs with different battery capacity. The electric outlets in existing homes are most likely ready for Level 1 charging, which is about sufficient for fully recharging a PHEV20 SUV during normal nighttime, provided the outlet is not being heavily utilized by other loads. Shorter available charging time or owning a PHEV or an EV with a larger battery make the capability to fully charge overnight with a Level 1 system less likely, but upgrading to a Level 2 system in such cases will allow full recharge to happen more quickly.

Table V-95 shows the application of charge level by vehicle type and range. Charging types were chosen based on nominal time to charge a fully-depleted battery in a vehicle with no net weight reduction. Charge times exceeding 9 hours for Level 1 were deemed unacceptable and Level 2 charging was specified. For charge times between 6 hours and 9 hours on Level 1, a mix of Level 1 and Level 2 was specified. This was done to recognize the varying consumer value of faster, but more expensive, Level 2 charging over Level 1 charging.

Table V-95: Charger Type by Vehicle Technology and Class

NHTSA Vehicle Class	PHEV20		PHEV40		EV75		EV100		EV150	
	L1	L2	L1	L2	L1	L2	L1	L2	L1	L2
Subcompact PC/Perf. PC Compact PC/Perf. PC	100%	-	25%	75%	-	100%	-	100%	-	100%
Midsize PC/Perf. PC	100%	-	10%	90%	-	100%	-	100%	-	100%

287 Morrow, Karner, and Francfort, "Plug-in Hybrid Electric Vehicle Charging Infrastructure Review," INL/EXT-08-15058, November 2008. Docket No. NHTSA-2010-0131 or Available at http://avt.inel.gov/pdf/phev/phevInfrastructureReport08.pdf (last accessed November 14, 2011).
288 May and Mattila, "Plugging In: A Stakeholder Investment Guide for Public Electric-Vehicle Charging Infrastructure," Rocky Mountain Institute, July 2009, Docket No. NHTSA-2010-0131 or Available at http://projectgetready.com/docs/Plugging%20In%20-%20A%20Stakeholder%20Investment%20Guide.pdf (last accessed November 14, 2011)
289 ETEC, 2009.
290 Electrification Coalition, "Electrification Roadmap", November 2009. Available at http://www.electrificationcoalition.org/electrification-roadmap.php. (last accessed November 14, 2011). Docket No. NHTSA-2010-0131-0143.

Large PC/Perf. PC	100%	-	-	100%	-	100%	-	100%	-	100%
Minivan Midsize LT	100%	-	-	100%	-	100%	-	100%	-	100%
Small LT	100%	-	-	100%	-	100%	-	100%	-	100%
Large LT	50%	50%	-	100%	-	100%	-	100%	-	100%

For this final rule, consistent with the proposal, the resultant costs associated with in-home chargers and installation of in-home chargers are included in the total cost for an EV and or PHEV. However, here we summarize specially the costs for chargers and installation labor. The agencies have estimated the DMC of a level 1 charge cord at $31 (2010$) based on typical costs of similar electrical equipment sold to consumers today and that for a level 2 charger at $204 (2010$). Labor associated with installing either of these chargers is estimated at $1,020 (2010$). Further, we have estimated that all PHEV20 vehicles (PHEVs with a 20 mile range) would be charged via a level 1 charger and that all EVs, regardless of range, would be charged via a level 2 charger. For the PHEV40 vehicles (PHEVs with a 40 mile range), we have estimated that: 25% of subcompacts would be charged with a level 1 charger with the remainder charged via a level 2 charger; 10% of midsize cars would be charged with a level 1 charger with the remainder charged via a level 2 charger; and all remaining PHEV 40 vehicles would be charged via a level 2 charger. All costs presented here are considered applicable in the 2025 model year. The agencies have applied the learning curve 19 as presented in Section 0 to all charger costs. The agencies have also applied a High1 ICM of 1.56 through 2024 then 1.34 thereafter. Installation costs, being labor costs, have no learning impacts or ICMs applied.

P2 Hybrid

A P2 hybrid is hybrid technology that uses a transmission-integrated electric motor placed between the engine and a gearbox or CVT and coupled to the engine crankshaft via a clutch. The engine and the drive motor are mechanically independent of each other, allowing the engine or motor to power the vehicle separately or combined. Disengaging the engine clutch allows all-electric operation and more efficient brake-energy recovery. The P2 HEV system is similar to the Honda IMA HEV architecture, with the exception of the added clutch and larger batteries and motors. Examples of this include the Hyundai Sonata HEV and Infiniti M35h. The agencies believe that the P2 is an example of a “strong” hybrid technology that is typical of what will be prevalent in the timeframe of this rule. The agencies could have equally chosen the power-split architecture as the representative HEV architecture. These two HEVs have similar average effectiveness values (combined city and highway fuel economy), though the P2 systems may have lower cost due to having only a single, smaller motor/generator.

For purposes of this rulemaking analysis, the agencies are assuming that P2 hybrids will become the dominant technology in the MYs 2017-2025 timeframe, replacing costlier power-split or 2-

mode architectures while providing substantially similar efficiency improvement. At the present time, P2 hybrids are relatively new to the market and the agencies have not attempted to quantify any measurable performance differential between these technologies. As mentioned, the 2011 Hyundai Sonata, 2011 Volkswagen Touareg Hybrid, the 2011 Porsche S Hybrid, and the 2012 Infiniti M35 Hybrid are examples of a P2 hybrid currently in production and available to consumers. While generally positive, some early reviews have specifically critiqued the drivability of the vehicle.[291] The agencies recognize that manufacturers will have several years to test, develop and improve P2 technology in the years before 2017. We expect that manufacturers will address any perceived integration issues in early production models. However, we believe it is important to continue to monitor development of P2 hybrids and market acceptance of this technology. We will continue to gather information on these issues and consider them as part of the mid-term evaluation. NHTSA sought comment regarding the potential of P2 hybrids to overcome these issues or others, and we specifically sought comment from automakers developing and considering P2 technology on whether they believe these to be significant impediments to deployment and how they may be addressed. No comments were submitted.

The effectiveness used for vehicle packages with the P2-hybrid configuration within this analysis reflects what the agencies believe to be a conservative estimate of system performance. Vehicle simulation modeling of technology packages using the P2 hybrid has recently been completed under a contract with Ricardo Engineering. The agencies have updated the effectiveness of hybrid electric vehicle packages using the new Ricardo vehicle simulation modeling runs for this analysis.

Due to the lower cost and comparative effectiveness of P2 hybrid in relative to other strong hybrid technologies, such as power-split hybrid and 2-mode hybrid, the agencies assume P2 hybrid application for all vehicle sub-classes in this FRM analysis, consistent with the proposal. Based on the recent Ricardo study, the effectiveness for P2 hybrid used in this FRM, consistent with the proposal, is 46.2 percent for subcompact and compact passenger cars, 48.6 percent for midsize passenger car, 49.4 percent for large passenger car, 46.1 percent for small light truck, 45.7 percent for midsize SUV, truck and minivan and 45.1 percent for large pickup truck relative to the baseline vehicle. This represents an increase in strong HEV effectiveness of approximately 2 percent as compared to the estimate employed in the MYs 2012-2016 final rule based on published data for new HEVs that have entered into production, such as 2011 Hyundai

[291] Car and Driver praised the Sonata's fuel economy but followed with "the integration of the hybrid system is far less impressive" (June, 2011), while Edmunds.com criticized the "clumsy braking response" (http://www.edmunds.com/hyundai/sonata-hybrid/2011/, last accessed Nov. 3, 2011). Other reviews have indicated that the driveability issues are more pronounced when the vehicle is in fuel-efficient "Blue Mode." *See*, *e.g.*, http://www.cars.com/hyundai/sonata-hybrid/2011/expert-reviews/?revid=56695(last accessed Nov. 3, 2011).

Sonata hybrid, 2010 Hyundai Elantra LPI HEV (Korean market only), 2011 Infiniti G35 Hybrid and 2011 Volkswagen Touareg Hybrid).

Additionally, for the Large Car, Minivan, and Small Truck subclasses for this FRM analysis, the agencies estimated that HEV effectiveness could be increased by allowing for down-powering of the gasoline engine. This could impact the towing capacity for some vehicles when converted to a HEV powertrain.[292] The agencies believe that consumers interested in these vehicles who require towing capacity could acquire it by purchasing a vehicle with a non-hybrid powertrain (as they do today).[293] The approach used by the agencies allows more HEV and engine down-powering being applied to vehicle fleet, which increases estimated overall HEV system incremental effectiveness by 5 to 10 percent for Large Cars, Minivans, and Small Trucks, similar to the HEV effectiveness value assumed for Small Cars and Compact Cars.[294] Moreover, it is likely that some fraction of consumers who purchase the larger engine option do so for purposes of hauling and acceleration performance, not just maximum towing.

The battery sizing is different for the 2008 and 2010 baseline vehicle fleets, because vehicle mass for each subclass is slightly different between the two baseline fleets, thus requiring a slightly different battery size to maintain equivalent performance. The battery sizes with no applied mass reduction are listed in **Table V-96**.

Table V-96: NHTSA Battery Sizes for P2 Hybrid Applied in CAFE Model without Mass Reduction (kWh)

Baseline Fleet	Subcompact PC/ Perf PC Compact PC/ Perf PC	Midsize PC/Perf PC	Large PC/Perf PC	Midsize LT Minivan	Small LT	Large LT
2008	0.81	1.00	1.16	1.28	1.04	1.49
2010	0.84	1.02	1.20	1.27	1.06	1.56

292 At issue are those small SUVs and Minivans with a towing capacity of at least 3500 lbs when equipped with an OEM or dealer installed towing package. While their towing capacity should be maintained, they may see a performance degradation in the event that the motive power is delivered exclusively by the gasoline engine which could occur during an extended uphill drive at maximum capacity.

293 The agencies recognize that assuming that certain consumers will choose to purchase non-hybrid vehicles in order to obtain their desired towing capacity could lead to some increase in fuel consumption and CO_2 emissions as compared to assuming that towing capacity is maintained for hybrid vehicles across the board. However, the agencies think it likely that the net improvement in fuel consumption and CO_2 emissions due to the increased numbers of hybrids available for consumers to choose could offset the potential increase in fuel consumption and CO_2 emissions resulting from consumers selecting the higher-performance non-hybrid powertrain vehicles.

294 The effectiveness of HEVs for heavier vehicles which require conventional towing capabilities is markedly less because the rated power of the IC engine must be similar to its non-hybrid brethren. As such, there is less opportunity for downsizing with these vehicles.

The costs for P2 hybrids without mass reduction as used in the CAFE model are listed in Table **V-97**. The battery costs are calculated using the battery sizes for both the 2008 and 2010 baseline fleets. NHTSA accounts the cost impact from the interaction between mass reduction and sizing of the electrification system (battery and non-battery system) as a cost synergy as described in Section "*How Did NHTSA Account for the Cost Synergy between Mass Reduction and Electrification System in CAFE Model?*" The agencies have applied a high complexity ICM to both the battery and non-battery component costs for P2 hybrids, although the timing of the ICMs varies: for the battery components in P2 hybrids, the ICM switches from the short-term value of 1.56 to the long-term value of 1.35 in 2024, while for the non-battery component the switch to long-term ICMs happens in 2018.

Table V-97 NHTSA Costs for P2 Hybrid Applied in CAFE Model without Mass Reduction (2010$)

Tech.	Cost Type	NHTSA Vehicle Class	Baseline Fleet	2017	2018	2019	2020	2021	2022	2023	2024	2025
Battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$733	$711	$689	$669	$648	$629	$610	$592	$574
			2008	$726	$704	$683	$662	$642	$623	$604	$586	$569
Battery	DMC	Midsize PC/Perf PC	2010	$818	$793	$769	$746	$724	$702	$681	$661	$641
			2008	$809	$784	$761	$738	$716	$694	$674	$653	$634
Battery	DMC	Large PC/Perf PC	2010	$959	$931	$903	$876	$849	$824	$799	$775	$752
			2008	$946	$918	$890	$864	$838	$813	$788	$765	$742
Battery	DMC	Midsize LT Minivan	2010	$887	$860	$834	$809	$785	$761	$739	$716	$695
			2008	$885	$858	$832	$807	$783	$760	$737	$715	$693
Battery	DMC	Small LT	2010	$796	$773	$749	$727	$705	$684	$663	$643	$624
			2008	$787	$763	$740	$718	$697	$676	$655	$636	$617
Battery	DMC	Large LT	2010	$1,029	$998	$968	$939	$911	$884	$857	$831	$807
			2008	$1,020	$989	$960	$931	$903	$876	$850	$824	$799
Non-battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$1,474	$1,445	$1,416	$1,388	$1,360	$1,333	$1,306	$1,280	$1,254
			2008	$1,468	$1,438	$1,410	$1,381	$1,354	$1,327	$1,300	$1,274	$1,249
Non-battery	DMC	Midsize PC/Perf PC	2010	$1,645	$1,612	$1,580	$1,549	$1,518	$1,487	$1,457	$1,428	$1,400
			2008	$1,627	$1,595	$1,563	$1,531	$1,501	$1,471	$1,441	$1,413	$1,384
Non-battery	DMC	Large PC/Perf PC	2010	$1,949	$1,910	$1,872	$1,834	$1,798	$1,762	$1,727	$1,692	$1,658
			2008	$1,906	$1,868	$1,830	$1,794	$1,758	$1,723	$1,688	$1,655	$1,621
Non-battery	DMC	Midsize LT Minivan	2010	$1,817	$1,780	$1,745	$1,710	$1,676	$1,642	$1,609	$1,577	$1,546
			2008	$1,798	$1,762	$1,727	$1,693	$1,659	$1,626	$1,593	$1,561	$1,530

Non-battery	DMC	Small LT	2010	$1,587	$1,555	$1,524	$1,493	$1,464	$1,434	$1,406	$1,378	$1,350
			2008	$1,557	$1,526	$1,496	$1,466	$1,436	$1,408	$1,380	$1,352	$1,325
Non-battery	DMC	Large LT	2010	$1,918	$1,879	$1,842	$1,805	$1,769	$1,733	$1,699	$1,665	$1,631
			2008	$1,901	$1,863	$1,825	$1,789	$1,753	$1,718	$1,684	$1,650	$1,617
Battery	IC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$413	$411	$410	$409	$407	$406	$405	$404	$248
			2008	$409	$408	$406	$405	$404	$402	$401	$400	$246
Battery	IC	Midsize PC/Perf PC	2010	$461	$459	$458	$456	$455	$453	$452	$451	$277
			2008	$456	$454	$453	$451	$450	$448	$447	$446	$274
Battery	IC	Large PC/Perf PC	2010	$541	$539	$537	$535	$534	$532	$530	$529	$325
			2008	$533	$532	$530	$528	$526	$525	$523	$522	$320
Battery	IC	Midsize LT Minivan	2010	$500	$498	$496	$495	$493	$492	$490	$489	$300
			2008	$499	$497	$495	$494	$492	$490	$489	$488	$299
Battery	IC	Small LT	2010	$449	$447	$446	$444	$443	$442	$440	$439	$270
			2008	$443	$442	$440	$439	$438	$436	$435	$434	$266
Battery	IC	Large LT	2010	$580	$578	$576	$574	$572	$571	$569	$567	$348
			2008	$575	$573	$571	$569	$567	$566	$564	$562	$345
Non-battery	IC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$943	$941	$578	$577	$576	$575	$574	$574	$573
			2008	$939	$937	$575	$574	$574	$573	$572	$571	$570
Non-battery	IC	Midsize PC/Perf PC	2010	$1,053	$1,050	$645	$644	$643	$642	$641	$640	$639
			2008	$1,041	$1,039	$638	$637	$636	$635	$634	$633	$632
Non-battery	IC	Large PC/Perf PC	2010	$1,247	$1,244	$764	$763	$762	$761	$759	$758	$757
			2008	$1,219	$1,217	$747	$746	$745	$744	$743	$741	$740
Non-battery	IC	Midsize LT Minivan	2010	$1,162	$1,160	$712	$711	$710	$709	$708	$707	$706
			2008	$1,150	$1,148	$705	$704	$703	$702	$701	$700	$699
Non-battery	IC	Small LT	2010	$1,015	$1,013	$622	$621	$620	$619	$618	$617	$616
			2008	$996	$994	$610	$610	$609	$608	$607	$606	$605
Non-battery	IC	Large LT	2010	$1,227	$1,224	$752	$751	$749	$748	$747	$746	$745
			2008	$1,216	$1,213	$745	$744	$743	$742	$741	$739	$738
Battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$1,145	$1,122	$1,099	$1,077	$1,056	$1,035	$1,015	$996	$822
			2008	$1,135	$1,111	$1,089	$1,067	$1,046	$1,025	$1,006	$986	$814
Battery	TC	Midsize PC/Perf PC	2010	$1,278	$1,252	$1,227	$1,202	$1,179	$1,155	$1,133	$1,111	$918
			2008	$1,264	$1,239	$1,213	$1,189	$1,166	$1,143	$1,121	$1,099	$907
Battery	TC	Large PC/Perf PC	2010	$1,500	$1,469	$1,440	$1,411	$1,383	$1,356	$1,330	$1,304	$1,077
			2008	$1,480	$1,449	$1,420	$1,392	$1,364	$1,337	$1,311	$1,286	$1,062

Battery	TC	Midsize LT Minivan	2010	$1,386	$1,358	$1,331	$1,304	$1,278	$1,253	$1,229	$1,205	$995
			2008	$1,383	$1,355	$1,327	$1,301	$1,275	$1,250	$1,226	$1,202	$993
Battery	TC	Small LT	2010	$1,245	$1,220	$1,195	$1,171	$1,148	$1,125	$1,104	$1,082	$894
			2008	$1,230	$1,205	$1,181	$1,157	$1,134	$1,112	$1,090	$1,069	$883
Battery	TC	Large LT	2010	$1,609	$1,576	$1,544	$1,513	$1,483	$1,454	$1,426	$1,399	$1,155
			2008	$1,595	$1,562	$1,531	$1,500	$1,470	$1,442	$1,414	$1,386	$1,145
Non-battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$2,418	$2,386	$1,994	$1,965	$1,936	$1,908	$1,881	$1,854	$1,827
			2008	$2,407	$2,375	$1,985	$1,956	$1,927	$1,899	$1,872	$1,845	$1,819
Non-battery	TC	Midsize PC/Perf PC	2010	$2,698	$2,663	$2,225	$2,192	$2,160	$2,129	$2,098	$2,068	$2,039
			2008	$2,668	$2,633	$2,201	$2,168	$2,137	$2,106	$2,075	$2,046	$2,016
Non-battery	TC	Large PC/Perf PC	2010	$3,196	$3,155	$2,636	$2,597	$2,559	$2,522	$2,486	$2,450	$2,415
			2008	$3,125	$3,085	$2,577	$2,540	$2,503	$2,466	$2,431	$2,396	$2,362
Non-battery	TC	Midsize LT Minivan	2010	$2,979	$2,940	$2,457	$2,421	$2,386	$2,351	$2,317	$2,284	$2,252
			2008	$2,949	$2,910	$2,432	$2,396	$2,361	$2,327	$2,294	$2,261	$2,229
Non-battery	TC	Small LT	2010	$2,602	$2,568	$2,146	$2,115	$2,084	$2,054	$2,024	$1,995	$1,966
			2008	$2,554	$2,520	$2,106	$2,075	$2,045	$2,015	$1,986	$1,958	$1,930
Non-battery	TC	Large LT	2010	$3,144	$3,103	$2,593	$2,555	$2,518	$2,482	$2,446	$2,411	$2,376
			2008	$3,116	$3,076	$2,570	$2,533	$2,496	$2,460	$2,424	$2,389	$2,355

Power Split Hybrid

Power-split hybrid (PSHEV) is a hybrid electric drive system that replaces the traditional transmission with a single planetary gear set and two motor/generators. The smaller motor/generator uses the engine to either charge the battery or to supply additional power to the drive motor. The second, more powerful motor/generator is permanently connected to the vehicle's final drive and always turns with the wheels. The planetary gear splits engine power between the first motor/generator and the drive motor to either charge the battery or supply power to the wheels. Power-split hybrid technology is currently in production and used on vehicles, such as Toyota Prius and Ford Fusion Hybrid, but the agencies have chosen not to apply it in this FRM analysis, consistent with the proposal, because the agencies believe that P2 hybrid is a more cost-effective hybrid technology, as described in the previous section.

2-Mode Hybrid

2-mode hybrid (2MHEV) – is a hybrid electric drive system that uses an adaptation of a conventional stepped-ratio automatic transmission by replacing some of the transmission clutches with two electric motors that control the ratio of engine speed to vehicle speed, while clutches allow the motors to be bypassed. This improves both the transmission torque capacity for heavy-duty applications and reduces fuel consumption at highway speeds relative to other types of hybrid electric drive systems.

2-mode hybrid technology exists in the baseline fleet, and OEMs have used 2-mode hybrids on vehicles with towing requirements, such as the Chevrolet Tahoe and the Chevrolet Silverado pickup truck. However, the agencies have chosen not to apply it in this FRM analysis, consistent with the proposal, because the agencies believe that P2 hybrid is a more cost-effective hybrid technology, as described in the previous section. The agencies may re-consider this hybrid technology in vehicles with towing requirements, such as pickup trucks, in future rulemakings, based on new information obtained.

Plug-in Electrical Hybrid Vehicles (PHEV)

Plug-In Hybrid Electric Vehicles (PHEVs) are very similar to Hybrid Electric Vehicles, but with three significant functional differences. The first is the addition of a means to charge the battery pack from an outside source of electricity (*e.g.*, the electric grid). Second, a PHEV would have a larger battery pack with more energy storage, and a greater capability to be discharged. Finally, a PHEV would have a control system that allows the battery pack to be significantly depleted during normal operation.

Table V-98 below illustrates how PHEVs compare functionally to both hybrid electric vehicles (HEV) and electric vehicles (EV). These characteristics can change significantly within each vehicle class/subclass, so this is simply meant as an illustration of the general characteristics. In reality, the design options are so varied that all of these vehicles exist on a continuum, with HEVs on one end and EVs on the other.

Table V-98 Conventional Vehicles, HEVs, PHEVs, and EVs Compared

	Increasing Electrification			
Attribute	Conventional	HEV	PHEV	EV
Drive Power	Engine	Blended Engine/Electric	Blended Engine/Electric	Electric
Engine Size	Full Size	Full Size or Smaller	Smaller or Much Smaller	No Engine
Electric Range	None	None to Very Short	Short to Medium	Medium to Long
Battery Charging	None	On-Board	Grid/On-Board	Grid Only

Deriving some of their propulsion energy from the electric grid provides several advantages for PHEVs. PHEVs offer a significant opportunity to replace petroleum used for transportation energy with domestically-produced electricity. The reduction in petroleum usage does, of course, depend on the amount of electric drive the vehicle is capable of under its duty cycle. PHEVs also provide electric utilities the possibility to increase electricity generation during "off-peak" periods (such as overnight) when there is excess generation capacity and electricity prices are lower. Utilities like to increase this "base load" because it increases overall system efficiency and lowers average costs. PHEVs can lower localized emissions of criteria pollutants and air toxics, especially in urban areas, by operating on electric power: the emissions from the power generation occur outside the urban area at the power generation plant, which provides health benefits for residents of the more densely populated urban areas by moving emissions of ozone precursors out of the urban air shed. Additionally, unlike most other alternative fuel technologies, PHEVs can initially use an existing infrastructure for refueling (charging and liquid refueling) so investments in infrastructure may be reduced.

In analyzing the impacts of grid-connected vehicles like PHEVs and EVs, the emissions from the electricity generation can be accounted for if a full upstream and downstream analysis is desired. These effects are considered in NHTSA's assessment of the benefits of this rulemaking, *see* Chapter VIII below, as well as NHTSA's EIS, but they are not considered directly for purposes of determining the effectiveness of the technologies at improving fuel economy.

PHEVs will be considerably more costly than conventional vehicles and some other advanced technologies due to the fact that PHEVs require both conventional internal combustion engine and electrical driving systems and the larger expensive battery pack.

For purposes of CAFE analysis, we assume that all future PHEVs during the rulemaking timeframe will meet the range requirements to qualify as a dual fuel vehicle. When calculating the fuel economy of a dual-fuel PHEV, NHTSA uses a petroleum equivalency factor for electricity consumption as stated in 49 U.S.C. 32904 and 32905. Because PHEVs are just starting to enter the marketplace, fuel economy estimates for these vehicles remain difficult to obtain for purposes of this analysis. NHTSA therefore based the effectiveness estimations for PHEVs and EVs on experimental data. When evaluating the effectiveness of PHEVs and EVs at reducing fuel consumption, NHTSA referenced the UDDS and highway fuel economy data of 3 pairs of vehicles for which NHTSA has fuel economy data in the CAFE database:

- The MiniE electric vehicle and the gasoline-powered Mini with automatic transmission,
- The Tesla Roadster electric vehicle and the gasoline-powered rear-wheel-drive Lotus Elise Sedan with a 6-speed manual transmission,[295] and
- The MY 2012 Nissan Leaf electric vehicle and the gasoline-powered Nissan Sentra with automatic transmission.[296]

[295] The Tesla Roadster is based on the Lotus Elise body, which makes the Elise the most comparable vehicle to the Roadster for purposes of this analysis.

The fuel economy and fuel consumption for the first two pairs are shown in Table **V-99**; the agency was unable to show the information for the last pair because the information for the Nissan Leaf is confidential.

Table V-99 EV Fuel Economy and Fuel Consumption

104 Mile Range (Mini Website)	**Fuel Economy [mpg]**	**Fuel Consumption [gpm]**
MiniE (mpg)	342.4	0.0029206
Mini Gas ATX (mpg)	38.6	0.0259067
227 Mile Range (EPA)		
Tesla Roadster	346.8	0.0028835
Lotus Elise Sedan M6 RWD	30.6	0.0326797

Because technologies are applied in the CAFE model in an incremental manner, the effectiveness for each technology is incremental to the previous technology on the decision tree. In the electrification decision tree of the CAFE model, the order of technology selection starts from gasoline-only powertrain, then moves to strong hybrid, to plug-in hybrid electric vehicle, and finally to electric vehicle. So the incremental effectiveness for each step has to be defined. In order to calculate the effectiveness of the PHEV technology for purposes of CAFE analysis, operation on both gasoline and electricity has to be considered.

First, the incremental fuel economy benefit for gasoline operation is determined using the incremental effectiveness of strong hybrid (SHEV) from the LPM, which indicates that the incremental effectiveness for SHEV is 46.2 percent. For example, the fuel economy for Mini Gas ATX is 38.6 mpg. Applying the 46.2 percent fuel consumption reduction, the fuel economy for an SHEV Mini can be calculated as follows.

$$SHEV\ Fuel\ Economy\ based\ on\ Mini = \frac{1}{\left(\frac{1}{38.6} \times (100\% - 46.2\%\right)} = 71.7\ mpg$$

Then the fuel economy from gasoline source for PHEV is assumed to be the same as SHEV fuel economy, *e.g.,* 71.7 mpg in the case of Mini E.

[296] Sentra is used as the baseline for Leaf comparison because these two vehicles are of similar size from the same manufacturer.

Next, the petroleum-equivalent fuel economy for electric operation for the PHEV is set to be equal to the measured fuel economy of an example EV, *e.g.,* 342.4 mpg in the case of the Mini E. And finally, the fuel economy benefit from the gasoline operation and the fuel economy benefit from electric operation need to be combined. Through MY 2019, for compliance purposes, the statute requires the fuel economy of PHEVs to be calculated assuming that 50 percent of the operation is on electricity and 50 percent on gasoline.[297] After 2019, NHTSA will use the utility factor method defined by SAE standard J1711 for calculating CAFE fuel economy of PHEV. NHTSA expects that a PHEV with a 30 mile charge depleting range may reasonably represent the PHEVs that manufacturers may produce in MYs 2017 to 2025. According to SAE standard J2841, a vehicle with 30 mile charge depleting range has a 0.668 city specific utility factor and a 0.337 highway specific utility factor, which together give a 0.52 combined utility factor (55% city/45% highway split). Therefore NHTSA selected a PHEV with a 30 mile range for the CAFE model analysis, and the selection of a PHEV with a 30 mile range maintains continuity between pre-2020 and post-2020 PHEV fuel economy calculations. NHTSA assumes a 0.50 utility factor for MY2020 and beyond.

NHTSA thus calculated the combined fuel economy for PHEV for purposes of this analysis using a 50-50 weighting factor, as follows:

$$PHEV\ Combined\ Fuel\ Economy = \frac{1}{\frac{Gasoline\ FE\ Weighing\ Factor}{Gasoline\ Fuel\ Economy} + \frac{Electric\ FE\ Weighing\ Factor}{EV\ Fuel\ Economy}}$$

$$= \frac{1}{\frac{0.5}{71.7} + \frac{0.5}{342.4}} = 118.6\text{ mpg}$$

The incremental fuel consumption reduction for PHEV is then calculated relative to SHEV. Using the example of Mini E, the incremental fuel consumption reduction for PHEV relative to SHEV is 39.5 percent, as shown below:

[297] *See* 49 U.S.C. § 32905.

$$Incremental\ Fuel\ Consumption\ Reduction\ for\ PHEV$$
$$= \frac{\left(\frac{1}{PHEV\ Fuel\ Economy} - \frac{1}{SHEV\ Fuel\ Economy}\right)}{\frac{1}{SHEV\ Fuel\ Economy}} x100\%$$
$$= \frac{\left(\frac{1}{118.6} - \frac{1}{71.7}\right)}{\frac{1}{71.7}} x100\% = -39.5\%$$

Table **V-100** lists NHTSA's incremental effectiveness calculation for two pairs of vehicles, the Mini E and the Tesla Roadster. Again, the table does not contain an incremental fuel consumption calculation for PHEV based on the Nissan Leaf due to the confidentiality of that vehicle's current fuel economy rating for compliance purposes. The derived incremental effectiveness for Nissan Leaf is 40.6 percent. Together, the average incremental effectiveness of these three pairs of vehicles is 40.65 percent, which is the number used by NHTSA in the CAFE modeling for this FRM analysis, consistent with the proposal.

Table V-100 Incremental Effectiveness Calculation for purposes of CAFE modeling

Mini E

	Gasoline	**SHEV2**	**PHEV1**	**EV1**
Combined Fuel Economy [mpg]	***38.6***	71.7	118.6	***342.4***
Gasoline Fuel Economy [mpg]		71.7	71.7	
Electric Petroleum Equivalent Fuel Economy [mpg]			342.4	
Combined Fuel Consumption[gpm]		0.0139414	0.0084310	0.0029206
Gasoline Fuel Consumption [gpm]		0.0139414	0.0139414	
Incremental Combined Fuel Consumption [%]			**39.5%**	**65.4%**
Gasoline Weighing Factor[%]			50%	0%
Electricity Weighing Factor [%]			50%	100%

Tesla

	Gasoline	**SHEV2**	**PHEV1**	**EV1**
Combined Fuel Economy [mpg]	***30.6***	56.7	97.4	***346.8***
Gasoline Fuel Economy [mpg]		56.7	56.7	
Electric Petroleum Equivalent Fuel Economy [mpg]			346.8	
Combined Fuel Consumption[gpm]		0.017647	0.0102653	0.0028835
Gasoline Fuel Consumption [gpm]		0.017647	0.0176471	
Incremental Combined Fuel Consumption [%]			**41.8%**	**71.9%**
Gasoline Weighing Factor[%]			50%	0%
Electricity Weighing Factor [%]			50%	100%

Once the fuel economy of the PHEV is calculated, the effectiveness of PHEV incremental to EV can be calculated similarly using the formula below.

$$Incremental\ Fuel\ Consumption\ Improvement\ for\ EV = \frac{\left(\frac{1}{EV\ Fuel\ Economy} - \frac{1}{PHEV\ Fuel\ Economy}\right)}{\frac{1}{PHEV\ Fuel\ Economy}} x100\%$$

Using that formula, the average effectiveness for the three pairs of vehicles is 68.54 percent, which is the value used in the analysis for this FRM analysis, consistent with the proposal.

The cost of PHEV consists of three parts: the cost for the battery, the cost for the non-battery systems (including, for example, the gasoline engine and transmission), and the cost for the charger and the labor to install it. Costs for PHEVs without mass reduction as used in the CAFE model are listed in **Table V-101** . NHTSA accounts for the cost synergy due to the interaction between mass reduction and sizing of the electrification system (battery and non-battery system) as described in Section *"How Did NHTSA Account for the Cost Synergy between Mass Reduction and Electrification System in CAFE Model?"* of this chapter. EPA developed costs for a PHEV20 and a PHEV40 with the methodologies discussed in Section "*Battery Pack Sizing and Hybrid System Sizing*"; because NHTSA modeled a PHEV 30 for this final rule, NHTSA averaged EPA's direct costs for the PHEV20 and the PHEV40.

For indirect costs, a high complexity ICM is used for the non-battery component costs for PHEVs and PHEV chargers, which switches from the short-term value of 1.56 to the long-term value of 1.35 at 2018. A higher ICM factor is used for PHEV batteries due to the fact that they represent a more complex technology. The ICM for PHEV batteries switches from the short-term value of 1.77 to the long-term value of 1.50 at 2024.

Table V-101 NHTSA Costs for PHEV30 Applied in the CAFE Model with No Mass Reduction (2010$)

Tech.	Cost Type	NHTSA Vehicle Class	Baseline Fleet	2017	2018	2019	2020	2021	2022	2023	2024	2025
Battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$6,208	$8,259	$8,259	$6,607	$6,607	$6,607	$6,607	$6,607	$5,286
			2008	$6,095	$8,097	$8,097	$6,477	$6,477	$6,477	$6,477	$6,477	$5,182
Battery	DMC	Midsize	2010	$7,415	$5,932	$5,932	$4,746	$4,746	$4,746	$4,746	$4,746	$3,797

		PC/Perf PC	2008	$7,251	$5,801	$5,801	$4,640	$4,640	$4,640	$4,640	$4,640	$3,712
Battery	DMC	Large PC/Perf PC	2010	$9,835	$7,868	$7,868	$6,294	$6,294	$6,294	$6,294	$6,294	$5,035
			2008	$9,610	$7,688	$7,688	$6,150	$6,150	$6,150	$6,150	$6,150	$4,920
Non-battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$2,586	$2,535	$2,484	$2,434	$2,386	$2,338	$2,291	$2,245	$2,200
			2008	$2,522	$2,472	$2,422	$2,374	$2,326	$2,280	$2,234	$2,190	$2,146
Non-battery	DMC	Midsize PC/Perf PC	2010	$3,252	$3,187	$3,124	$3,061	$3,000	$2,940	$2,881	$2,824	$2,767
			2008	$3,132	$3,070	$3,008	$2,948	$2,889	$2,831	$2,775	$2,719	$2,665
Non-battery	DMC	Large PC/Perf PC	2010	$4,685	$4,591	$4,499	$4,409	$4,321	$4,235	$4,150	$4,067	$3,986
			2008	$4,494	$4,405	$4,316	$4,230	$4,145	$4,063	$3,981	$3,902	$3,824
Charger	DMC	All	2008/2010	$210	$168	$168	$134	$134	$134	$134	$134	$108
Charger Labor	DMC	All	2008/2010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010
Battery	IC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$2,671	$2,579	$2,579	$2,506	$2,506	$2,506	$2,506	$2,506	$1,578
			2008	$2,622	$2,532	$2,532	$2,460	$2,460	$2,460	$2,460	$2,460	$1,550
Battery	IC	Midsize PC/Perf PC	2010	$3,190	$3,081	$3,081	$2,993	$2,993	$2,993	$2,993	$2,993	$1,885
			2008	$3,119	$3,012	$3,012	$2,927	$2,927	$2,927	$2,927	$2,927	$1,844
Battery	IC	Large PC/Perf PC	2010	$4,231	$4,086	$4,086	$3,970	$3,970	$3,970	$3,970	$3,970	$2,501
			2008	$4,134	$3,993	$3,993	$3,879	$3,879	$3,879	$3,879	$3,879	$2,444
Non-battery	IC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$1,655	$1,651	$1,014	$1,012	$1,011	$1,009	$1,008	$1,006	$1,005
			2008	$1,614	$1,610	$989	$987	$986	$984	$983	$981	$980
Non-battery	IC	Midsize PC/Perf PC	2010	$2,081	$2,077	$1,275	$1,273	$1,271	$1,269	$1,267	$1,265	$1,264
			2008	$2,004	$2,000	$1,228	$1,226	$1,224	$1,222	$1,220	$1,219	$1,217
Non-battery	IC	Large PC/Perf PC	2010	$2,997	$2,991	$1,836	$1,834	$1,831	$1,828	$1,825	$1,823	$1,820
			2008	$2,875	$2,869	$1,762	$1,759	$1,756	$1,754	$1,751	$1,749	$1,746
Charger	IC	All	2008/2010	$67	$65	$65	$62	$62	$62	$62	$62	$37
Charger Labor	IC	All	2008/2010	$0	$0	$0	$0	$0	$0	$0	$0	$0
Battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$8,878	$7,545	$7,545	$6,479	$6,479	$6,479	$6,479	$6,479	$4,757
			2008	$8,717	$7,408	$7,408	$6,361	$6,361	$6,361	$6,361	$6,361	$4,670
Battery	TC	Midsize PC/Perf PC	2010	$10,605	$9,013	$9,013	$7,739	$7,739	$7,739	$7,739	$7,739	$5,682
			2008	$10,370	$8,813	$8,813	$7,567	$7,567	$7,567	$7,567	$7,567	$5,556
Battery	TC	Large PC/Perf PC	2010	$14,066	$11,954	$11,954	$10,264	$10,264	$10,264	$10,264	$10,264	$7,536
			2008	$13,744	$11,681	$11,681	$10,030	$10,030	$10,030	$10,030	$10,030	$7,364

Non-battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$4,241	$4,186	$3,498	$3,446	$3,396	$3,347	$3,299	$3,251	$3,205
			2008	$4,136	$4,082	$3,411	$3,361	$3,312	$3,264	$3,217	$3,171	$3,126
Non-battery	TC	Midsize PC/Perf PC	2010	$5,333	$5,264	$4,399	$4,334	$4,271	$4,209	$4,148	$4,089	$4,031
			2008	$5,136	$5,069	$4,236	$4,174	$4,113	$4,054	$3,995	$3,938	$3,882
Non-battery	TC	Large PC/Perf PC	2010	$7,682	$7,582	$6,336	$6,243	$6,152	$6,063	$5,975	$5,890	$5,806
			2008	$277	$233	$233	$197	$197	$197	$197	$197	$145
Charger	TC	All	2008/2010	$277	$233	$233	$197	$197	$197	$197	$197	$145
Charger Labor	TC	All	2008/2010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010

Electric Vehicle (EV)

Electric vehicles (EV) are vehicles with all-electric drive and with vehicle systems powered by energy-optimized batteries charged primarily from grid electricity. While the MYs 2012-2016 final rule analysis did not anticipate a significant penetration of EVs, in this analysis, EVs with several different ranges have been included. As discussed in the section above for PHEVs, NHTSA uses DOE's petroleum equivalency factor in calculating the fuel economy effectiveness for EVs since electric operation does not involve miles per gallon. The PEF is determined by the U.S. Department of Energy as specified in 10 CFR Part 474. The PEF accounts for U.S. average fossil-fuel electricity generation and transmission efficiencies, petroleum refining and distribution efficiency, the energy content of gasoline, and includes a 0.15 divisor to incentivize the use of electricity in vehicles. The current PEF for electricity is 82.049 kWh per gallon of gasoline.

Using the fuel economy of the PHEV calculated as shown in the previous section, the effectiveness of EV incremental to PHEV can be calculated similarly using the formula below.

$$\mathit{Incremental\ Fuel\ Consumption\ Improvement\ for\ EV}$$

$$= \frac{\left(\frac{1}{EV\ Fuel\ Economy} - \frac{1}{PHEV\ Fuel\ Economy}\right)}{\frac{1}{PHEV\ Fuel\ Economy}} x100\%$$

The average effectiveness for the three pairs of EVs of 68.54 percent is used in CAFE modeling as incremental effectiveness relative to PHEVs.

For battery costs, NHTSA assumes that battery packs for EV applications will be designed to last for the full useful life of the vehicle at a useable state of charge equivalent to 80 percent of the nominal battery pack capacity. NHTSA considered both a 75-mile range EV (EV75) and a 150-mile range EV (EV150) in this FRM analysis, consistent with the NPRM. The EV75 was employed to represent costs relevant to vehicles sold to "early adopters." We assumed that as this technology is entering the market, the OEM will try to keep costs low at the beginning to spur the technology, which, given the high cost of the battery packs at this early stage of EVs, will require the battery pack size to be limited to reduce cost. Therefore NHTSA applied a 75-mile range EV for early adoption of this technology in the market, up to 5% penetration. Larger battery packs to address "range anxiety" concerns should not be necessary at this stage, since we assume that early adopters tend to be urban drivers. As the technology develops and as the market penetration increases beyond 5%, NHTSA expects that OEMs would provide longer driving range to help the consumers overcome range anxiety. NHTSA applied 150-mile EV for this broad market adoption of this technology.

The cost of an EV consists of three parts: the cost of the battery pack, the cost of non-battery systems, and the cost of a charger and charger installation labor. The battery sizes applied in the CAFE model for each type of EV and vehicle subclass are listed in Table V-92 below.

Table V-102 NHTSA Battery Sizes for EVs Applied in CAFE Model without Mass Reduction (kWh)

	Baseline Fleet	Subcompact PC/ Perf PC Compact PC/ Perf PC	Midsize PC/Perf PC	Large PC/Perf PC	Midsize LT Minivan	Small LT	Large LT
EV75	2008	22.79	28.03	33.28	n/a	29.48	n/a
	2010	23.65	28.72	34.54	n/a	29.95	n/a
EV100	2008	30.39	37.38	44.37	n/a	39.3	n/a
	2010	31.54	38.3	46.05	n/a	39.94	n/a
EV150	2008	45.58	56.07	66.55	n/a	58.96	n/a
	2010	47.31	57.45	69.08	n/a	59.9	n/a

A high complexity ICM was applied to the non-battery component cost for EVs and EV chargers, which switches from the short-term value of 1.56 to the long-term value of 1.35 at 2018. A higher ICM factor was applied to EV batteries due to the fact that they represent a more complex technology. The ICM for EV battery switches from the short-term value of 1.77 to the long-term value of 1.50 at 2024. The costs of EVs without mass reduction as applied in the

CAFE model for this analysis are listed in Table V-103 to Table V-104. NHTSA accounts for the cost synergy due to the interaction between mass reduction and sizing of the electrification system (battery and non-battery system) as described in Section "*How Did NHTSA Account for the Cost Synergy between Mass Reduction and Electrification System in CAFE Model?*"

Table V-103 NHTSA Costs Applied in CAFE model for EV75 with No Mass Reduction (2010$)

Tech.	Cost Type	NHTSA Vehicle Class	Baseline Fleet	2017	2018	2019	2020	2021	2022	2023	2024	2025
Battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$10,324	$8,259	$8,259	$6,607	$6,607	$6,607	$6,607	$6,607	$5,286
			2008	$10,121	$8,097	$8,097	$6,477	$6,477	$6,477	$6,477	$6,477	$5,182
Battery	DMC	Midsize PC/Perf PC	2010	$12,140	$9,712	$9,712	$7,769	$7,769	$7,769	$7,769	$7,769	$6,215
			2008	$11,881	$9,505	$9,505	$7,604	$7,604	$7,604	$7,604	$7,604	$6,083
Battery	DMC	Large PC/Perf PC	2010	$15,634	$12,507	$12,507	$10,006	$10,006	$10,006	$10,006	$10,006	$8,005
			2008	$15,238	$12,190	$12,190	$9,752	$9,752	$9,752	$9,752	$9,752	$7,802
Non-battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$410	$398	$386	$375	$363	$352	$345	$338	$332
			2008	$354	$343	$333	$323	$313	$304	$298	$292	$286
Non-battery	DMC	Midsize PC/Perf PC	2010	$1,267	$1,229	$1,193	$1,157	$1,122	$1,088	$1,067	$1,045	$1,024
			2008	$1,156	$1,122	$1,088	$1,055	$1,024	$993	$973	$954	$935
Non-battery	DMC	Large PC/Perf PC	2010	$2,236	$2,169	$2,104	$2,041	$1,980	$1,920	$1,882	$1,844	$1,808
			2008	$2,080	$2,018	$1,957	$1,899	$1,842	$1,786	$1,751	$1,716	$1,681
Charger	DMC	All	2008/2010	$395	$316	$316	$253	$253	$253	$253	$253	$202
Charger Labor	DMC	All	2008/2010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010
Battery	IC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$4,441	$4,289	$4,289	$4,167	$4,167	$4,167	$4,167	$4,167	$2,625
			2008	$4,354	$4,205	$4,205	$4,086	$4,086	$4,086	$4,086	$4,086	$2,573
Battery	IC	Midsize PC/Perf PC	2010	$5,222	$5,044	$5,044	$4,901	$4,901	$4,901	$4,901	$4,901	$3,087
			2008	$5,111	$4,936	$4,936	$4,796	$4,796	$4,796	$4,796	$4,796	$3,021
Battery	IC	Large PC/Perf PC	2010	$6,725	$1,717	$1,712	$1,708	$1,703	$1,699	$1,696	$1,693	$1,090
			2008	$6,555	$6,331	$6,331	$6,151	$6,151	$6,151	$6,151	$6,151	$3,874
Non-battery	IC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$316	$315	$314	$313	$313	$312	$311	$311	$200
			2008	$272	$272	$271	$270	$269	$269	$268	$268	$172
Non-battery	IC	Midsize PC/Perf PC	2010	$976	$973	$970	$968	$965	$963	$961	$960	$618
			2008	$890	$888	$885	$883	$881	$878	$877	$876	$563
Non-battery	IC	Large PC/Perf PC	2010	$1,722	$18	$18	$18	$18	$18	$18	$18	$10
			2008	$1,602	$1,597	$1,593	$1,588	$1,584	$1,580	$1,578	$1,575	$1,014
Charger	IC	All	2008/2010	$126	$121	$121	$117	$117	$117	$117	$117	$70
Charger Labor	IC	All	2008/2010	$0	$0	$0	$0	$0	$0	$0	$0	$0

Battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$14,765	$12,548	$12,548	$10,775	$10,775	$10,775	$10,775	$10,775	$7,911
			2008	$14,475	$12,302	$12,302	$10,563	$10,563	$10,563	$10,563	$10,563	$7,755
Battery	TC	Midsize PC/Perf PC	2010	$17,362	$14,755	$14,755	$12,670	$12,670	$12,670	$12,670	$12,670	$9,302
			2008	$16,992	$14,441	$14,441	$12,400	$12,400	$12,400	$12,400	$12,400	$9,104
Battery	TC	Large PC/Perf PC	2010	$22,359	$19,002	$19,002	$16,317	$16,317	$16,317	$16,317	$16,317	$11,980
			2008	$21,793	$18,521	$18,521	$15,903	$15,903	$15,903	$15,903	$15,903	$11,676
Non-battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$726	$713	$700	$688	$676	$664	$657	$649	$532
			2008	$626	$615	$603	$593	$582	$572	$566	$559	$458
Non-battery	TC	Midsize PC/Perf PC	2010	$2,243	$2,203	$2,163	$2,125	$2,087	$2,051	$2,028	$2,005	$1,642
			2008	$2,047	$2,010	$1,973	$1,938	$1,904	$1,871	$1,850	$1,829	$1,498
Non-battery	TC	Large PC/Perf PC	2010	$3,959	$3,887	$3,817	$3,749	$3,683	$3,619	$3,578	$3,538	$2,897
			2008	$3,682	$3,615	$3,550	$3,487	$3,426	$3,367	$3,328	$3,291	$2,695
Charger	IC	All	2008/2010	$521	$437	$437	$370	$370	$370	$370	$370	$272
Charger Labor	IC	All	2008/2010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010

Table V-104 NHTSA Costs Applied for EV100 in CAFE model with No Mass Reduction (2010$)

Tech.	Cost Type	NHTSA Vehicle Class	Baseline Fleet	2017	2018	2019	2020	2021	2022	2023	2024	2025
Battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$12,341	$9,873	$9,873	$7,898	$7,898	$7,898	$7,898	$7,898	$6,319
			2008	$12,063	$9,651	$9,651	$7,720	$7,720	$7,720	$7,720	$7,720	$6,176
Battery	DMC	Midsize PC/Perf PC	2010	$14,159	$11,327	$11,327	$9,062	$9,062	$9,062	$9,062	$9,062	$7,250
			2008	$13,919	$11,135	$11,135	$8,908	$8,908	$8,908	$8,908	$8,908	$7,127
Battery	DMC	Large PC/Perf PC	2010	$17,482	$13,985	$13,985	$11,188	$11,188	$11,188	$11,188	$11,188	$8,951
			2008	$17,025	$13,620	$13,620	$10,896	$10,896	$10,896	$10,896	$10,896	$8,717
Non-battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$410	$398	$386	$375	$363	$352	$345	$338	$332
			2008	$354	$343	$333	$323	$313	$304	$298	$292	$286
Non-battery	DMC	Midsize PC/Perf PC	2010	$1,267	$1,229	$1,193	$1,157	$1,122	$1,088	$1,067	$1,045	$1,024
			2008	$1,156	$1,122	$1,088	$1,055	$1,024	$993	$973	$954	$935
Non-battery	DMC	Large PC/Perf PC	2010	$2,236	$2,169	$2,104	$2,041	$1,980	$1,920	$1,882	$1,844	$1,808
			2008	$2,080	$2,018	$1,957	$1,899	$1,842	$1,786	$1,751	$1,716	$1,681
Charger	DMC	All	2008/2010	$395	$316	$316	$253	$253	$253	$253	$253	$202

Charger Labor	DMC	All	2008/2010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010
Battery	IC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$5,309	$5,127	$5,127	$4,982	$4,982	$4,982	$4,982	$4,982	$3,138
			2008	$5,189	$5,012	$5,012	$4,870	$4,870	$4,870	$4,870	$4,870	$3,067
Battery	IC	Midsize PC/Perf PC	2010	$6,091	$5,883	$5,883	$5,716	$5,716	$5,716	$5,716	$5,716	$3,600
			2008	$5,988	$5,783	$5,783	$5,619	$5,619	$5,619	$5,619	$5,619	$3,539
Battery	IC	Large PC/Perf PC	2010	$7,520	$7,263	$7,263	$7,057	$7,057	$7,057	$7,057	$7,057	$4,445
			2008	$7,324	$7,073	$7,073	$6,873	$6,873	$6,873	$6,873	$6,873	$4,329
Non-battery	IC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$316	$315	$314	$313	$313	$312	$311	$311	$200
			2008	$272	$272	$271	$270	$269	$269	$268	$268	$172
Non-battery	IC	Midsize PC/Perf PC	2010	$976	$973	$970	$968	$965	$963	$961	$960	$618
			2008	$890	$888	$885	$883	$881	$878	$877	$876	$563
Non-battery	IC	Large PC/Perf PC	2010	$1,722	$1,717	$1,712	$1,708	$1,703	$1,699	$1,696	$1,693	$1,090
			2008	$1,602	$1,597	$1,593	$1,588	$1,584	$1,580	$1,578	$1,575	$1,014
Charger	IC	All	2008/2010	$126	$121	$121	$117	$117	$117	$117	$117	$70
Charger Labor	IC	All	2008/2010	$0	$0	$0	$0	$0	$0	$0	$0	$0
Battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$17,650	$15,000	$15,000	$12,880	$12,880	$12,880	$12,880	$12,880	$9,457
			2008	$17,253	$14,662	$14,662	$12,590	$12,590	$12,590	$12,590	$12,590	$9,244
Battery	TC	Midsize PC/Perf PC	2010	$20,250	$17,210	$17,210	$14,778	$14,778	$14,778	$14,778	$14,778	$10,850
			2008	$19,907	$16,918	$16,918	$14,527	$14,527	$14,527	$14,527	$14,527	$10,666
Battery	TC	Large PC/Perf PC	2010	$25,002	$21,248	$21,248	$18,245	$18,245	$18,245	$18,245	$18,245	$13,396
			2008	$24,349	$20,693	$20,693	$17,769	$17,769	$17,769	$17,769	$17,769	$13,046
Non-battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$726	$713	$700	$688	$676	$664	$657	$649	$532
			2008	$626	$615	$603	$593	$582	$572	$566	$559	$458
Non-battery	TC	Midsize PC/Perf PC	2010	$2,243	$2,203	$2,163	$2,125	$2,087	$2,051	$2,028	$2,005	$1,642
			2008	$2,047	$2,010	$1,973	$1,938	$1,904	$1,871	$1,850	$1,829	$1,498
Non-battery	TC	Large PC/Perf PC	2010	$3,959	$3,887	$3,817	$3,749	$3,683	$3,619	$3,578	$3,538	$2,897
			2008	$3,682	$3,615	$3,550	$3,487	$3,426	$3,367	$3,328	$3,291	$2,695
Charger	IC	All	2008/2010	$521	$437	$437	$370	$370	$370	$370	$370	$272
Charger Labor	IC	All	2008/2010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010

Table V-105 NHTSA Costs Applied for EV150 in CAFE model with No Mass Reduction (2010$)

Tech.	Cost Type	NHTSA Vehicle Class	Baseline Fleet	2017	2018	2019	2020	2021	2022	2023	2024	2025
Battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$16,369	$13,095	$13,095	$10,476	$10,476	$10,476	$10,476	$10,476	$8,381
			2008	$15,939	$12,751	$12,751	$10,201	$10,201	$10,201	$10,201	$10,201	$8,161
Battery	DMC	Midsize PC/Perf PC	2010	$19,585	$15,668	$15,668	$12,534	$12,534	$12,534	$12,534	$12,534	$10,028
			2008	$19,240	$15,392	$15,392	$12,313	$12,313	$12,313	$12,313	$12,313	$9,851
Battery	DMC	Large PC/Perf PC	2010	$22,552	$18,042	$18,042	$14,433	$14,433	$14,433	$14,433	$14,433	$11,547
			2008	$21,936	$17,549	$17,549	$14,039	$14,039	$14,039	$14,039	$14,039	$11,231
Non-battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$410	$398	$386	$375	$363	$352	$345	$338	$332
			2008	$355	$344	$334	$324	$314	$305	$299	$293	$287
Non-battery	DMC	Midsize PC/Perf PC	2010	$1,267	$1,229	$1,193	$1,157	$1,122	$1,088	$1,067	$1,045	$1,024
			2008	$1,157	$1,123	$1,089	$1,056	$1,025	$994	$974	$954	$935
Non-battery	DMC	Large PC/Perf PC	2010	$2,236	$2,169	$2,104	$2,041	$1,980	$1,920	$1,882	$1,844	$1,808
			2008	$2,082	$2,019	$1,959	$1,900	$1,843	$1,788	$1,752	$1,717	$1,682
Charger	DMC	All	2008/2010	$395	$316	$316	$253	$253	$253	$253	$253	$202
Charger Labor	DMC	All	2008/2010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010
Battery	IC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$7,042	$6,801	$6,801	$6,608	$6,608	$6,608	$6,608	$6,608	$4,162
			2008	$6,857	$6,622	$6,622	$6,434	$6,434	$6,434	$6,434	$6,434	$4,053
Battery	IC	Midsize PC/Perf PC	2010	$8,425	$8,137	$8,137	$7,906	$7,906	$7,906	$7,906	$7,906	$4,980
			2008	$8,277	$7,993	$7,993	$7,767	$7,767	$7,767	$7,767	$7,767	$4,892
Battery	IC	Large PC/Perf PC	2010	$9,702	$9,370	$9,370	$9,104	$9,104	$9,104	$9,104	$9,104	$5,734
			2008	$9,437	$9,114	$9,114	$8,855	$8,855	$8,855	$8,855	$8,855	$5,578
Non-battery	DMC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$316	$315	$314	$313	$313	$312	$311	$311	$200
			2008	$273	$273	$272	$271	$270	$270	$269	$269	$173
Non-battery	DMC	Midsize PC/Perf PC	2010	$976	$973	$970	$968	$965	$963	$961	$960	$618
			2008	$891	$889	$886	$884	$881	$879	$878	$876	$564
Non-battery	DMC	Large PC/Perf PC	2010	$1,722	$1,717	$1,712	$1,708	$1,703	$1,699	$1,696	$1,693	$1,090
			2008	$1,603	$1,598	$1,594	$1,590	$1,585	$1,581	$1,579	$1,576	$1,014

Charger	IC	All	2008/2010	$126	$121	$121	$117	$117	$117	$117	$117	$70
Charger Labor	IC	All	2008/2010	$0	$0	$0	$0	$0	$0	$0	$0	$0
Battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$23,411	$19,896	$19,896	$17,084	$17,084	$17,084	$17,084	$17,084	$12,543
			2008	$22,796	$19,373	$19,373	$16,635	$16,635	$16,635	$16,635	$16,635	$12,214
Battery	TC	Midsize PC/Perf PC	2010	$28,010	$23,805	$23,805	$20,441	$20,441	$20,441	$20,441	$20,441	$15,007
			2008	$27,517	$23,385	$23,385	$20,080	$20,080	$20,080	$20,080	$20,080	$14,743
Battery	TC	Large PC/Perf PC	2010	$32,254	$27,411	$27,411	$23,537	$23,537	$23,537	$23,537	$23,537	$17,281
			2008	$31,372	$26,662	$26,662	$22,894	$22,894	$22,894	$22,894	$22,894	$16,809
Non-battery	TC	Subcompact PC/Perf PC Compact PC/Perf PC	2010	$726	$713	$700	$688	$676	$664	$657	$649	$532
			2008	$628	$617	$606	$595	$585	$574	$568	$561	$460
Non-battery	TC	Midsize PC/Perf PC	2010	$2,243	$2,203	$2,163	$2,125	$2,087	$2,051	$2,028	$2,005	$1,642
			2008	$2,048	$2,011	$1,975	$1,940	$1,906	$1,873	$1,852	$1,831	$1,499
Non-battery	TC	Large PC/Perf PC	2010	$3,959	$3,887	$3,817	$3,749	$3,683	$3,619	$3,578	$3,538	$2,897
			2008	$3,685	$3,618	$3,552	$3,489	$3,428	$3,369	$3,330	$3,293	$2,697
Charger	IC	All	2008/2010	$521	$437	$437	$370	$370	$370	$370	$370	$272
Charger Labor	IC	All	2008/2010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010	$1,010

Vehicle Technologies

Mass Reduction

From 1987-2011, there has been a generally increasing trend in the weight of the light duty vehicle fleet as shown in Figure V-37 from EPA's Fuel Economy Trends Report[298]. A number of factors have contributed to this weight increase, including the choices of manufacturers and consumers to build and purchase larger vehicles, including heavier trucks, SUVs, and CUVs. Also contributing to this weight increase has been an increase in vehicle content including: safety features (air bags, antilock brakes, energy absorbent and intrusion resistant vehicle structures, etc.), noise reduction (additional damping material), added comfort and convenience features (air

[298] "Light-Duty Automotive Technology, Carbon Dioxide Emissions, and Fuel Economy Trends: 1975 Through 2011", EPA420-R-12-001a, U.S. Environmental Protection Agency Office of Transportation and Air Quality, March 2012

conditioning, power locks and windows), luxury features (infotainment systems, powered seats), etc.

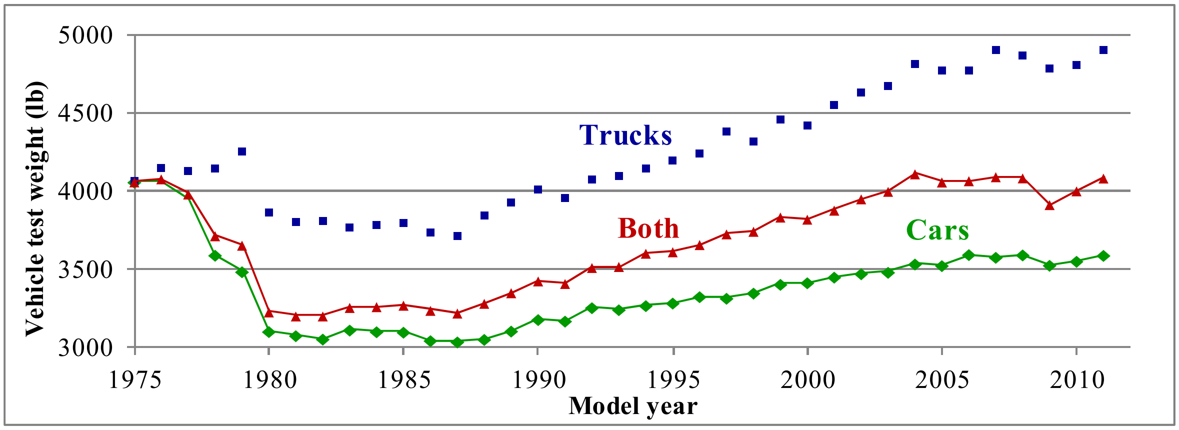


Figure V-37 Light duty fleet weight trends: 1975-2011

Despite this increase in weight, the average acceleration of vehicles has grown steadily faster without any marked or consistent reduction in fuel economy since 1987, as shown in Figure V-38. This combination of increased vehicle performance, stable fuel economy, and increased vehicle weight has been partially enabled by the development and adoption of more efficient technologies, especially in engines and transmissions. The impressive improvements in powertrain efficiency during this period have offset increases in energy consumption that result from improvements in weight carrying, towing and volume capacities, safety, consumer features, vehicle refinement, and acceleration performance.

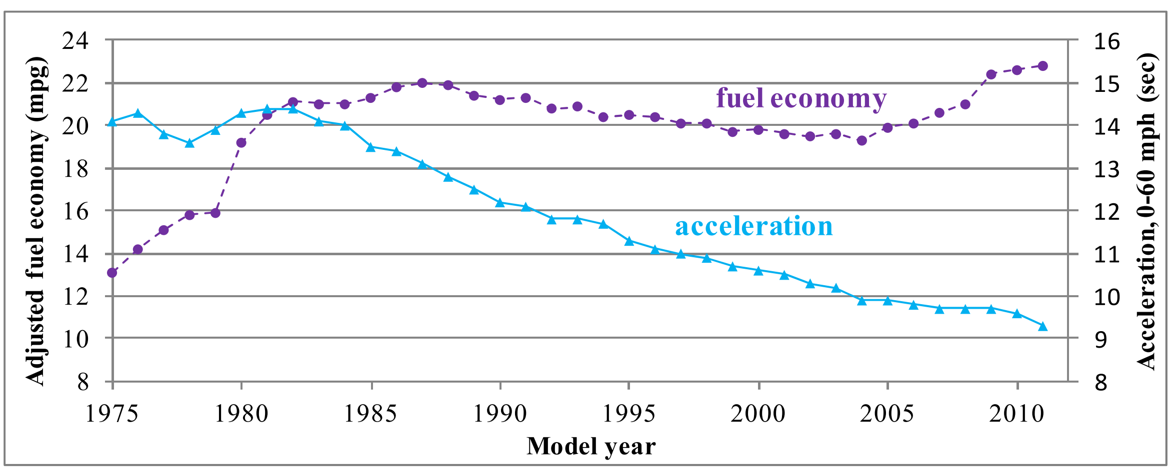


Figure V-38 Light duty fleet trends for acceleration and fuel economy: 1975-2011

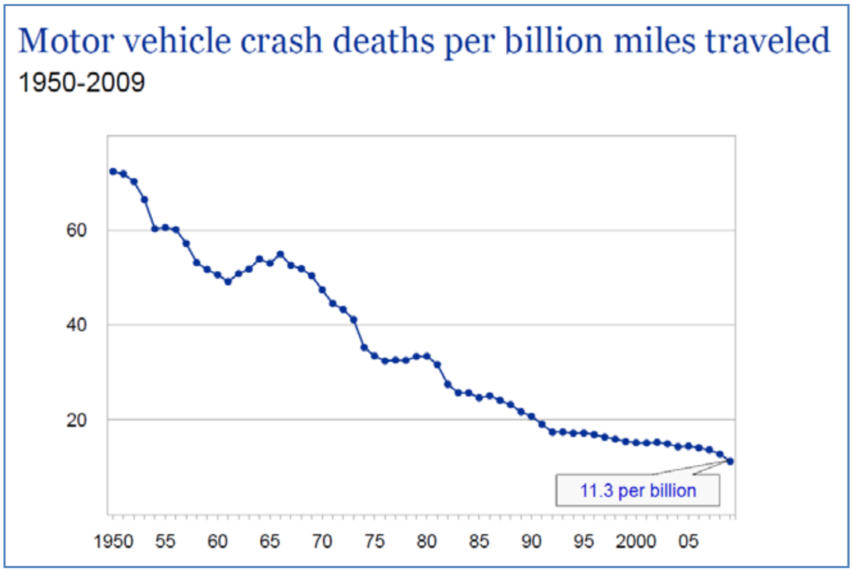


Figure V-39 U.S. Vehicle Fatality Rates for the past 60 years[299]

Vehicle mass reduction (also referred to as "down-weighting" or 'light-weighting"), reduces the energy needed to overcome inertial forces, thus yielding lower fuel consumption and GHG emissions. While keeping everything else constant, a lighter vehicle will require less energy to operate than a heavier vehicle. Mass reduction can be achieved through a number of approaches described below, even while maintaining vehicle size. Alternatively, mass reduction can also be achieved by vehicle "downsizing" which involves reducing vehicle exterior dimensions, such as shifting from a midsize vehicle to a compact vehicle. Consistent with the proposal, the agencies did not analyze downsizing as a mass reduction strategy in this analysis for the final rule. In part, this is because a manufacturer's ability to downsize its vehicles is constrained by consumer preferences (such as for interior passenger or cargo volume), which are in turn influenced by many factors that are difficult to predict in the future, such as the consumer's utility needs, fuel prices, economic conditions, etc. Also, the final CAFE and GHG emission standards are based on vehicle footprint (the area bounded by where the four tires contract the ground), and generally assign higher fuel economy targets (and lower CO2 emission targets) for vehicles with smaller footprints and lower fuel economy targets (and higher CO2 emission targets) for vehicles with larger footprints. As discussed in Chapter 2 of the joint TSD, the agencies believe the shape of the footprint-based target curves will not create incentives for manufacturers to either upsize or downsize their vehicles. Based on these considerations, the agencies are assuming that manufacturers will favor mass reduction through material substitution, design optimization, and adopting other advanced manufacturing technologies rather than compromising a vehicle's

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[299] Adrian Lund, IIHS, "The Relative Safety of Large and Small Passenger Vehicles." *Available at* http://www.nhtsa.gov/staticfiles/rulemaking/pdf/MSS/MSSworkshop-Lund.pdf (last accessed Jun. 10, 2012).

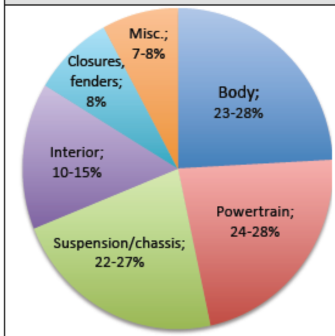
attributes and functionality, such as occupant or cargo space, vehicle safety, comfort, acceleration, etc. Consequently, the compliance paths the agencies have investigated for the promulgated standards do not include downsizing.

Mass reduction has an important relationship with vehicle powertrain selection and sizing. Vehicle powertrain selection depends on an OEM's product strategy, and may include a variety of options such as naturally aspirated engines, boosted and downsized gasoline engines, diesel engines, or vehicle electrification (P/H/EV). Regardless of the strategy selected, vehicle mass reduction for non-powertrain systems is an important enabler to further reduce vehicle fuel consumption and reduce the size of the powertrain system. The term "glider" refers to a complete vehicle minus the powertrain. Figure V-40 illustrates the mass breakdown by system for a typical vehicle[300]. The non-powertrain systems normally account for 75 percent of vehicle weight. The agencies have accounted for some of the costs of engine mass reduction when applying engine downsizing technologies. The agencies have also accounted for the amount of mass change due to the application of hybrid and electrification technologies in the vehicle electrification sections. Therefore, this section focuses on both the mass reduction of the glider as well as mass reduction technologies that are specifically targeted at reducing the weight of the powertrain[301] rather than on mass reduction resulting from powertrain efficiency improvements. An example of a mass reduction technology for the powertrain that is not related to powertrain efficiency improvement is material substitution, such as changing the engine block from cast iron to aluminum or changing the size of the fuel tank). Mass reduction is calculated for both the glider and the vehicle including powertrain in the studies sponsored by the agencies as shown later in this section.

[300] Lutsey, "Review of technical literature and trends related to automobile mass-reduction technology", UCD-ITS-RR-10-10, May 2010 . *Available at* http://pubs.its.ucdavis.edu/publication_detail.php?id=1390 (last accessed Jun. 10, 2012).

[301] Rather than on mass reduction resulting from powertrain efficiency improvements, such as in the case of adding a turbocharger to a downsized engine.

Approximate vehicle mass breakdown[a]



System	Major components in system
Body-in-white	Passenger compartment frame, cross and side beams, roof structure, front-end structure, underbody floor structure, panels
Powertrain	Engine, transmission, exhaust system, fuel tank
Chassis	Chassis, suspension, tires, wheels, steering, brakes
Interior	Seats, instrument panel, insulation, trim, airbags
Closures	Front and rear doors, hood, lift gate
Miscellaneous	Electrical, lighting, thermal, windows, glazing

[a] *Based on Stodolsky et al, 1995a; Bjelkengren, 2008; Lotus Engineering, 2010; the actual system definitions and system component inclusion can vary, and percentage weight breakdown can vary substantially by vehicle*

Figure V-40 Vehicle system mass approximation

A vehicle can be divided into 6 major systems, which are shown in Figure V-40. Mass reduction can potentially be applied to any of a vehicle's subsystems, including the engine, exhaust system, transmission, chassis, suspension, brakes, body, closure panels, glazing, seats and other interior components, engine cooling systems, and HVAC systems. While manufacturers may reduce the mass of some individual components during a vehicle refresh, they generally undertake larger amounts of mass reduction systematically and more broadly across all vehicle systems when redesigning a vehicle. In the redesign process, OEMs normally set weight targets by benchmarking other vehicles in the same segment and projecting weight trends into the future, and then identifying targets for all components and subsystems that support achieving the target. The agencies believe this holistic approach, which takes into consideration all secondary mass savings, is likely the most effective way for OEMs to achieve large amounts of mass reduction.

During a vehicle redesign where mass reduction is a strategic vehicle program goal, OEMs can consider modular systems design, secondary mass effects, multi-material concepts, and new manufacturing processes to help optimize the design. There are several studies in the public domain that illustrate the potential for these approaches to achieve significant amounts of mass reduction, although it is important to also recognize that the studies use some assumptions that do not account for some of the considerations that are important to manufacturers. One example is the need to share components across platforms to manage cost and part complexity for assembly and service, which limits the ability to optimize the amount of mass reduction on every vehicle component. Care must also be taken in any study to assure that vehicle functionality and performance, such as stiffness, NVH, safety and vehicle dynamics, continue to meet manufacturer objectives and consumer demands. It is important for design studies to use tools such as simulation modeling to assess the design's ability to meet functionality and performance targets. In this rulemaking, the agencies have targeted to preserve vehicle function and performance in their analysis of mass reduction. An example of this approach is illustrated in

Figure V-25, which summarizes the results of the phase I Lotus Engineering mass reduction study of a Toyota Venza.

Mass-reduction features, findings	• Redesign conventional mid-size vehicle for mass optimization, with two redesign architectures • Low Development vehicle technology with industry-leading manufacturing techniques that were deemed feasible for 2014 (for model year 2017 production) for assembly at existing facilities • High Development vehicle technology, with modifications to conventional joining and assembly processes that were deemed feasible for 2017 (for model year 2020) production • Extensive use of material substitution with high-strength steel, advanced high–strength steel, aluminum, magnesium, plastics and composites throughout vehicles • Conservative use of emerging design and parts integration concepts to minimize technical risk • Using synergistic total vehicle substantial mass reduction opportunities found at minimized piece costs • The Low Development vehicle was found to have likely piece cost reductions, whereas the High Development vehicle had nominal estimated cost increase of 3% (with potential for cost reduction)
Mass-reduction impact	• Body structure reduction for Low Development Vehicle: 55 lb (6.6%) • Body structure reduction for High Development Vehicle: 356 lb (42%) • Overall glider reduction for Low Development Vehicle: 538 lb (19%) • Overall glider reduction for High Development Vehicle: 1096 lb (39%) • Overall vehicle reduction for Low Development Vehicle (with hybrid powertrain): 657 lb (17.6%) • Overall vehicle reduction for High Development Vehicle (with hybrid powertrain): 1209 lb (32%)
Status	• Engineering design study conducted by Lotus Engineering • First phase of project, development of two mass-reduced vehicle designs completed in April 2010 • Second phase to test structural integrity, impact load paths, crash worthiness to validate the vehicle designs.
Source	• Lotus Engineering, Inc. 2010. An Assessment of Mass Reduction Opportunities for a 2017-2020 Model Year
Illustrations	

Figure V-41 Example of a holistic vehicle redesign study from Lotus Engineering[302]

Mass reduction can be considered in terms of the "percent by which the redesigned vehicle is lighter than the previous version," recognizing that the value likely represents both "primary" mass reduction (that which the manufacturer set out to make lighter), and "secondary" mass reduction (from ancillary systems and components that can now be lighter due to the primary mass reductions).

As summarized by NAS in its 2011 report,[303] there are two key strategies for primary mass reduction: 1) changing the design to use less material or 2) substituting lighter materials for heavier materials. The first key strategy of using less material compared to the baseline

[302] Lotus Engineering, Inc. "An Assessment of Mass Reduction Opportuties for a 2017-2020 Model Year Vehicle program", March 2010, Docket EPA-HQ-OAR-2010-0799 or NHTSA-2010-0131-0099.
[303] Committee on the Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy; National Research Council, "Assessment of Fuel Economy Technologies for Light-Duty Vehicles", 2011. *Available at* http://www.nap.edu/catalog.php?record_id=12924 (last accessed Jun 27, 2012).

component can be achieved by optimizing the design and structure of the component, system or vehicle structure. For example, a number of "body on frame" vehicles have been redesigned with a lighter "unibody" construction, eliminating components, reducing the weight of the body structure, and resulting in significant reductions in overall mass and related costs. The unibody design currently dominates the passenger car segment and has increased penetration into what used to be mostly body-on-frame vehicles, such as SUVs. This technique was used in the 2011 Ford Explorer redesign, which also employed the extensive use of high strength steels.[304] Figure V-42 depicts body-on-frame and unibody designs for two sport utility vehicles.

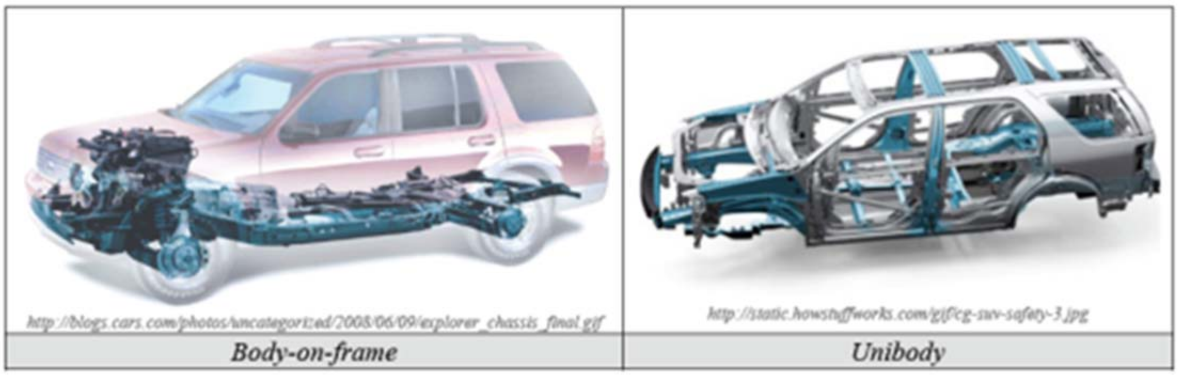


Figure V-42 Illustration of Body-on-Frame (BoF) and Unibody vehicle construction

To further reduce mass inefficiencies in vehicle design, vehicle manufacturers are using continually-improving Computer Aided Engineering (CAE) tools. For example, the Future Steel Vehicle (FSV) project[305] sponsored by WorldAutoSteel used three levels of optimization: topology optimization, low fidelity 3G (Geometry Grade and Gauge) optimization, and sub-system optimization, to achieve 30 percent mass reduction in the body structure of a vehicle with a mild steel unibody structure (see Figure V-43). Designs similar to those proposed in the FSV project have been applied in production vehicles, such as the B-pillar of 2010 Ford Focus.[306]

[304] Ford Sustainability Report 2010/11, http://corporate.ford.com/microsites/sustainability-report-2010-11/issues-climate-plan-economy (last accessed Aug. 26, 2011)
[305] ETA, US Steel, Tata Steel, "The ACP Process™ as Applied to the Future Steel Vehicle", Docket NHTSA-2010-0131", http://www.eta.com/index.php/engineering/product-design-development/the-acp-process/success-stories/181-the-acp-process-as-applied-to-the-future-steel-vehicle- (last accessed Aug. 2, 2012)
[306] SAE World Congress, "Focus B-pillar 'tailor rolled' to 8 different thicknesses," Feb. 24, 2010. *Available at* http://www.sae.org/mags/AEI/7695 (last accessed Jun. 10, 2012).

2.4 T4: Body Structure Sub-System Optimisation

The final design attained from the LF3G optimisation was used as the basis for the sub-system optimisation, as well as the source of the boundary conditions. Load path mapping was conducted on the model to identify the most dominant structural sub-systems in the body structure. Load path mapping considers the dominant loads in the structural sub-systems for each of the load cases as shown in Figure 2-7.

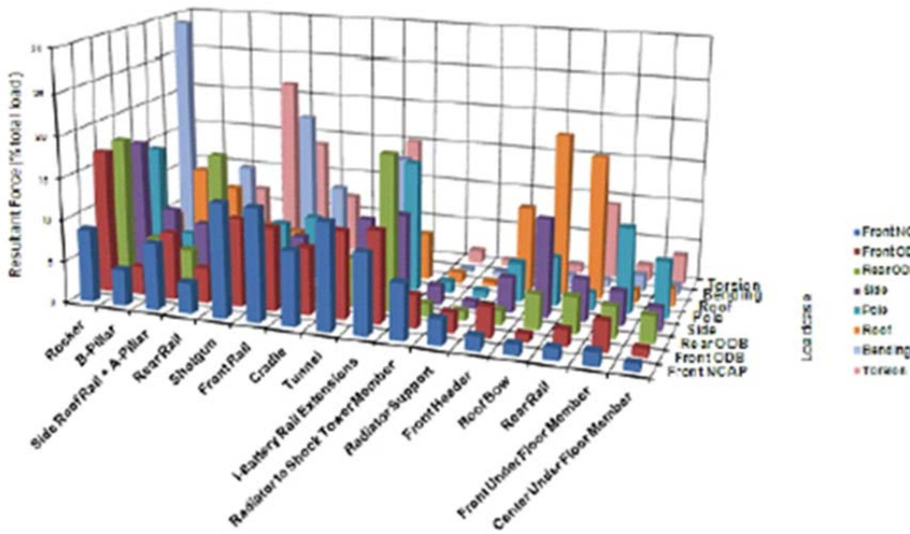


Figure 2-7: T4 Load Path Mapping – Major Load Path Components

Based on load path mapping, seven structural sub-systems (Figure 2-8) were selected for further optimisation using the spectrum of FSV's potential manufacturing technologies.

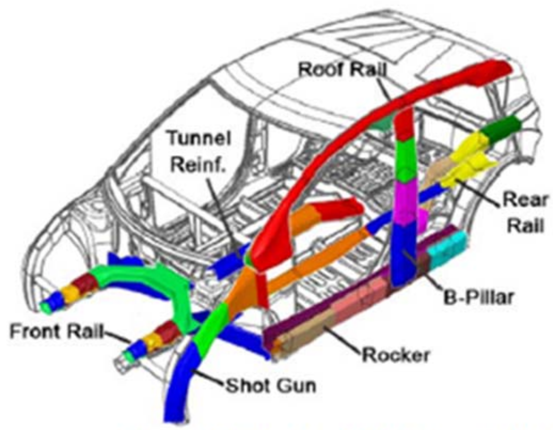


Figure 2-8: Structural Sub-Systems Selected

FutureSteelVehicle

WorldAutoSteel

Figure V-43 Example of vehicle body load path mapping for mass optimization

Vehicle manufacturers have long used these continually-improving CAE tools to optimize vehicle designs. But because any design must meet component and system functionality and manufacturability targets, there are practical limitations to the amount of additional mass reduction that can be achieved through optimization. For example, an optimization program would need to account for safety, stiffness, NVH, manufacturing, and other requirements to assure the design is suitable for its intended function and for mass production. Additionally, ultimate optimization of vehicle design for mass reduction may be limited by an OEM's use of shared components and common platform for multiple vehicle models. While optimization may concentrate on the vehicle that has the largest production volume for a platform, designs must also support the most demanding functional requirements of all of the vehicles that share that platform, or those functional requirements will not be met. In addition, the engineering resources and capital for tooling and equipment that would be needed to optimize every vehicle component at each redesign affects the ability to fully optimize a new vehicle to achieve all of the theoretically possible secondary mass reduction. Therefore, some level of mass inefficiency will inherently exist on many or all of the vehicles that share a platform. The agencies sought comment and information in the NPRM on the degree to which shared vehicle components and architectures affect the feasible amount of mass reduction and the cost for mass reduction relative to what could be achieved if mass reduction was optimized for a single vehicle design. Volkswagen confirmed in its comments that with platform sharing, "a weight reduction technology which may be acceptable in terms of price or performance for one model may disrupt the economics or utility of another."[307]

Using less material can also be achieved through improving the manufacturing process, such as by using improved joining technologies and parts consolidation. This method is often used in combination with applying new materials. For example, more precise manufacturing techniques such as laser welding may reduce the flange size necessary for welding, and thus marginally decrease the mass of an assembly. Also, when complex assemblies are constructed from fewer pieces, the mass of the assembly tends to be lower. However, while synergies in mass reduction certainly exist, and while certain technologies can enable one another (*e.g.*, parts consolidation and molding of advanced composites), others may be incompatible (*e.g*., laser welding and magnesium casting).

The second key strategy to reduce mass of an assembly or component involves the substitution of lower density and/or higher strength materials. Table V-106 shows material usage typical of contemporary high-volume vehicles. Material substitution includes replacing materials, such as mild steel, with higher-strength and advanced steels, aluminum, magnesium, and composite materials. The substitution of advanced high strength steel (AHSS) for mild steel can reduce the mass of a strength-critical part because the gauge of the AHSS components can be reduced, despite the fact that the densities of the materials are not significantly different. Aluminum has also been used over the years in a variety of components, such as vehicle closures, suspension

[307] VW comments, NHTSA-2010-0131-0247, at page 16

parts, engine cradles, etc. Aluminum has one third the density of steel and therefore can provide a notable amount of mass reduction. Changing parts from steel to aluminum generally requires part redesign, and extra material may have to be added for strength or durability. Aluminum also has a shorter fatigue life than steel and therefore the alloy selected and the application must be carefully considered. Magnesium can provide additional mass reduction as it has lower density than aluminum. It has been used for instrument panel cross-car beams by several OEMs for a number of years. It has also been used in an engine block produced by BMW for several years. Its brittle nature must be considered, however, when selecting the alloy and the application within the vehicle.

Table V-106 Distribution of Material in Typical Contemporary Vehicles (e.g., Toyota Camry or Chevrolet Malibu)[308]

Material	Comments	Approximate Content in Cars Today, by Weight (percent)
Iron and mild steel	Under 480 Mpa	55
High-strength steel	≥ 480 Mpa (in body structure)	15
Aluminum	No aluminum closure panels; aluminum engine block and head and wheels	10
Plastic	Miscellaneous parts, mostly interior trim, light lenses, facia, instrument panel	10
Other (magnesium, titanium, rubber, etc.)	Miscellaneous parts	10

Automobiles also utilize a wide range of plastic types, including polypropylenes, polyesters, and vinyl esters. These materials are utilized in hatches, roofs, interior panels, instrument panels, and hundreds of other parts. Although primarily used in nonstructural vehicle components, plastics have continued to make in-roads in bumper systems and in composite beam applications, and some studies have found potential to supplant structural beams and frame components. Lighter plastics have also been developed by the industry, and the application of these materials has been increasing.

Included in the category of plastics are composites like glass fiber and carbon fiber reinforced polymers. While these more costly advanced materials have primarily been used in a limited number of low production volume vehicle applications, some manufacturers are considering these composites for broader use. While these materials currently have the potential to be applied to components with little or no exposure to impact pulses, the advanced microstructure and limited industry experience may make these longer-term solutions. For example, advanced composite materials (such as carbon fiber-reinforced plastic), depending on the specific fiber, matrix, reinforcement architecture, and processing method, can be subject to dozens of competing damage and failure mechanisms that may complicate a manufacturer's ability to ensure equivalent levels of durability and crashworthiness. As the industry gains experience with

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[308] Committee on the Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy; National Research Council, "Assessment of Fuel Economy Technologies for Light-Duty Vehicles", 2011, Docket NHTSA-2010-0131-0100. Also *available at* http://www.nap.edu/catalog.php?record_id=12924 (last accessed Jun 27, 2012).

these materials, these concerns will inevitably diminish, but may remain relevant during the timeframe of this final rulemaking.

In practice, material substitution tends to be quite specific to the manufacturer and situation. Some materials work better than others for particular vehicle components, and a manufacturer may invest more heavily in adjusting to a particular type of advanced material, thus complicating its ability to consider others. The agencies recognize that like any type of mass reduction, material substitution has to be conducted not only with consideration to maintaining equivalent component strength, but also to maintaining all the other attributes of that component, system or vehicle, such as crashworthiness, durability, and noise, vibration and harshness (NVH).

If vehicle mass is reduced sufficiently through application of the two primary strategies of using less material and material substitution described above, secondary mass reduction options may become available. Secondary mass reduction is enabled when the load requirements of a component are reduced as a result of primary mass reduction. If the primary mass reduction reaches a sufficient level, a manufacturer may use a smaller, lighter, and potentially more efficient powertrain while maintaining vehicle acceleration performance. If a powertrain is downsized, approximately half of the mass reduction may be attributed to the reduced torque requirement which results from the lower vehicle mass. The lower torque requirement enables a reduction in engine displacement, changes to transmission torque converter and gear ratios, and changes to final drive gear ratio. The reduced powertrain torque enables the downsizing and/or mass reduction of powertrain components and accompanying reduced rotating mass (*e.g.*, for transmission, driveshafts/halfshafts, wheels, and tires) without sacrificing powertrain durability. Likewise, the combined mass reductions of the engine, drivetrain, and body in turn reduce stresses on the suspension components, steering components, wheels, tires, and brakes, which can allow further reductions in the mass of these subsystems. Reducing the unsprung masses such as the brakes, control arms, wheels, and tires further reduce stresses in the suspension mounting points, which will allow for further optimization and potential mass reduction.

Secondary mass reduction can occur for each kilogram of primary mass reduction, when all subsystems are redesigned to take the initial primary mass reduction into account. In the MYs 2012-2016 rulemaking analysis, the agencies assumed that 1 kg of primary mass reduction could enable up to 1.25 kg of secondary mass reduction. In the two most recent mass reduction projects by EPA and NHTSA, every 1 kg of primary mass reduction enabled 0.7 kg of secondary mass reduction. We note that these estimates may not be applicable in all real-world instances of mass reduction, and that the literature indicates that the amount of secondary mass reduction potentially available varies significantly from an additional 0.5 kg to 1.25 kg per 1 kg of primary mass reduction, depending on assumptions such as which components or systems primary mass reduction is applied to, and whether the powertrain is available for downsizing.[309,310,311] The amount of secondary mass reduction is also affected by the degree of component sharing that occurs among a manufacturer's models. Component sharing is used by manufacturers to achieve production economies of scale that affect cost and the number of unique parts that must be managed in production and for service. In addition, the engineering resources and capital for tooling and equipment that would be needed to optimize every vehicle component at each redesign affects the ability to fully optimize a new vehicle to achieve all of the theoretically possible secondary mass reduction. While there is agreement in the literature that primary mass reduction can enable secondary mass reduction, the agencies recognize that care must be taken when reviewing reports on mass reduction methods and practices to ascertain the manner and extent to which compounding effects have been considered.

All manufacturers are using some or all of these methods to reduce mass in the vehicles they are producing today, and the agencies expect that the industry will continue to learn and improve the application of these techniques for more vehicles during the rulemaking timeframe. We consider mass reduction in net percentage terms in our analysis not only because effectively determining specific appropriate mass reduction methods for each vehicle in the baseline fleet is a large task beyond the scope of this rulemaking, but also because we recognize that even as manufacturers reduce mass to make vehicles more efficient, they may also be adding mass in the form of increased vehicle features and safety content in response to market forces and other governmental regulations. For these reasons, when the agencies discuss the amount of mass reduction that we are assuming is feasible for purposes of our analysis, we are implicitly balancing both the considerable opportunities that we believe exist for mass reduction in the future, and the reality that vehicle manufacturing is complex and that mass reduction methods must be applied thoughtfully and judiciously as safety and content demands on vehicles continue to increase over time. Despite our considerable discussion of the topic, the agencies' application of mass reduction in our analysis is fairly simplified. As applied in our models, the percentage reduction for a given vehicle that is assumed for a given year is an abstraction of all the specific mass reduction methods described above.

How much mass reduction do the agencies believe is feasible in the rulemaking timeframe?

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[309] Malen, E. and K. Reddy, "*Preliminary Vehicle Mass Estimation Using Empirical Subsystem Influence Coefficients,*" Auto-Steel Partnership Report, May 2007. Docket NHTSA-2010-0131. Available at http://www.a-sp.org/~/media/Files/Autosteel/Research/Lightweighting/mass_compoundingpdf.ashx (last accessed Jun. 27, 2012).

[310] Bull, M., R. Chavali, A. Mascarin, "Benefit Analysis: Use of Aluminum Structures in "*Conjunction with Alternative Powertrain Technologies in Automobiles*," Aluminum Association Research Report, May 2008. Docket NHTSA-2010-0131-0097. Available at http://aluminumintransportation.org/downloads/IBIS-Powertrain-Study.pdf (last accessed Aug. 17, 2011).

[311] Bjelkengren, C, "The Impact of Mass Decompounding on Assessing the Value of Vehile Lightweighting", Docket NHTSA-2010-0131, Available at http://msl.mit.edu/theses/Bjelkengren_C-thesis.pdf (last accessed Aug 3, 2012).

Feasibility, if narrowly defined as the ability to reduce mass without any constraints, is nearly unbounded. However, in practice, the feasible amount of mass reduction is affected by other considerations. Cost effectiveness is one of those constraints and is discussed further below in the mass reduction cost section. In the analysis for the current rulemaking for MYs 2017-2025, the agencies reviewed a number of public reports and accompanying data, as well as confidential information from manufacturers, and believe that mass reduction of up to 20 percent from a MY 2008 baseline vehicle can be achieved in a cost effective manner using technologies currently in production. More detail on studies reviewed by the agencies and additional studies currently in progress by the agencies is located below in Table V-115 and in the paragraphs under the question "*What additional studies are the agencies conducting to inform our estimates of mass reduction amounts, cost, and effectiveness?"*

From a general planning perspective, nearly all automakers have made some public statement regarding vehicle mass reduction being a core part of the overall technology strategy that they will utilize to achieve future fuel economy and CO_2 emission standards.

- Estimates from Ducker Worldwide indicate that the automobile industry will see an annual increase in AHSS of about 10% through 2020[312].
- Ford has stated that it intends to reduce the weight of its vehicles by 250-750 lb per model from 2011 to 2020[313]. For context, the midpoint of that range of reductions would correspond to a 12% reduction from the current Ford new light-duty vehicle sales fleet.
- Mazda has released a statement about achieving a 220-lb reduction per vehicle by 2016[314]. This is equivalent to about a 6% reduction for the company's current fleet.
- Land Rover executives have stated that the company remains committed to a goal of reducing curb weights of its SUVs by as much as 500 kilograms over the next 10 years[315].
- In its comment to the NPRM, Volkswagen stated that they expect to reduce the mass of their vehicles by 7-10% on average during the period of this regulation.

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[312] American Iron and Steel Institute (AISI), 2009. "New Study Finds Increased Use of Advanced High-Strength Steels Helps Decrease Overall Vehicle Weight." Docket NHTSA-2010-0131. *Available at* http://www.steel.org/en/sitecore/content/Global/Document%20Types/News/2009/Auto%20-%20New%20Study%20Finds%20Increased%20Use%20of%20Advanced%20High-Strength%20Steels.aspx (last accessed on Aug 3, 2012).

[313] Ford, 2010. "The 5.0Liter is Back: 2011 Ford Mustang GT Leads Class with 412 HP, Fuel Efficiency, Chassis Dynamics." Docket NHTSA-2010-0131. *Available at* http://media.ford.com/article_display.cfm?article_id=31645 (last accessed Aug. 3, 2012).

[314] Information copied from http://www.mazda.com/csr/environment/making_car/ weight_reduction.html and docketed. EPA-HQ-OAR-2010-0799.

[315] The New York Times, "Automakers Resolve to Drop a Few pounds", Sept 2011. http://www.nytimes.com/2011/09/18/automobiles/autoshow/in-frankfurt-automakers-vow-to-drop-a-few-pounds.html?_r=1&smid=tw-nytimeswheels&seid=auto EPA Docket EPA-HQ-OAR-2010-0799.

Several reports focusing on the OEM's approaches for light weighting are summarized in the University of California Davis study as shown Table V-107.

Table V-107 Automaker industry statements regarding plans for vehicle mass-reduction technology

Affiliation	Quote	Source
General Motors	"We use a lot of aluminum today – about 300 pounds per vehicle - and are likely to use more lightweight materials in the future"	Keith, 2010
Ford	"The use of advanced materials such as magnesium, aluminum and ultra high-strength boron steel offers automakers structural strength at a reduced weight to help improve fuel economy and meet safety and durability requirements"	BMW and SGL, 2010
Nissan	"We are working to reduce the thickness of steel sheet by enhancing the stregnth, expanding the use of aluminum and other lightweight materials, and reducing vehicle weight by rationalizing vehicle body structure"	Goede et al, 2009
BMW	"Lightweight construction is a core aspect for sustainable mobility improving both fuel consumption and CO2 emissions, two key elements of our Efficient Dynamics strategy … we will be able to produce carbon fiber components in large volumes at competitive costs for the first time. This is particularly relevant for electric-powered vehicles."	Nunez, 2009
Volkswagen	"Material design and manufacturing technologies remain key technologies in vehicle development. Only integrated approaches that work on these three key technologies will be successful in the future. In addition to the development of metals and light metals, the research on fibre-reinforced plastics will play a major role."	Goede et al, 2009
Fiat	"A reduction of fuel consumption attains big importance because of the possible economical savings. In order to achieve that, different ways are followed: alternative engine concepts (for example electric engines instead of combustion ones) or weight reduction of the vehicle structure. Using lightweight materials and different joining techniques hleps to reach this aim"	Nunez, 2009
Volkswagen	"Lightweight design is a key measure for reducing vehicle fuel consumption along with powertrain efficiency, aerodynamics and electrical power management"	Krinke, 2009
BMW	"A dynamic vehicle with a low fuel consumption finally demands a stiff body with a low weight. To achieve the initially mentioned targets, it is therefore necessary to design a body which offers good stiffness values and a high level of passive safety at a low weight."	Prestorf, 2009
BMW	"Light weight design can be achieved by engineering light weight, manufacutring light weight and material light weight design."	Prestorf, 2009

Although the focus on mass reduction by manufacturers is widespread, the agencies believe the practical limits of mass reduction will be different for each vehicle model as each model starts with a different mix of conventional and advanced materials, components, and features intended to meet the function and price of a particular market segment. A vehicle that already has a significant fraction of advanced high strength steel (AHSS) or any other advanced material in its structure, for example, will not have the opportunity to realize the same percentage of mass reduction as a vehicle of more traditional construction. Given the myriad methods of achieving mass reduction, and the difficulty in obtaining data, accounting for the current level of mass reduction technology for every model in production in a baseline model year would be an impractical task. However, the agencies believe that reducing vehicle weight to reduce fuel consumption has a continuum of solutions and the technologies employed will have levels of effectiveness and feasibility that will vary by manufacturers and by vehicle.

What was the agency's methodology for estimating safety effects for the final rule?

As explained in preamble section II.G, the agencies consider the latest 2012 statistical analysis of historical crash data by NHTSA to represent the best estimates of the potential relationship between mass reduction and fatality increases in the future fleet. This section discusses how the agencies used NHTSA's 2012 analysis to calculate specific estimates of safety effects of the final rule, based on the analysis of how much mass reduction manufacturers might use to meet the final rule.

The CAFE/GHG standards do not mandate mass reduction or require that mass reduction occur in any specific manner. However, mass reduction is one of the technology applications available to the manufacturers and a degree of mass reduction is used by both agencies' models to determine the capabilities of manufacturers and to predict both cost and fuel consumption/emissions impacts of more stringent CAFE/GHG standards. To estimate the amount of mass reduction to apply in the rulemaking analysis, the agencies considered fleet safety effects for mass reduction. The agencies use the results from the Kahane studies to analyze the fleet safety effect of mass reduction. The Kahane studies are discussed in details in Chapter IX of this FRIA. As shown in Table IX-1 and Table IX-2 in Chapter IX, , both the Kahane 2011 preliminary report and the Kahane 2012 final report show that applying mass reduction to CUVs and light duty trucks will generally decrease societal fatalities, while applying mass reduction to passenger cars will increase fatalities. The CAFE model uses coefficients from the Kahane study along with the mass reduction level applied to each vehicle model to project societal fatality effects in each model year. NHTSA used the CAFE model and conducted iterative modeling runs varying the maximum amount of mass reduction applied to each subclass in order to identify a combination that achieved a high level of overall fleet mass reduction while not adversely affecting overall fleet safety. These maximum levels of mass reduction for each subclass were then used in the CAFE model for the rulemaking analysis. The agencies believe that mass reduction of up to 20 percent is feasible on light trucks, CUVs and minivans as discussed in the Joint TSD Section 3.3.5.5, as well as this section of FRIA. Thus, the amount of mass reduction selected for this rulemaking is based on our assumptions about how much is technologically feasible without compromising safety. While we are confident that manufacturers will build safe vehicles and meet (or surpass) all applicable federal safety standards, we cannot predict with certainty that they will choose to reduce mass in exactly the ways that the agencies have analyzed in response to the standards. In the event that manufacturers ultimately choose to reduce mass and/or footprint in ways not analyzed or anticipated by the agencies, the safety effects of the rulemaking may likely differ from the agencies' estimates.

In this final rule analysis, NHTSA utilized the 2012 Kahane study relationships between weight and safety, expressed as percent changes in fatalities per 100-pound mass reduction while holding footprint constant. However, as mentioned previously, there are several identifiable safety trends already occurring, or expected to occur in the foreseeable future, that are not accounted for in the study. For example, the two important new safety standards that were discussed above for electronic stability control and head curtain airbags have already been issued and began phasing in after MY 2008. The recent shifts in market shares from pickups and SUVs to cars and CUVs may continue, or grow, if gasoline prices remain high or rise further. The growth in vehicle miles travelled may continue to stagnate if the economy does not improve or gasoline prices remain high. And improvements in driver (and passenger) behavior, such as higher safety belt use rates, may continue. All of these will tend to reduce the absolute number of fatalities in the future. The agencies estimated the overall change in fatalities by calendar year after adjusting for ESC, Side Impact Protection, and other Federal safety standards and behavioral changes projected through this time period. The smaller percent changes in risk from mass reduction (from both the Kahane 2011 preliminary analysis and the Kahane 2012 final analysis), coupled with the reduced number of baseline fatalities, results in smaller absolute increases in fatalities than those predicted in the MYs 2012-2016 rulemaking.

NHTSA examined the impacts of identifiable safety trends over the lifetime of the vehicles produced in each model year from 2007 through 2020. An estimate of these impacts was contained in a previous agency report that examined the impact of both safety standards and behavioral safety trends on fatality rates.[316] In the NPRM analysis, based on these projections, we estimated a 12.6 percent reduction in fatality levels between the 2007 fatality base year and 2020 for the combination of safety standards and behavioral changes anticipated in this study (such as electronic stability control, head-curtain air bags, and increased belt use). See 76 FR at 74959. The estimates derived from applying NHTSA fatality percentages to a baseline of 2007

[316] Blincoe, L. and Shankar, U, "The Impact of Safety Standards and Behavioral Trends on Motor Vehicle Fatality Rates," DOT HS 810 777, January 2007. See Table 5 comparing 2020 to 2007 (37,906/43,363 = 0.874 or a reduction of 12.6% (100%-87.4% = 12.6%). Since 2008 was a recession year, it did not seem appropriate to use that as a baseline, so 2007 was used as the baseline for fatalities in the NPRM. Note that additional improvements may occur between 2020 and 2025. However, since current research only projected the impact of changes through 2020, only those improvements could have been applied to that analysis.

fatalities were multiplied by 0.874 to account for changes that NHTSA believes will take place in passenger car and light truck safety between the 2007 baseline on-road fleet used for this particular safety analysis and year 2020. Using this same methodology, for the final rule analysis, which is based on a 2010 baseline fleet, we estimated a 9.6[317] percent reduction in fatality level between 2010 and 2020 for the anticipated combination of safety standards and behavioral changes that will occur during that time frame. The estimates derived from applying NHTSA fatality percentages to a baseline of 2010 fatalities were multiplied by 0.904 to account for changes that NHTSA believes will take place in passenger car and light truck safety between the 2010 baseline on-road fleet and year 2020.

To estimate the amount of mass reduction to apply in the rulemaking analysis, the agencies considered fleet safety effects for mass reduction. As previously discussed the agencies believe that mass reduction of up to 20 percent is feasible on light trucks, CUVs and minivans, [318] but that less mass reduction should be implemented on other vehicle types to avoid increases in societal fatalities. For the NPRM analysis, NHTSA used the mass reduction levels shown in Table V-108 with the fatality coefficients derived in Kahane 2011 preliminary study.

Table V-108 Mass Reduction Levels to Achieve Safety Neutral Results in the CAFE NPRM Analysis

Absolute %	Subcompact and Subcompact Perf. PC	Compact and Compact Perf. PC	Midsize PC and Midsize Perf. PC	Large PC and Large Perf. PC	Minivan LT	Small, Midsize and Large LT
MR1*	0.0%	2.0%	1.5%	1.5%	1.5%	1.5%
MR2	0.0%	0.0%	5.0%	7.5%	7.5%	7.5%
MR3	0.0%	0.0%	0.0%	10.0%	10.0%	10.0%
MR4	0.0%	0.0%	0.0%	0.0%	15.0%	15.0%
MR5	0.0%	0.0%	0.0%	0.0%	20.0%	20.0%

Notes:

*MR1-MR5: different levels of mass reduction used in CAFE model

In order to find a safety neutral compliance path for use in the agencies' final rulemaking analysis given the coefficients from the Kahane 2012 study, the maximum amount of mass reduction applied in the final rule analysis has been modified from the NPRM levels for compact

317 Blincoe, L. and Shankar, U, "The Impact of Safety Standards and Behavioral Trends on Motor Vehicle Fatality Rates," DOT HS 810 777, January 2007. See Table 5 comparing 2020 to 2010 (37,906/41,945 = 0.904 or a reduction of (100%-90.4% = 9.6%). Note that additional improvements may occur between 2020 and 2025. However, since current research only projected the impact of changes through 2020, only those improvements could be applied to this analysis.

318 When applying mass reduction, NHSTA capped the maximum amount of mass reduction to 20 percent for any individual vehicle class. The 20 percent cap is the maximum amount of mass reduction the agencies believe to be feasible in MYs 2017-2025 time frame.

passenger cars and midsize passenger cars as shown in Table V-109. Specifically, the maximum amount of mass reduction for compact passenger cars and compact performance passenger cars is reduced in the agencies' respective models from 2% as used in the NPRM to 0% in the final rule analysis, while for midsize passenger cars and midsize performance passenger cars, it is reduced from 5% as used in the NPRM to 3.5% in the final rule analysis.

Table V-109 Mass Reduction Levels to Achieve Safety Neutral Results in the Final Rule Analysis

Absolute %	Subcompact and Subcompact Perf. PC	Compact and Compact Perf. PC	Midsize PC and Midsize Perf. PC	Large PC and Large Perf. PC	Minivan LT	Small, Midsize and Large LT
MR1*	0.0%	0.0%	1.5%	1.5%	1.5%	1.5%
MR2	0.0%	0.0%	3.5%	7.5%	7.5%	7.5%
MR3	0.0%	0.0%	0.0%	10.0%	10.0%	10.0%
MR4	0.0%	0.0%	0.0%	0.0%	15.0%	15.0%
MR5	0.0%	0.0%	0.0%	0.0%	20.0%	20.0%

Notes:

*MR1-MR5: different levels of mass reduction used in CAFE model

For the CAFE model, these percentages apply to a vehicle's total weight, including the powertrain. Table V-110 shows the amount of mass reduction in pounds for these percentage mass reduction levels for a typical vehicle weight in each subclass.

Table V-110 Examples of Mass Reduction (in Pounds) for Different Vehicle Subclasses Using the Percentage Information As Defined in Table V-109 for Final Rule Analysis

Mass Reduction (lbs)	Subcom-pact and Subcompact Perf. PC	Compact and Compact Perf. PC	Midsize PC and Midsize Perf. PC	Large PC and Large Perf. PC	Minivan LT	Small LT	Midsize LT	Large LT
Typical Vehicle Weight (lbs)	2795	3359	3725	4110	4250	3702	4260	5366
MR1 (lbs)	0	0	56	62	64	56	64	80
MR2 (lbs)	0	0	130	308	319	278	320	402
MR3 (lbs)	0	0	0	411	425	370	426	537
MR4 (lbs)	0	0	0	0	638	555	639	805
MR5 (lbs)	0	0	0	0	850	740	852	1073

The amounts of mass reduction shown in Table V-109 are for conventional vehicles. The agencies assume that vehicles with hybrid and electric powertrain are heavier than conventional vehicles because of the mass of battery systems. In comparing anecdotal data for HEVs, EPA and NHTSA assume a slight weight increase of 4-5% for HEVs as compared to baseline non-hybridized vehicles. The added weight of the Li-ion pack, motor and other electric hardware were offset partially by the reduced size of the base engine as stated in TSD section 3.4.3.8. We believe that this assumption accurately reflects real-world HEV, PHEV and EV construction. As an example, for a subcompact PHEV with 20 mile range operating on electricity, the agencies assume that to achieve no change in total vehicle mass, it would be necessary to reduce the mass of the glider by 6 percent because of the additional weight of the electrification system. The mass reduction for P/H/EVs can be found Section 3.3.3.9 in the joint TSD and elsewhere in this chapter.

These maximum amounts of mass reduction discussed above were applied in the technology input files for the CAFE model. Within some of the light truck classes, additional limitations were placed on the maximum amount of mass reduction for some of the vehicles based on which Kahane study safety class the vehicles were in, as is explained below. By way of background, NHTSA divides vehicles into classes for purposes of applying technology in the CAFE model in a way that differs from the Kahane study which divides vehicles into classes for purposes of determining safety coefficients. These differences require that the "safety class" coefficients be applied to the appropriate vehicles in the CAFE "technology subclasses." For the reader's reference, for purposes of this final rule, the safety classes and the technology subclasses relate[319] as shown in Table V-111.

Table V-111 Mapping between Safety Classes and Technology Classes

Safety Class	Tech Class
PC (Passenger Car)	Subcompact PC Subcompact Perf. PC Compact PC Compact Perf. PC Midsize PC Midsize Perf. PC Large PC Large Perf. PC
LT (Light Truck)	Small LT Midsize LT Large LT

[319] This is not to say that all vehicles within a technology subclass will necessarily fall within a single safety class – as the chart shows, some technology subclasses are divided among safety classes.

CM (CUV and Minivan)	Subcompact PC Subcompact Perf. PC Large PC Large Perf. PC Minivan Small LT Midsize LT Large LT

In the NPRM analysis, the maximum amount of mass reduction for vehicles that would fall into the light truck safety class and would also fall into the small and midsize light truck technology subclasses was limited to 10%, as shown in Table V-112. In the final rule analysis, in order to find a safety-neutral compliance path using the new safety coefficients, for vehicles in the light truck safety class that also fall into the Small LT technology subclass, mass reduction was limited to a maximum of 1.5%, as shown in Table V-113. For vehicles in the light truck safety class that also fall into the Midsize LT technology subclass, the amount of mass reduction applied depends on vehicle mass: if the vehicle curb weight is greater than or equal to 4,000 pounds, the maximum amount of mass reduction allowed is 7.5%; if the vehicle curb weight is less than 4,000 pounds, the maximum amount is 1.5%. Small and midsize light truck (Small LT and Midsize LT) that fall in the CUV and Minivan (CM) safety class are allowed up to 20% mass reduction. These changes from the NPRM analysis were incorporated in order to maximize the amount of overall fleet mass reduction in a way that achieved a safety neutral result with the updated coefficients from the Kahane 2012 study.

Table V-112. Maximum Amount of Mass Reduction Limits for Light Truck Safety Vehicle Class for the NPRM CAFE Model Analysis

NRPM - 2008 Market Input File	**Tech Class**	
Safety Class	Small LT	Midsize LT
LT	Apply MR3 at 10%	Apply MR3 at 10%
CM*	MR5 (20%)	MR5 (20%)

*CM = CUV and MiniVan

Table V-113. Maximum Amount of Mass Reduction Limits for Light Truck Safety Vehicle Class for the Final Rule CAFE Model Analysis

Final Rule -2008 & 2010 Market Input File	**Tech Class**	
Safety Class	Small LT	Midsize LT

LT	Apply MR1 at 1.5%	Vehicle Weight ≥ 4000, apply MR2 at 7.5%; Vehicle Weight < 4000, apply MR1 at 1.5%.
CM	MR5 (20%)	MR5 (20%)

Table V-114 shows CAFE model results for societal safety for each model year based on the application of the above mass reduction limits.[320] These are the estimated increases or decreases in fatalities over the lifetime of the model year fleet. A positive number means that fatalities are projected to increase, a negative number (indicated by parentheses) means that fatalities are projected to decrease. The results are significantly affected by the mass reduction limitations used in the CAFE model, which allow more mass reduction in the heavy LTVs, CUVs, and minivans than in other vehicles. As the negative coefficients only appear for LTVs greater than 4,594 lbs, CUVs, and minivans, a statistically significant improvement in safety can only occur if more weight is taken out of these vehicles than out of passenger cars or smaller light trucks. Combining passenger car and light truck safety estimates for the final rule results in a decrease in fatalities over the lifetime of the nine model years of MY 2017-2025 of 8 fewer fatalities with the 2010 baseline and of 107 fewer fatalities with the 2008 baseline. Broken up into passenger car and light truck categories, there is an increase of 135 fatalities in passenger cars and a decrease of 143 fatalities in light trucks with the 2010 baseline, and there is an increase of 78 fatalities in passenger cars and a decrease of 185 fatalities in light trucks with the 2010 baseline. NHTSA also analyzed the results for different regulatory alternatives in Chapter IX of this FRIA; the difference in the results by alternative depends upon how much mass reduction is used in that alternative and the types and sizes of vehicles that the mass reduction applies to.

Table V-114 NHTSA Calculated Mass-Safety-Related Fatality Impacts of the Final Rule over the Lifetime of the Vehicles Produced in each Model Year Using 2008 and 2010 Baseline

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 2	7 - 5	13 - 13	12 - 12	18 - 13	19 - 10	23 - 11	22 - 9	19 - 1	135 - 78
Light Trucks	2010 2008	(5) - (5)	(9) - (13)	0 - (17)	(5) - (29)	(18) - (27)	(21) - (27)	(24) - (27)	(30) - (29)	(31) - (11)	(143) - (185)
Total	2010 2008	(2) - (3)	(3) - (8)	13 - (3)	7 - (17)	(1) - (14)	(2) - (17)	(2) - (16)	(8) - (20)	(12) - (10)	(8) - (107)

In its comments, Volkswagen wrote that "Smaller cars and economy models have less potential for mass reduction than larger or more premium vehicles." This is in agreement with the

[320] NHTSA has changed the definitions of a passenger car and light truck for fuel economy purposes between the time of the Kahane 2003 analysis and the NPRM (as well as this final rule). About 1.4 million 2-wheel-drive SUVs have been redefined as passenger cars instead of light trucks. The Kahane 2011 and 2012 analyses continue to use the definitions used in the Kahane 2003 analysis.

agencies' application of mass reduction in the final rule analysis. Volkswagen, furthermore, agreed with the agencies assessment of the weight increase due to HEVs.

How much do the agencies estimate mass reduction will cost in the rulemaking timeframe?

Automakers are currently utilizing various mass reduction techniques across the light-duty vehicle fleet, and will continue to use and in some cases expand these approaches for the 2017 to 2025 time frame. These approaches may include optimized design, geometry, part consolidations, and materials substitution. Unlike the other technologies described in this chapter, mass reduction is potentially more complex in that we cannot define it as a single piece of equipment or hardware change to implement the technological improvement. Mass reduction, depending upon the level of reduction targeted, has the potential to impact nearly every system on the vehicle. Because of this complexity, there are unique challenges to estimating the cost for mass reduction and for demonstrating the feasibility of reducing vehicle mass by a given amount. This section describes the cost estimates used for the agencies' analysis.

In the analysis for the MYs 2012-2016 rulemaking, the agencies assumed a constant cost for mass reduction of $1.32 for each pound reduced up to a mass reduction level of 10 percent (or $1.48/lb using an ICM factor of 1.1 for a low-complexity technology). The $1.32/lb estimate was based on averaging three studies: the 2002 NAS Report, a 2008 study by Sierra Research, and a 2007 study by MIT researchers.[321]

Since the MYs 2012-2016 final rule, the agencies have given further consideration to the cost of mass reduction, and now believe that a cost that varies with the level of mass reduction provides a better estimate. The agencies believe that as the vehicle fleet progresses from lower to higher levels of mass reduction and becomes increasingly optimized for mass and other attributes, the cost for mass reduction will progressively increase. The higher levels of mass reduction may, for example, require applying more advanced materials and technologies than lower levels of mass reduction, which means that the cost of achieving those higher levels may increase accordingly. The unit cost of mass reduction versus the amount of mass reduction might be linear, parabolic, or some other higher order relationship. In the 2017-2025 Notice of Intent, 75 FR 62739 (Oct. 13, 2010), CARB, EPA and NHTSA derived a second order curve based on a study with two vehicle redesigns conducted by Lotus Engineering completed in 2010, such that zero mass

[321] Specifically, the 2002 NAS Report estimated that vehicle weight could be reduced by 5 percent (without engine downsizing) at a cost of $210-$350, which translates into $1.50/lb assuming a 3,800 lb base vehicle and using the midpoint cost; Sierra Research estimated that a 10 percent reduction (with compounding) could be accomplished for $1.01/lb, and MIT researchers estimated that a 14 percent reduction (with no compounding) could be accomplished for $1.36/lb. References for these studies are available in endnotes to Chapter 3 of the TSD for the MYs 2012-2016 final rule.

reduction had zero cost, and the dollars per pound increased with greater levels of mass reduction. Since the publication of the TAR, the agencies have identified a number of additional studies in the literature relating to the costs of vehicle mass reduction, which are discussed below. The studies show that for low or high mass reduction, the costs can range from small cost savings to significant cost increases. The economic costs associated with mass reduction are difficult to determine conclusively due to the broad range of methods employed to achieve mass reduction. The costs on a specific vehicle or component depend on many factors, such as the design, materials selected, raw material price, appropriate manufacturing processes, production volume, component functionality, required engineering and development, etc.

Cost data thus varies widely in the literature. Of the various studies reviewed by the agencies, not all are equal in their original intent, rigor, transparency, or applicability to this regulatory purpose. The individual studies range from complete vehicle redesign to advanced optimization of individual components, and were conducted by researchers with a wide range of experience and background. Some of the studies were literature reviews, while others developed new designs for lighter components or complete lighter vehicles, while yet others built physical components or systems, and conducted testing on those components and systems. Some of the studies focused only on a certain sub-system (which is a building block for the overall vehicle design), while some of them took a systematic approach and re-designed the whole vehicle to achieve the maximum mass reduction and cost reduction. The latter studies typically identified a specific baseline vehicle, and then utilized different engineering approaches and investigated a variety of mass-reduction concepts that could be applied to that vehicle. Some of the differences between studies emanate from the characteristics of the baseline vehicle and its adaptability to the new technology or method, and the cost assumptions relating to the original components and the redesigned components. Assumptions regarding the degree and cost of any associated mass de-compounding can also confound comparisons.[322] Despite this variation in the literature, in actual practice, we believe manufacturers will choose a target mass reduction for a whole vehicle and for each sub-system, and work to find the lowest total cost method to achieve those targets. Such a process would consider numerous primary and secondary cost factors (including

[322] The concept of secondary weight savings or mass compounding (also called mass decompounding) derives from the qualitative understanding that as vehicle weight decreases, other vehicle systems can also decrease in mass while maintaining the original vehicle level of performance and function. For instance, following a primary weight reduction in the vehicle (e.g. Body in White), the designs of some of the other dependent vehicle subsystems (tires, suspensions, brakes, powertrain, body structure) may be redesigned and reduced in mass to account for the overall lighter vehicle. The lighter vehicle is also associated with lighter loads, less friction and drag, and may require less power to be accelerated, and the powertrain may therefore be scaled down in size with a potential for reduced mass, even while maintaining equivalent acceleration performance and functionality. The compounded or secondary mass savings from these additional systems may then drive further mass reductions in the original primary weight reduction (e.g. Body in White). Mass compounding factors found in literature are rough estimates of the secondary mass reduction amount.

engineering, facilities, equipment, tooling, and retraining costs) as well as technological and manufacturing risks.[323]

Regardless of the confidence in specific estimates, the agencies must select a curve that will be applied to the whole fleet that will define the average cost per kg of mass reduction as a function of total percentage of mass reduction. There are many significant challenges that make it difficult for the agencies to establish an estimated cost curve based on the literature, such as the differences in the baselines used in the studies, whether the studies considered platform sharing and powertrain sharing, and other considerations.

The costs for mass reduction employed for the main analysis for this final rule are the same as those in the NPRM. The agencies considered updating cost estimates based on the studies that were underway when the NPRM was issued. Those studies included the EPA/ICCT funded Phase 2 Toyota Venza Low Development project and the NHTSA funded Honda Accord mass reduction project, which are described in the section titled "*What additional studies are the agencies conducting to inform our estimates of mass reduction amounts, cost, and effectiveness?*" However, these studies were in the middle of the peer review process and had not yet been finalized at the time when the inputs for the main analysis for this final rule were required. For the final rule, the agencies decided to continue to use the same costs for mass reduction that were used in the NRPM.

The agencies examined all the studies in Table V-115 including information supplied by manufacturers (during meetings held subsequent to the TAR) when deciding the mass reduction cost estimate used for the proposal, which has been carried forward for this FRM.[324] The agencies considered three major factors in examining these studies. First, whether a study was rigorous in terms of how it evaluates and validates mass reduction from technological and design perspectives. This includes consideration of a study's comprehensiveness, the technical rigor of its methodology, the validation methods employed, and the relevance of the technologies evaluated in the study given our rulemaking time frame. Second, whether a study was rigorous in terms of its estimation of costs, including the completeness and rigor of the methodology, such as whether the study includes data for all categories of direct manufacturing costs, and whether the study presents detailed cost information for both the baseline and the light-weighted design.

[323] We also note that the cost of mass reduction in the CAFE model is quantified on a per pound basis that is a function of the percentage decrease in vehicle mass. We assume that OEMs would find the most cost-effective approach to achieve such a mass reduction. Realistically, this would depend heavily on the baseline vehicle as well as the size and adaptability of the initial design to the new technology. Thus, the CAFE model strives to be realistic in the aggregate while recognizing that the figures proposed for any specific model may be debatable.

[324] The agencies considered confidential cost information provided by OEMs that covered a range of components, systems, designs and materials. Some of these cost estimates are higher than some of the literature studies, and manufacturers provided varying levels of detail on the basis for the costs such as whether mass compounding is included, or whether the costs include markup factors.

And third, the degree of peer review, including if the study is peer-reviewed, and whether it has effectively addressed any critical technical, methodological, and cost issues raised by the peer-review, if this information is available.

Some of the variation may be attributed to the complexity of mass reduction as it is not one single discrete technology and can have direct as well as indirect effects on other systems and components. The 2010 NAS study speaks to this point when it states on page 7-1 that "[t]he term material substitution oversimplifies the complexity of introducing advanced materials, because seldom does one part change without changing others around it." These variations underscore that there is not a unique mass reduction solution as there are many different methods with varying costs for taking mass out of vehicles, and every manufacturer, even every vehicle, could have a different approach depending on the specific vehicle, assembly plant and model year of implementation. The agencies recognize that there are challenges to characterizing the mass reduction plans for the entire future fleet due to the complexity and variety of methods available. So far the agencies have not found any study that addresses how to generalize the mass reduction that is achievable on a single vehicle to the whole fleet.

Table V-115 contains a summary of the data contained in the studies, and the OEM CBI data, which the agencies reviewed. There is a degree of uncertainty associated with comparing the costs from the range of studies in the literature when trying to summarize them in a single table, and we encourage interested stakeholders to carefully review the information in the literature. For some of the cost estimates presented in the papers there are unknowns such as: what year the costs are estimated for, whether mass decompounding (and potential resultant cost savings) was taken into account, and whether mark-ups or indirect costs were included. The agencies tried to normalize the cost estimations from all these studies by converting them to 2009 year dollars, applying mass compounding factor of 1.35 for mass reduction amount more than 10 percent if it has not been applied in the study, and factoring out the RPE specified in the study to derive direct manufacturing costs for comparison. There are some papers that give cost for only component mass reduction, others that have more general subsystem costs and others yet that estimate total vehicle mass reduction costs (which often include and present data at the subsystem level). Other studies have multiple scenarios for different materials, different vehicle structures and mass reduction strategies. Thus, a single study which contains more than one vehicle can be broken down into a range of vehicle types, or at the subsystem level, or even at the component level. While Table V-115 is inclusive of all of the information reviewed by the agencies for the NPRM, for the reasons described above the technical staff for the two agencies applied various different approaches in evaluating the information. The linear mass-cost relationship developed for the proposal is carried forward to this final rule and presented below is the consensus assessment from the two agencies of the appropriate mass cost for this final rule.

Table V-115 Mass Reduction Studies Considered for Estimating Mass Reduction Cost for this FRM

Studies	Cost Year	Cost Information from Studies									
		Mass Reduction [lb]	Compounding Factor	Mass Reduction with Compounding [lb]	Baseline Vehicle Weight [lb]	Mass Reduction w/Compounding [%]	Cost [$]	RPE	Dollar Multiplier to 2009	2009 Direct Manufacturing Cost [$]	Unit Cost of Mass Reduction [$/lb]
Individual Cost Data Points											
AISI, 1998 (ULSAB)	1998	103	1	103	2977	3.5%	-$32	1.0	1.28	-$41	-$0.40
AISI, 2000 (ULSAC)	2000	6	1	6	2977	0.2%	$15	1.0	1.24	$18	$2.99
Austin et al, 2008 (Sierra Research) - ULS Unibody	2008	320	1	320	3200	10.0%	$209	1.61	1.01	$131	$0.41
Austin et al, 2008 (Sierra Research) - AL Unibody	2008	573	1	573	3200	17.9%	$1,805	1.61	1.01	$1,134	$1.98
Austin et al, 2008 (Sierra Research) - ULS BoF	2008	176	1	176	4500	3.9%	$171	1.61	1.01	$107	$0.61
Austin et al, 2008 (Sierra Research) - AL BoF	2008	298	1	298	4500	6.6%	$1,411	1.61	1.01	$887	$2.98
Bull et al, 2008 (Alum Assoc.) - AL BIW	2008	279	1	279	3378	8.3%	$455	1.0	1.01	$460	$1.65
Bull et al, 2008 (Alum Assoc.) - AL Closure	2008	70	1	70	3378	2.1%	$151	1.0	1.01	$153	$2.17
Bull et al, 2008 (Alum Assoc.) - Whole Vehicle	2008	573	1	573	3378	17.0%	$122	1.0	1.03	$126	$0.22
Cheah et al, 2007 (MIT) - 20%	2007	712	1	712	3560	20.0%	$646	1.0	1.03	$667	$0.94
Das, 2008 (ORNL) - AL Body & Panel	2008	637	1	637	3363	19.0%	$180	1.5	1.01	$121	$0.19
Das, 2008 (ORNL) – FRPMC	2008	536	1.0	536	3363	15.9%	-$280	1.5	1.01	-$189	-$0.35
Das, 2009 (ORNL) - CF Body & Panel, AL Chassis	2009	933	1	933	3363	27.7%	$1,490	1.5	1.00	$993	$1.06
Das, 2010 (ORNL) - CF Body & Panel, Mg Chassis	2010	1173	1	1173	3363	34.9%	$373	1.5	1.00	$248	$0.21
EEA, 2007 - Midsize Car - Adv Steel	2007	236	1	236	3350	7.0%	$179	1.0	1.03	$185	$0.78
EEA, 2007 - Midsize Car - Plast/Comp	2007	254	1	254	3350	7.6%	$239	1.0	1.03	$247	$0.97
EEA, 2007 - Midsize Car – Al	2007	586	1.35	791	3350	23.6%	$1,388	1.0	1.03	$1,434	$1.81
EEA, 2007 - Midsize Car – Mg	2007	712	1.35	961	3350	28.7%	$1,508	1.0	1.03	$1,558	$1.62
EEA, 2007 - Light Truck - Adv Steel	2007	422	1	422	4750	8.9%	$291	1.0	1.03	$301	$0.71
EEA, 2007 - Light Truck - Plast/Comp	2007	456	1	456	4750	9.6%	$398	1.0	1.03	$411	$0.90
EEA, 2007 - Light Truck - Al	2007	873	1.35	1179	4750	24.8%	$1,830	1.0	1.03	$1,891	$1.60
EEA, 2007 - Light Truck - Mg	2007	1026	1.35	1385	4750	29.2%	$1,976	1.0	1.03	$2,042	$1.47
Geck et al, 2008 (Ford)	2008	1310	1	1310	5250	25.0%	$500	1.0	1.01	$506	$0.39
Lotus, 2010 – LD	2010	660	1	660	3740	17.6%	-$121	1.0	1.00	-$120	-$0.18
Lotus, 2010 – HD	2010	1217	1	1217	3740	32.5%	$362	1.0	1.00	$360	$0.30
Montalbo et al, 2008 (GM/MIT) - Closure - HSS	2008	25	1	25	4000	0.6%	$10	1.0	1.01	$10	$0.41
Montalbo et al, 2008 (GM/MIT) - Closure - AL	2008	120	1	120	4000	3.0%	$110	1.0	1.01	$111	$0.92
Montalbo et al, 2008 (GM/MIT) - Closure - Mg/AL	2008	139	1	139	4000	3.5%	$110	1.0	1.01	$111	$0.80
Plotkin et al, 2009 (Argonne)	2009	683	1	683	3250	21.0%	$1,300	1.0	1.00	$1,300	$1.90

Table V-115(… Continued) Mass Reduction Studies Considered for Estimating Mass Reduction Cost for this FRM

Studies	Cost Year	Cost Information from Studies									
		Mass Reduction [lb]	Compounding Factor	Mass Reduction with Compounding [lb]	Baseline Vehicle Weight [lb]	Mass Reduction w/Compounding [%]	Cost [$]	RPE	Dollar Multiplier to 2009	2009 Direct Manufacturing Cost [$]	Unit Cost of Mass Reduction [$/lb]
Cost Curves											
NAS, 2010	2010					1.0%					$ 1.41
	2010					2.0%					$ 1.46
	2010					5.0%					$ 1.65
	2010					10.0%					$ 1.52
	2010					20.0%					$ 1.88
OEM1	2010					8.0%					$ 6.00
	2010					9.0%					$ 7.00
	2010					9.5%					$ 8.00
	2010					10.0%					$ 12.00
	2010					11.0%					$ 25.00
OEM2	2010					0.4%					$ -
	2010					0.9%					$ 0.10
	2010					1.9%					$ 0.20
	2010					2.3%					$ 0.33
	2010					2.4%					$ 0.38
	2010					3.1%					$ 0.60
	2010					3.6%					$ 0.76
	2010					4.0%					$ 0.85
	2010					4.1%					$ 0.88
	2010					4.5%					$ 0.98
	2010					4.8%					$ 1.09
	2010					5.0%					$ 1.17
OEM3	2010					4.0%					$ 0.57
	2010					7.5%					$ 1.01
	2010					10.0%					$ 1.51
OEM4	2011					6.9%					$ 0.97
	2011					8.1%					$ 1.02
	2011					16.4%					$ 1.95

EPA and NHTSA scrutinized the various available studies in the literature as well as confidential information provided by several auto firms based on the kinds of factors described above for purposes of estimating the cost of mass-reduction in the 2017-2025 timeframe. We determined that there was wide variation across the studies with respect to costs estimates, applicability to the 2017-2025 time frame, and technical rigor. The mass cost curve that was developed is defined by the following equation and is shown in Figure V-44:

Mass Reduction Direct Manufacturing Cost (DMC) ($/lb)

= $4.36/(%-lb) x Percentage of Mass Reduction Level (%) (2010$)

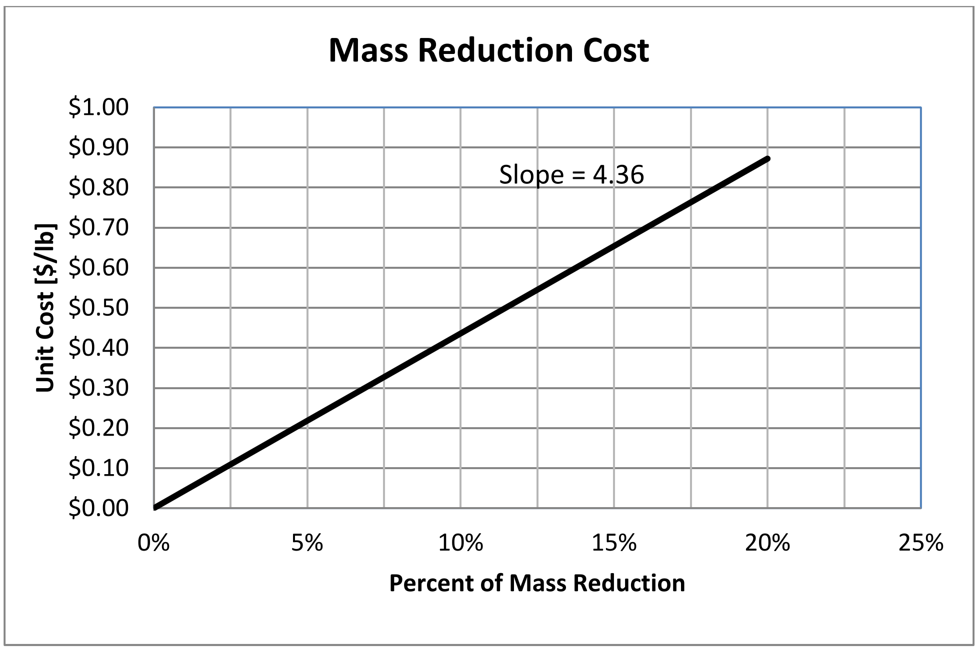

Figure V-44 Mass Reduction Direct Manufacturing Cost ($/lb)

For example, this results in an estimated $175 cost increase for a 10% mass reduction of a 4,000lb vehicle (or $0.44/lb), and a $394 cost increase for 15% reduction on the same vehicle (or $0.66/lb).

As mentioned in the NPRM, due to the wide variation in data used to select this estimated cost curve, the agencies have also conducted cost sensitivity studies in their respective RIAs in both the proposal and final rule using values of +/-40%. The wide variability in the applicability and rigor of the studies also provides justification for continued research in this field.

The agencies consider this DMC to be applicable to the MY2017 and consider mass reduction technology to be on the flat portion of the learning curve in the MY2017-2025 timeframe. To estimate indirect costs for applied mass reduction of up to 15%, the agencies have applied a low complexity ICM of 1.24 through 2018 and 1.19 thereafter. To estimate indirect costs for applied mass reduction of 15% to 25%, the agencies have applied a medium complexity ICM of 1.39 through 2024 and 1.29 thereafter. To estimate indirect costs for applied mass reduction greater than 25%, the agencies believe it is appropriate to apply a high1 complexity ICM of 1.56 through 2024 and 1.35 thereafter.

The agencies sought comment in the draft Joint TSD for the NPRM (p. 210) regarding options for realistically and appropriately assessing the degree of feasible mass reduction for vehicles in the rulemaking timeframe and the total costs to achieve that mass reduction, but got no specific response. The agencies also sought comments on what practical limiting factors need to be considered when considering maximum feasible amount of mass reduction; the degree to which these limiting factors will impact the amount of feasible mass reduction (in terms of the percent of mass reduction); the best method(s) to assess an appropriate and feasible fleet-wide amount mass reduction amount (because each study mainly focuses on a single vehicle); etc. In its comments, VW stated that it "projects full vehicle weight reductions during the time period of this regulation on average in the order of 7-10%." VW noted that this was lower than the agencies' estimates in the NPRM of upwards of 20% mass reduction for large cars and some trucks, which VW stated may exceed cost effective limits. As stated later in this section, the detailed studies sponsored by the agencies suggest that 20% mass reduction is likely feasible for the rulemaking period without using exotic materials or highly advanced technologies. The accompanying detailed cost analysis indicates that the cost of reducing mass by 20% can potentially be economical. The agencies also noted in the NPRM that we expected to refine our estimate of both the amount and the cost of mass reduction between the NPRM and the final rule based on the agencies' ongoing work described a later section, below. As stated before, due to the limited time and the extensive scope of these studies, the agencies did not finish them in time for inclusion in the final rule analysis.

How effective do the agencies estimate that mass reduction will be?

A rule of thumb used by researchers and industry, based on testing and simulation, is that 10 percent reduction in vehicle mass can be expected to generate a 6 to 8 percent increase in fuel economy if the vehicle powertrain and other components are also downsized accordingly.[325] In the analysis for the MYs 2012-2016 final rule, NHTSA and EPA estimated that a 10 percent mass reduction with engine downsizing would result in a 6.5 percent reduction in fuel

[325] NAS 2010, "Assessment of Fuel Economy Technologies for Light-Duty Vehicles." June 2010, page 7-14

consumption while maintaining equivalent vehicle performance (*i.e.*, 0-60 mph time, towing capacity, etc.), consistent with estimates in the 2002 NAS report. For small amounts of mass reduction, such as the 1.5 percent used at vehicle refresh in NHTSA's modeling, no engine downsizing was used, so a 10 percent mass reduction without engine downsizing was assumed to result in a 3.5 percent reduction in fuel consumption. In this FRM, both agencies have chosen to use the effectiveness value for mass reduction from EPA's lumped parameter model to maintain consistency. EPA's lumped parameter model-estimated mass reduction effectiveness is based on a simulation model developed by Ricardo, Inc. under contract to EPA. The 2011 Ricardo simulation results show an effectiveness of 5.1 percent for every 10 percent reduction in mass. NHTSA has assumed that for mass reduction amounts less than 10 percent, the effectiveness is 3.5 percent. For mass reduction greater than 10 percent, NHTSA estimates the effectiveness is 5.1 percent in order to avoid double counting benefits – because the effectiveness of engine downsizing is included in the effectiveness of the engine decision tree when applying engine downsizing, it should appropriately be removed from the mass reduction effectiveness value in the mass reduction decision tree. EPA applies an effectiveness of 5.1 percent for every 10 percent mass reduction, and this scales linearly from 0 percent mass reduction up to the maximum applied mass reduction for any given vehicle, which in this final rule is never larger than 20 percent.

What additional studies are the agencies conducting to inform our estimates of mass reduction amounts, cost, and effectiveness?

In the MYs 2012-2016 final rule, the agencies stated that there are several areas concerning vehicle mass reduction and vehicle safety on which the agencies will focus their research efforts and undertake further study. The following vehicle level projects focus on the goals stated in the MYs 2012-2016 final rule, which include determining the maximum potential for mass reduction in the MY 2017-2025 timeframe by using advanced materials and improved designs while continuing to meeting safety regulations and voluntary guidelines and while maintaining all aspects of vehicle functionality. The fourth study investigates the effects of resultant study designs on fleet safety by evaluating crash performance with objects and other vehicles of different size and mass.

1. NHTSA sponsored mass reduction study on a Honda Accord
2. EPA sponsored mass reduction study on a Toyota Venza (Phase 2 Low Development)
3. California Air Resources Board mass reduction study on a Toyota Venza (Phase 2 High Development)
4. NHTSA fleet-wide simulation study: crash analysis using the resultant designs from the studies 1-3 with objects and the design models of other vehicles with different size and mass.

Due to the extensive scope of work for these studies and tight time schedule, some of the studies were finished, but peer reviews and response to peer reviews were not completed in time to enable the results to inform the final rule. We note, however, that the intermediate results from the mass reduction studies would corroborate the level of feasible amount of mass reduction the agencies chose to apply in the NPRM and FRM analyses. Rulemaking modeling results show that the costs for mass reduction are not sensitive to the cost curve of the rulemaking. In the NPRM, EPA found that a +/- 40% change in the cost of mass reduction had very little impact on the cost of the program. This is largely because of safety restraints imposed in the amount of mass reduction selected for the various vehicle classes primarily drive the penetration rates of the technology, rather than the relative cost-effectiveness of the technology itself.

The following sections describe the status and results of the studies sponsored by the agencies.

NHTSA Sponsored Mass Reduction Study

BACKGROUND: NHTSA awarded a contract in December 2010 to Electricore, with EDAG and George Washington University (GWU) as subcontractors, to study the maximum feasible amount of mass reduction for a mid-size car – specifically, a Honda Accord - while keeping the vehicle functionality the same as the baseline vehicle. The Electricore/EDAG/GWU project team was charged with maximizing the amount of mass reduction using technologies that are considered feasible for production of 200,000 units per year during the time frame of this rulemaking while maintaining retail price in parity (within ±10%) with the baseline vehicle. In addition, all designs, materials, technologies and manufacturing processes must be realistically projected to be feasible for industry-wide application in MYs 2017-2025. The project focused on mass reduction and allowed powertrain downsizing, however alternative powertrains, such as diesels, HEVs and EVs, were not to be considered.

MATERIAL AND TECHNOLOGY SELECTION: For vehicle redesigns, OEMs normally select technologies, materials and manufacturing processes that are currently in use on existing vehicle platforms or planned to be in use on future vehicle platforms. The use of the same or similar technologies, materials and manufacturing processes helps maintain or improve component and vehicle reliability, manufacturability and cost. New materials, technologies and processes are often introduced in low-volume, high price vehicles first and then migrate to high production volume vehicle lines over time. This significantly reduces the risk to OEMs associated with implementing new technologies. Recognizing this when selecting materials, technologies and manufacturing processes, the Electricore/EDAG/GWU team utilized, to the extent possible, only those materials, technologies and design which are currently used or planned to be introduced in the near term (MY 2012-2015) on low-volume production vehicles. The recommended materials (Advanced High Strength Steels, Aluminum, Magnesium and Plastics) manufacturing processes (Stamping, Hot Stamping, Die Casting, Extrusions, Roll Forming) and assembly methods (Spot welding, Laser welding and Adhesive Bonding) are at present used, some to a lesser degree than others. These technologies can be fully developed within the normal product design cycle using the current design and development methods. The process parameters for manufacturing with Advanced High Strength Steels can be supported by computer simulation. This approach minimized those material and technology options which would likely be overly aggressive or unrealistic to implement in mass production in model years 2017-2025.

ENGINEERING APPROACH: The Electricore/EDAG/GWU team took a “clean sheet of paper” approach and adopted collaborative design, engineering and CAE process with built-in feedback loops to incorporate results and outcomes from each of the design steps into the overall vehicle design and analysis. The team tore down and benchmarked a 2011 Honda Accord and then undertook a series of baselines, noting the designs, materials, technologies and overall design optimization level of the baseline vehicle. Vehicle performance, safety simulation and cost analyses were run in parallel to the design study to help ensure that the design decisions for the concept vehicle would be informed by a well-documented baseline, thus enabling the resultant design to meet the defined project criteria.

While working within the constraint of maintaining the baseline Honda Accord’s exterior size and shape, the body structure was first redesigned using topology optimization with six load cases including bending stiffness, torsion stiffness, IIHS frontal impact, IIHS side impact, FMVSS pole impact, FMVSS rear impact and FMVSS roof crush cases. The load paths from topology optimization were analyzed and interpreted by technical experts and the results were then fed into low fidelity 3G (Gauge, Grade and Geometry) optimization programs to further optimize for material properties, material thicknesses and cross-sectional shapes while trying to achieve the maximum amount of mass reduction. The Electricore/EDAG/GWU team carefully reviewed the optimization results and built detailed CAD/CAE models for the body structure, closures, bumpers, suspension, and instrumentation panel. The vehicle designs were also carefully reviewed by manufacturing technical experts to ensure that they could be manufactured at high volume production rates. Detailed manufacturing layouts were created and were later used to estimate costs.

Multiple materials were used for this study. The body structure was redesigned using a significant amount of advanced high strength steel (AHSS). The closure and suspension were designed using a significant amount of aluminum. Magnesium was used for the instrumentation cross-car beam. A limited amount of composite material was used for the seat structure. Electricore and its sub-contractors consulted industry leaders and experts for each component and sub-system when deciding which mass reduction technologies were feasible.

DESIGN AND FUNCTION VALIDATION: In order to ensure that the light weighted vehicle had the same functionality as the baseline vehicle, Electricore and its sub-contractors used the CAD/CAE/powertrain models and conducted simulation modeling. This is the first mass reduction study that has been released publicly that includes such a broad array of vehicle simulation modeling analyses to assess vehicle functionality and performance relative to these critical attributes. These significant additional analyses provide greater confidence that the designs employed in this study are more feasible for production implementation than a study without these analyses, although the agency notes that significantly more testing and validation work is required to refine and finalize a design for production.

> Safety: Safety performance of the light-weighted design is compared to the safety rating of the baseline MY2011 Honda Accord for seven consumer information and federal safety crash tests using LS-DYNA[326]. These seven tests are NCAP frontal test, NCAP lateral MDB test, NCAP lateral pole test, IIHS roof crush, IIHS lateral MDB, IIHS front offset test, and FMVSS No. 301 rear impact tests. All tests achieved safety performance equivalent to MY 2011 Honda Accord when comparing crash pulse and passenger compartment intrusion levels, with no damage to the fuel tank. This study does not include restraint systems and dummy, which would be part of NHTSA's fleet simulation study.
>
> Body Stiffness/ Ride and Handling/NVH: Vehicle body torsional and bending stiffness are signatures for the vehicle structure performance. Higher stiffness is generally associated with a refined ride and handling qualities. The baseline vehicle body structure underwent testing for normal modes of vibration, and torsion and bending stiffness. A detailed FEA model of the light-weighted structure was created and analyzed using the MSC/NASTRAN simulation. The torsional stiffness of the light-weighted design is 30% higher than the baseline vehicle while the bending stiffness is 40% higher. The normal mode frequency test results for the light-weighted body structure, which represents vehicle dynamic stiffness, also are within 2.3% of the targets. These stiffness and modes results show that the light-weighted design will have improved ride and handling and improved NVH performance comparing to a vehicle with lower stiffness.
>
> Vehicle Ride and Handling: In the light-weighted design, the front suspension is redesigned using a MacPherson strut instead of the heavier double wishbone used in the baseline vehicle. Vehicle ride and handling is evaluated using MSC/ADAMS[327] modeling on five maneuvers, fish-hook test, double lane change maneuver, pothole test, 0.7G constant radius turn test and 0.8G forward braking test. The results from the fish-hook test show that the light-weighted vehicle can achieve a five-star rating for rollover, same as the baseline vehicle. The double lane change maneuver tests according to the ISO standard show that the chosen suspension geometry and vehicle parameters of the light-weighted design are within acceptable range for safe high speed maneuvers. These

[326] LS-DYNA is a software developed by Livermore Software Technologies Corporation used widely by industry and researchers to perform highly non-linear transient finite element analysis.
[327] MSC/ADAMS: Macneal-Schwendler Corporation/Automatic Dynamic Analysis of Mechanical Systems.

simulations are performed to further validate the chosen light-weighted front suspension design.

Durability: There are two types of durability, stress related and corrosion related. Stress related durability for the light-weighted vehicle is evaluated using strain-based analysis based on pot hole, 0.8G forward braking and 0.7G cornering road load cases using an ADAMS model. Results from the simulation show that the life of the light-weighted vehicle body structure exceeds the targets. Although timing and funding did not allow corrosion testing to be conducted, the Electricore/EDAG/GWU team considered the properties of materials used and the location and the functionality of the components to avoid potential issues with corrosion.

Powertrain Performance: The powertrain of the light-weighted vehicle is downsized from a 2.4L naturally aspirated engine to a 1.8L naturally aspirated engine to maintain the same vehicle acceleration and towing compared to the baseline 2011 Honda Accord. The powertrain simulation tool PSAT[328] is used to verify and validate the light-weighted vehicle for fuel economy and powertrain performance. The light-weighted vehicle with the 1.8L NA engine will have 32 mpg fuel economy with comparable 0-30 mph time, 0-60 mph time, quarter mile time, gradability and maximum speed at grade. The only metrics that the light-weighted vehicle performs less than the baseline vehicle is vehicle maximum speed (127 mph for the baseline Accord and 112 mph for the light-weighted design), which the Electricore/EDAG/GWU team and NHTSA believe is acceptable. As a result of the improved fuel economy, the fuel tank for the light-weighted vehicle can be reduced from 18.5 gallons to 15.8 gallons with the same driving range, which further reduced vehicle weight both by reducing fuel tank mass and the mass of fuel carried by the vehicle.

Manufacturability: The manufacturability of all proposed body structure panels were then assessed using simulation tools, which included HYPER-FORM for stamping parts, and other single step process simulation tools for parts manufactured using other methods, such as hot stamping for B-pillar.

COST ANALYSIS; A detailed cost analysis for the light weighted design and cost estimates for alternative design options were also conducted. For OEM-manufactured parts, a detailed cost model was built based on a Technical Cost Modeling (TCM) approach developed by the

[328] PSAT is a plug-and-play architecture software that allows the user to build and evaluate a vehicle's fuel economy and powertrain performance under varying load conditions and drive cycles. It uses MATLAB in a Simulink environment to record data, calculate and input powertrain requirements based on driver demand and current powertrain values. The software is sponsored by the U.S. Department of Energy and developed by Argonne National Laboratory (ANL). http://www.transportation.anl.gov/modeling_simulation/PSAT/index.html

Massachusetts Institute of Technology (MIT) Materials Systems Laboratory's research[329] for estimating the manufacturing costs of OEM parts. The costs were broken down into each of the operations involved in the manufacturing, such as for a sheet metal part production by starting from blanking the steel coil, until the final operation to fabricate the component. Total costs were then categorized into fixed cost, such as tooling, equipment, and facilities; and variable costs, such as labor, material, energy, and maintenance. These costs were assessed through an interactive process between the product designer, manufacturing engineers and cost analysts. For OEM-purchased parts, the costs were estimated by consultation with experienced cost analysts and Tier 1 suppliers. Forty-one concise spreadsheets are created for both the baseline vehicle and the light-weighted design in the cost model to calculate both the manufacturing and assembly costs.

FINAL RESULTS: To achieve the same vehicle performance as the baseline vehicle, the size of the engine for the light-weighted vehicle was proportionally reduced from 2.4L-177 HP to 1.8L-140HP. Overall the complete light weight vehicle achieved a total weight savings of 22 percent (332 kg) relative to the baseline vehicle (1480 kg) at an incremental cost increase of $319 or $0.96 per kg. Without the mass and cost reduction allowance for the powertrain (including engine, transmission, fuel system, exhaust system and fuel) the mass saving for the 'glider' is 24 percent (264 kg) at mass saving cost premium of $1.63 per kg of mass saving. The Electricore/EDAG/GWU team also developed a cost curve to cover a range of mass reduction levels from 0% to 28% for both the full vehicle with engine downsizing and for the glider only. When developing the cost curves, the project team used data that were developed in the study to derive a mass compounding factor (secondary mass reduction/total mass reduction), which was determined to be 0.7. The cost curves are shown in Figure V-45 and Figure V-46.

[329] Frank Field, Randolph Kirchain and Richard Roth, Process cost modeling: Strategic engineering and economic evaluation of materials technologies, JOM Journal of the Minerals, Metals and Materials Society, Volume 59, Number 10, 21-32. *Available at* http://msl.mit.edu/publications/Field_KirchainCM_StratEvalMatls.pdf (last accessed Jun. 10, 2012).

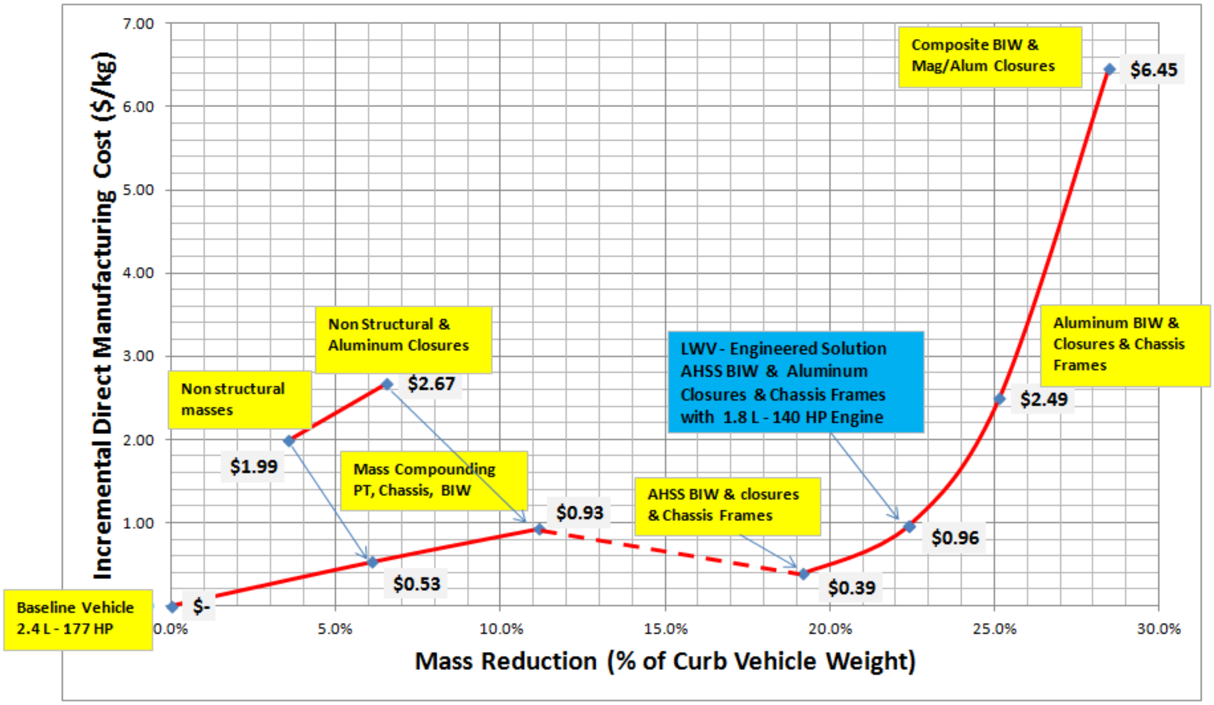

Figure V-45 Mass Reduction Cost with Allowance for Powertrain Downsizing

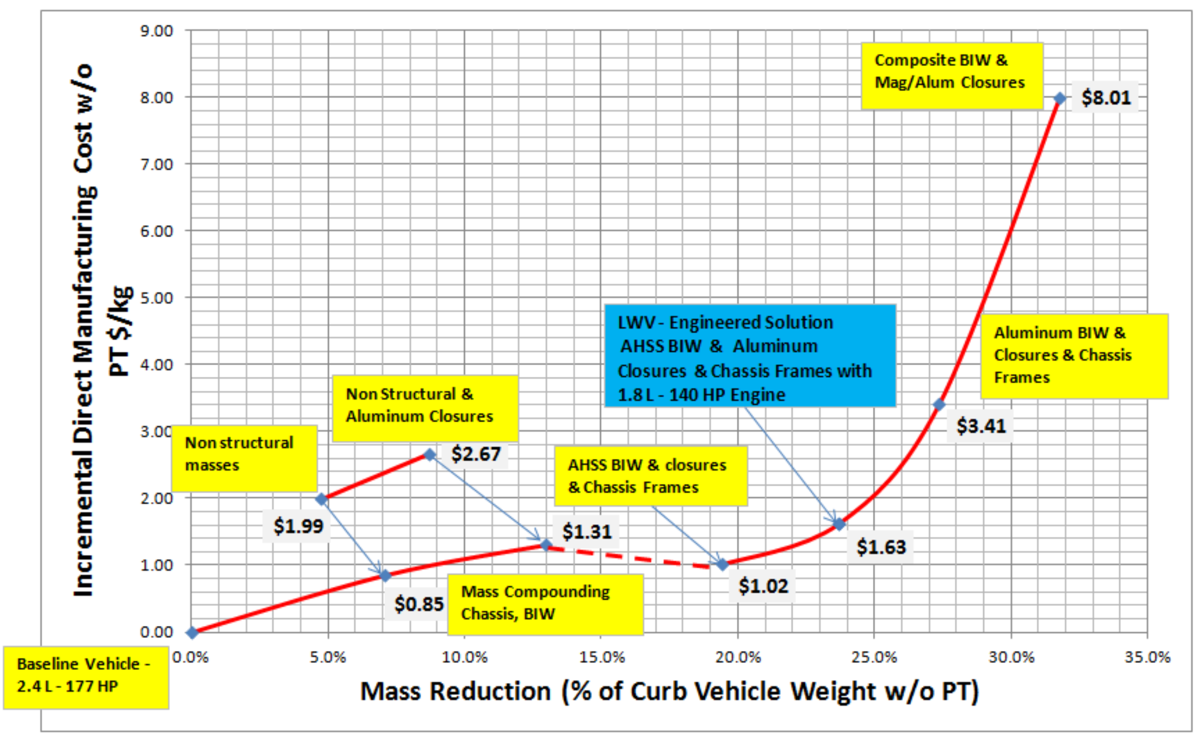

Figure V-46. Mass Reduction Cost for the Glider Only

PEER REVIEW: The study has been peer reviewed by three technical experts from industry, academia and a DOE national lab. In the peer reviewer charge letter, the agency asked the peer reviewers to comment on the following five specific items as well as any other potential areas for comments.

- Assumptions and data sources
- Vehicle design and optimization methodology and its rigorousness
- Vehicle functionality and crashworthiness testing methodological rigor
- Vehicle manufacturing cost methodology and its rigorousness
- Conclusions and findings

Comments from peer reviewers were generally positive. The peer reviewers concurred with the methodologies employed in the study and the technologies applied to the light-weighted design, although one peer reviewer commented that not enough composite materials were used in the design. One peer reviewer stated in his comments that “the main findings appear to be based on sound economic and engineering principles.” The peer reviewers stated that the cost estimates developed in the study, particularly based on the TCM model, seem to be reasonable, with one peer reviewer commenting the final cost is on the lower side and another commenting it on the higher side. All three peer reviewers looked into the details of the CAE and cost modeling. One significant concern identified in the peer review was whether the light-weighted vehicle maintained the same performance level in the NCAP side MDB test. In response to that concern, the Electricore/EDAG/GWU team conducted simulation testing and revised the B-pillar design, increasing the gauge for the steel for better performance. Because NCAP only measures injuries to dummies and the crash performance of the light-weighted design is based on the vehicle center of gravity crash pulse level, B-pillar velocity and passenger compartment and intrusion, to assess correlation of the model performance to the baseline vehicle, NHTSA asked a contractor who performs NHTSA’s NCAP testing to take additional measurements of the interior intrusion for the 2011 baseline Honda Accord. The updated design and the Honda Accord test data showed similar intrusion results for both NCAP and IIHS side impact tests, and those results support that the light-weighted design could possibly achieve similar NCAP and IIHS ratings, especially when the structure design is fine-tuned with the restraint system design, which NHTSA will study in the fleet simulation study described later on in this section. For other peer review comments, the Electricore/EDAG/GWU team addressed the comments fully in the report and also composed a response to peer review comment document, which is included at the end of the report. The final report[330], CAE model and cost model, and peer review comments[331] are available in Docket No. NHTSA-2010-0131 and can also be found on NHTSA’s website[332].

[330] Electricore/EDAG/GWU, “Mass Reduction for Light-Duty Vehicles for Model Years 2017-2025”, NHTSA Docket NHTSA-2010-0131.
[331] “Peer Review for ‘Mass Reduction for Light-Duty Vehicles for Model Year 2017-2025’”, NHTSA Docket NHTSA-2010-0131.
[332] http://www.nhtsa.gov/fuel-economy

EPA Sponsored Mass Reduction Study

EPA, along with ICCT, funded a contract with FEV, with subcontractors EDAG (CAE modeling) and Munro & Associates, Inc. (component technology research) to study the feasibility, safety and cost of 20% mass reduction on a 2017-2020 production ready mid-size crossover utility vehicle (CUV) specifically, a Toyota Venza while maintaining cost parity or reduction. The EPA report is entitled "*Light-Duty Vehicle Mass-Reduction and Cost Analysis – Midsize Crossover Utility Vehicle*"[333]. This study is a Phase 2 study of the low development design in the 2010 Lotus Engineering study "An Assessment of Mass Reduction Opportunities for a 2017-2020 Model Year Vehicle Program"[334], herein described as "Phase 1."

LOTUS PHASE 1 STUDY: The original 2009/2010 Phase 1 effort by Lotus Engineering was funded by Energy Foundation and ICCT to generate a technical paper which would identify potential mass reduction opportunities for a selected vehicle representing the crossover utility segment, a 2009 Toyota Venza. Lotus examined mass reduction for two scenarios – a low development (20% MR and 2017 production with technology readiness of 2014) and high development (40% MR and 2020 production with technology readiness of 2017). Lotus disassembled a 2009 Toyota Venza and created a bill of materials (BOM) with all components. Lotus then investigated emerging/current technologies and opportunities for mass reduction. The report included the BOM for full vehicle, systems, sub-systems and components as well as recommendations for next steps. The potential mass reduction for the low development design includes material changes to portions of the body in white (underfloor and body, roof, body side, etc.), seats, console, trim, brakes, etc. The original powertrain was changed to a hybrid configuration. The Phase 1 project achieved 19% (without the powertrain) at 99% of original cost at full phase-in after peer review comments taken into consideration.[335] This was calculated to be -$0.45/kg utilizing information from Lotus.

The Lotus Phase 1 study created a good foundation for the next step of analyses of CAE modeling for safety evaluations and in-depth costing (these steps were not within the scope of the Phase 1 study) as noted by the peer reviewer recommendations[336]. The study was peer reviewed. Mr. Sujit Das, of ORNL and an author of several reports on mass reduction, reported that the mass reduction opportunities were reasonable and likely to meet the stated objectives. Mr. Das also recommended using a consistent cost methodology. Dr. Malen, a professor at the

[333] FEV, "*Light-Duty Vehicle Mass-Reduction and Cost Analysis – Midsize Crossover Utility Vehicle.*" July 2012, EPA Docket: EPA-HQ-OAR-2010-0799.
[334] Systems Research and Application Corporation, "*Peer Review of Demonstrating the Safety and Crashworthiness of a 2020 Model-Year, Mass-Reduced Crossover Vehicle (Lotus Phase 2 Report)*", February 2012, EPA docket: EPA-HQ-OAR-2010-0799.
[335] Cost estimates were given in percentages – no actual cost analysis was presented for it was outside the scope of the study, though costs were estimated by the agency based on the report.
[336] RTI International,"Peer Review of Lotus Engineering Vehicle Mass Reduction Study" EPA-HQ-OAR-2010-0799-0710, November 2010.

University of Michigan, reported the mass reduction opportunities were reasonable and likely to meet the stated objectives and also recommended a data driven methodology that can be examined at each step of the analysis[337].

OBJECTIVES OF EPA PHASE 2 STUDY: Objectives for the EPA Phase 2 study included the creation of CAE body in white (BIW) models which could be used to analyze body stiffness, NVH modal characteristics and crash (FMVSS and NCAP) performance and inclusion of a more rigorous cost analysis including tooling and piece cost. In addition, EPA expanded the scope of the work to include an updated look (2012) at all of the mass reduction technologies and techniques so that FEV was not limited to only the ideas originally generated by Lotus which were determined in 2009. As part of this EPA Phase 2 study, FEV/EDAG analyzed the BIW ideas from Lotus's Phase 1 study through CAE modeling and FEV included the technologies for mass reduction with the information provided in the Phase 1 Lotus Engineering report for the low development scenario.

Similar to Lotus Phase 1 study, the EPA Phase 2 study begins with vehicle tear down and BOM development. FEV and its subcontractors tore down a MY 2010 Toyota Venza in order to create a BOM as well as understand the production methods for each component. Each component and sub-system chosen for mass reduction was scaled to the dimensions of the baseline vehicle, trying to maximize the amount of mass reduction with cost effective technologies and techniques that are considered feasible and manufacturable in high volumes in MY2017. FEV, in coordination with EDAG, constructed detailed CAD/CAE vehicle models of the body structure to account for other vehicle components, to evaluate vehicle safety. In addition to simulating various FMVSS and IIHS crash tests with the CAE model, the BIW CAE was evaluated for overall torsion mode, overall lateral bending mode, rear end match boxing mode and overall vertical bending rear end mode in addition to overall and bending and torsional stiffness. An in-depth cost analysis was also completed utilizing several cost models including the one described in the NHTSA project above.

Results for the EPA Phase 2 study of the 1710kg 2010 Toyota Venza include a 18% mass reduction (with powertrain) at -\$0.49/kg cost (cost savings). While the results for \$/kg appear similar between the Phase 1 Lotus study (without powertrain, 19% mass reduction at -\$0.44/kg), it should be noted that each study took slightly different approaches. The Phase 1 study included mass reduction of every system except the powertrain. The EPA Phase 2 study focused on the vehicle as a whole (including all systems), but also included the powertrain.

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[337] RTI International,"*Peer Review of Lotus Engineering Vehicle Mass Reduction Study*" EPA-HQ-OAR-2010-0799-0710, November 2010.

VERIFICATION OF THE LOTUS BIW DESIGN FOR NVH: The study started with a teardown of the 2010 Toyota Venza whose parts were then scanned for finite element analysis (FEA). Over 140 coupons from the BIW and several from the closures were also sent out to laboratories for verification of material properties for the model. The model's results for static bending, static torsion, and modal frequency simulations (NVH) were obtained and compared to actual results from a Toyota Venza vehicle[338]. After confirming that the results were within acceptable limits,[339] this model was then modified to create a light-weighted vehicle model based on the Lotus (phase 1) design and then the tests for NVH were compared. The results revealed that the original Lotus design required additional development to meet the acceptability criteria. EPA working with EDAG developed a new BIW using a similar material substitution methodology as Lotus, which was to exchange materials in parts of the existing design and not redesign the entire vehicle from scratch. After several iterations, the new EPA phase 2 design fell within the project's design criteria, i.e.it had NVH results similar to the baseline vehicle.

UPDATE RESEARCH ON MASS REDUCTION TECHNOLOGIES: FEV and Munro created a BOM based on the teardown analysis. Mass reduction technology review was conducted at the system and sub-system level. The staff at FEV and Munro consists of experts from the automotive industry and discussion also included outside venders of mass reduction technologies. Forty of the 150 Lotus Phase 1 concepts were included in the final mass reduction technology selection.

SAFETY FEASIBILITY: Two models, the baseline vehicle and the light-weighted design, were developed and analyzed for safety employing a number of FMVSS and EURO NCAP protocols.[340] Once EDAG confirmed the crash performance of the CAE baseline model was comparable to the NHTSA 2009 Toyota Venza vehicle crash results, the light weighted CAE model design was developed. The light-weighted CAE model was developed by applying mass reduction ideas developed by EDAG (for BIW and closures) and FEV/Munro (remaining vehicle systems[341]). Potential compliance with safety and performance of the light weighted CAE model in FMVSS and IIHS tests was inferred using quantitative measurements of vehicle delta velocity and intrusion.

COST ANALYSIS: The development of a bill of materials (BOM), on systems and sub-systems by FEV and Munro, was the basis for the cost analysis. This methodology is consistent with the peer reviewed approach described earlier in this chapter. The cost for the mass reduced

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[338] Note that the actual vehicle had a panoramic roof in its design and so the model was modified for this design and results were compared. The model was then re-fit with the full roof and the analysis continued.
[339] The goals for the Phase 1 report include the maintenance of utility/performance including NVH and this was interpreted as being within 5% of the modeled baseline value for static bending, static torsion, and modal frequency.
[340] FMVSS includes 208 Flat Frontal, 214 Side Impact, 301 Rear Impact, 216a Roof Crush and EURO NCAP includes ODB frontal crash -Euro NCAP/IIHS 40% offset.
[341] – for which a center of gravity (CG) was determined to represent all other components.

technologies were developed by determining the difference in cost for those new components compared to the old, and under the assumption of production scales of 200,000 units (appropriate for the Venza global production). FEV and Munro developed several thousand cost spreadsheets as the basis for the cost analyses for the mass reduction technologies and the BIW and closures. Costs include manufacturing (material, labor, burden) and markup (end item scrap, Sales, General and Administrative (SG&A), Profit, Engineering, Development and Testing (ED&T) and Research and Development (R&D)). A separate tooling cost analysis was also performed and at 18% mass reduction calculated a $0.05/kg for tooling. The cost analysis of the BIW and closures were done by EDAG and were based on a Technical Cost Modeling (TCM) approach developed by the Massachusetts Institute of Technology (MIT) Materials Systems Laboratory's research[342].

RESULTS: The light-weighting effort achieved an 18% mass reduction (with downsized powertrain[343]) on the base 1710 kg Toyota Venza at a cost of $-0.49/kg (a cost savings) which includes tooling (cost increase of $0.05/kg). A cost curve was developed to show the estimated $/kg over a variety of mass reduction levels utilizing the subset of technologies and techniques developed throughout the study (see Figure V-47). The two curves represent non-compounded mass reduction technologies ("primary") and compounded mass reduction scenario (a total of "primary" and "secondary"). These curves were determined by reviewing the BOM part by part and identifying the parts within systems that would benefit from mass reduction and be able to utilize mass compounding. It is important to note that the potential for secondary mass reduction was evaluated by applying the mass compounding ratio at many points along the whole cost curve. The cost curve was used to determine a value for the average cost per kilogram of cumulative mass reduction (in terms of $/kg for mass reduction at a specific mass reduction level).

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[342] Frank Field, Randolph Kirchain and Richard Roth, Process cost modeling: Strategic engineering and economic evaluation of materials technologies, JOM Journal of the Minerals, Metals and Materials Society, Volume 59, Number 10, 21-32. *Available at* http://msl.mit.edu/pubs/docs/Field_KirchainCM_StratEvalMatls.pdf (last accessed Aug. 22, 2011).

[343] The engine was downsized and dowweighted, however the number of cylinders remained the same and it remained naturally aspirated.

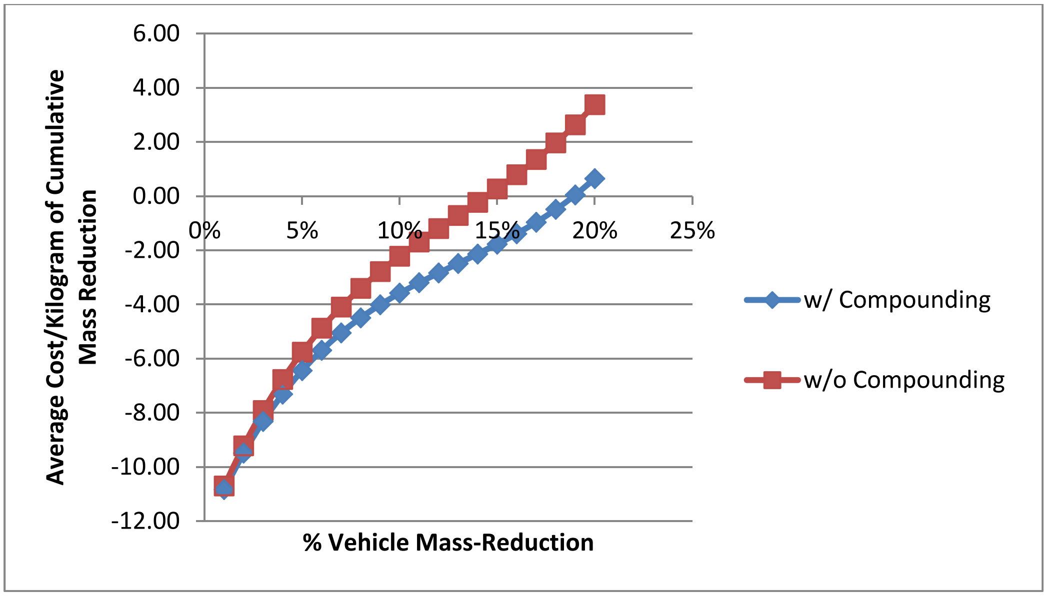

Figure V-47 Cost Curve for the 2010 Toyota Venza – EPA Study (FEV/EDAG/Munro)

PEER REVIEW: The peer review comments for this study were generally positive and concurred with the ideas and methodology of the EPA study. The documents for the peer review can be found in EPA docket EPA-HQ-OAR-2010-0799. After accounting for peer review comments to the draft report, mass reduction decreased by 0.5% and though some of the adjustments resulted in a cost savings, the overall cost increased slightly. Changes to the BIW CAE models resulted in minimal differences.

There were many positive comments about the report. While the report included mass reduction and cost analyses for several hundred items, there were some concerns identified in the peer review comments that influenced the overall amount of mass reduction and the cost. These included: 1) engine magnesium block cost, 2) the (brake) rotor design, 3) aluminum hollow suspension stabilizer bar, 4) the closure aluminum material cost.

There were several areas where peer reviewers suggested changes that did not impact percent mass reduction or cost. First, more information was included to better describe the wheel mass technology. Second the BIW models were updated to eliminate the inconsistencies in material assignments - revising the number of through thickness integration points for the shell elements and correcting the asymmetrical thickness assignments. Finally, the baseline and optimized BIW models were further refined to include definitions of welding properties, transverse shear scale factor, element type, element formulation and material failure criteria. Based on these updates the crash models were rerun and the results included in the final report.

California Air Resources Board Sponsored Mass Reduction Study

The California Air Resources Board (CARB) funded a study with Lotus Engineering to further develop the high development design from Lotus' 2010 Toyota Venza work ("Phase 1"). The CARB-sponsored Lotus "Phase 2" study provides the updated design, crash simulation results, detailed costing, and analysis of the manufacturing feasibility of the BIW and closures. Based on the findings of the safety validation work, Lotus made revisions to strengthen the vehicle structure through the use of a more aluminum-intensive BIW (and with less magnesium). In addition to the increased use of advanced materials, the new design by Lotus included a number of instances in which multiple parts were integrated, resulting in a reduction in the number of manufactured parts in the lightweight BIW. The Phase 2 study reports that the number of parts in the BIW was reduced from greater than 400 to less than 170. The BIW was analyzed for torsional stiffness and crash test safety with Computer-Aided Engineering (CAE). The new design's torsional stiffness was 32.9 kNm/deg, which is higher than the baseline vehicle and comparable to more performance-oriented models. The analysis included validation of the lightweight vehicle design for standard FMVSS/IIHS front, side, rear, offset, roof, intrusion, and seatbelt safety tests. Crash tests simulated in CAE showed results that were listed as acceptable for all crash tests analyzed.

The cost analysis for the Phase 2 lightweight design involved new piece, tooling, and assembly work on the BIW and closures, and the technologies and costs for the non-BIW components were carried over from the Phase 1 work. The Lotus design achieved a 37% (141 kg) mass reduction in the body structure, a 38% (484kg) mass reduction in the vehicle excluding the powertrain, and a 32% (537 kg) mass reduction in the entire vehicle including the powertrain. The Phase 2 report included an investigation into the manufacturing and assembly processes to assess whether the low mass aluminum BIW design can feasibly and cost-effectively be constructed for 60,000 units. Lotus found that the assembly and tooling cost savings, due to the lower number of BIW parts, relative to the baseline Venza partially offset the 60% increase in piece costs for the BIW for a resulting BIW cost increase of $239. Accounting for all of the other systems (excluding the powertrain) using the results from Phase I study, the impact is a cost savings of $476 for 484 kg reduced, or -$0.98/kg. For the complete vehicle with powertrain (hybrid powertrain), the overall cost savings for the whole vehicle including powertrain is $318 for 537 kg reduced, or -$0.59/kg. The hybrid engine was downsized from 120hp to 100hp and the corresponding hybrid system related components were removed or exchanged for a minimal change in overall mass. The report was peer reviewed by a cross section of experts, from academia, a DOE lab, DOE and an aluminum industry representative and the peer review comments are currently being addressed by Lotus and will be available by the final rulemaking. The documents will be found in EPA docket EPA-HQ-OAR-2010-0799. The final report is also located in this docket and will be available upon approval of the CAFE GHG rulemaking.

NHTSA Fleet Simulation Study

NHTSA has contracted with GWU to build a fleet simulation model to study the impact and relationship of light-weighted vehicle design with injuries and fatalities. This study will also include an evaluation of potential countermeasures to reduce any safety concerns associated with lightweight vehicles in the second phase. NHTSA has included three light-weighted vehicle designs in this study: the one from Electricore/EDAG/GWU mentioned above, one from Lotus Engineering funded by California Air Resource Board for the second phase of the study, evaluating mass reduction levels around 35 percent of total vehicle mass, and one funded by EPA and the International Council on Clean Transportation (ICCT). In addition to the lightweight vehicle models, these projects also created CAE models of the baseline vehicles. To estimate the fleet safety implications of light-weighting, CAE crash simulation modeling was conducted to generate crash pulse and intrusion data for the baseline and three light-weighted vehicles when they crash with objects (barriers and poles) and with four other vehicle models (Chevy Silverado, Ford Taurus, Toyota Yaris and Ford Explorer) that represent a range of current vehicles. The simulated acceleration and intrusion data were used as inputs to MADYMO occupant models to estimate driver injury. The crashes were conducted at a range of speeds and the occupant injury risks were combined based on the frequency of the crash occurring in real world data. The change in driver injury risk between the baseline and light-weighted vehicles will provide insight into the safety performance these light-weighting design concepts. This is a large and ambitious project involves several stages over several years. NHTSA and GWU have completed the first stage of this study. The frontal crash simulation part of the study is being finished and will be peer reviewed. The report for this study will be available in NHTSA-2010-0131. Information for this study can also be found at NHTSA's website[344].

The countermeasures section of the study is expected to be finished in early 2013. This phase of the study is expected to provide information about the relationship of light-weighted vehicle design with injuries and fatalities and to provide the capability to evaluate the potential countermeasures to safety concerns associated with light-weighted vehicles. NHTSA plans to include the following items in future phases of the study to help better understanding the impact of mass reduction on safety.

- Vehicle crash simulation between two light-weighted concept vehicles;
- Additional crash configurations, such as side impact, oblique and rear impact tests;
- Risk analysis for elderly and vulnerable occupants;
- Safety of light-weighted concept vehicles for different size occupants.
- Partner vehicle protection in crashes with other light-weighted concept vehicles.

[344] Website for fleet study can be found at http://www.nhtsa.gov/fuel-economy.

While this study is expected to provide information about the relationship of light-weighted vehicle design with injuries and fatalities and to provide meaningful information to NHTSA on potential countermeasures to reduce any safety concerns associated with lightweight vehicles, because this study cannot incorporate all of the variations in vehicle crashes that occur in the real world, it is expected to provide trend information on the effect of potential future designs on highway safety, but is not expected to provide information that can be used to modify the coefficients derived by Kahane that relate mass reduction to highway crash fatalities. Because the coefficients from the Kahane study are used in the agencies' assessment of the amount of mass reduction that may be implemented with a neutral effect on highway safety, the fact that the fleet simulation modeling study is not complete does not affect the agencies' assessment of the amount of mass reduction that may be implemented with a neutral effect on safety.

Safety considerations in establishing CAFE/GHG standards along with discussion of NHTSA's February 25, 2011, mass-size-safety workshop at DOT headquarters can be found in Section II.G of the preamble for this final rule. NHTSA intends to host additional workshops when the studies have reached a sufficient level of completion, to share the results with the public and continue the fruitful ongoing public dialogue on these issues.

Low Drag Brake (LDB)

Low drag brakes reduce the sliding friction of disc brake pads on rotors when the brakes are not engaged, because the brake pads are pulled away from the rotating disc either by mechanical or electric methods.

The 2012-2016 final rule and TAR estimated the effectiveness of low drag brakes to be as high as 1 percent. NHTSA and EPA have slightly revised the effectiveness down to 0.8 percent based on the 2011 Ricardo study and the updated lumped parameter model.

In the MYs 2012-2016 final rule, the agencies estimated the DMC at $57 (2007$). This DMC becomes $59 (updated to 2010$) for this analysis. The agencies consider low drag brake technology to be off the learning curve (i.e., fully learned out, so that the DMC does not change year-over-year) and have applied a low complexity ICM of 1.24 through 2018, switching to a long-term ICM of 1.19 thereafter. The resultant costs are shown Table V-116.

Table V-116 Costs for Low Drag Brakes (2010$)

Cost type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	$59	$59	$59	$59	$59	$59	$59	$59	$59
IC	$14	$14	$11	$11	$11	$11	$11	$11	$11

TC	$74	$74	$71	$71	$71	$71	$71	$71	$71

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost

Low Rolling Resistance Tires – Level 1and Level 2 (ROLL1 and ROLL2)

Tire rolling resistance is the frictional loss associated mainly with the energy dissipated in the deformation of the tires under load and thus influences fuel economy. Other tire design characteristics (*e.g.*, materials, construction, and tread design) influence durability, traction (both wet and dry grip), vehicle handling, and ride comfort in addition to rolling resistance. A typical low rolling resistance tire's attributes could include increased specified tire inflation pressure, material changes, tire construction with less hysteresis, geometry changes (*e.g.*, reduced aspect ratios), and reduction in sidewall and tread deflection. These changes would generally be accompanied with additional changes to vehicle suspension tuning and/or suspension design.

The agencies expect that greater reductions in tire rolling resistance will be possible during the rulemaking timeframe than are currently available, as tire manufacturers continue to improve their products in order to meet increasing demand by auto OEMs for tires that contribute more to their vehicles' fuel efficiency. Thus, for this final rule, consistent with the proposal, the agencies considered two "levels" of lower rolling resistance tires. The first level ("ROLL1") is defined as a 10 percent reduction in rolling resistance from a base tire, which was estimated to be a 1 to 2 percent fuel efficiency effectiveness improvement in MYs 2012-2016 final rule. Based on the 2011 Ricardo study, the agencies are now using 1.9 percent fuel efficiency effectiveness improvement for ROLL1 for all vehicle classes. ROLL1 tires are widely available today, and appear to comprise a larger and larger portion of tire manufacturers' product lines as the technology continues to improve and mature. The second level ("ROLL2") is defined as a 20 percent reduction in rolling resistance from a base tire, yielding an estimated 3.9 percent effectiveness improvement. In the CAFE model this results in a 2.0 percent incremental effectiveness increase from ROLL1. ROLL2 represents an additional level of rolling resistance improvement beyond what the agencies considered in the MYs 2012-2016 rulemaking analysis. NHTSA assumed that the increased traction requirements for braking and handling for performance vehicles could not be fully met with the ROLL2 designs in the MYs 2017-2025 timeframe. For this reason the CAFE model did not apply ROLL2 to performance vehicle classifications. However, the agency did assume that tractions requirement for ROLL1 could be met in this timeframe and thus allowed ROLL1 to be applied to performance vehicle classifications in the MYs 2017-2025 timeframe.

In the MYs 2012-2016 final rule, the agencies estimated the incremental DMC as $5 (2007$) per vehicle. This included costs associated with five tires per vehicle, four primary and one spare tire. There is no learning applied to ROLL1 due to the commodity based nature of this technology. Looking forward from 2016, the agencies continue to apply this same estimated

DMC, as adjusted for 2010 dollars.[345] The agencies consider ROLL1 to be fully learned out or "off" the learning curve (*i.e.*, the DMC does not change year-over-year) and have applied a low complexity ICM of 1.24 through 2018, and a long-term low complexity ICM of 1.19 thereafter, due to the fact that this technology is already well established in the marketplace.

To analyze the feasibility and cost for a second level of rolling resistance improvement, EPA, NHTSA, and CARB met with a number of the largest tire suppliers in the United States. The suppliers were generally optimistic about the ability to reduce tire rolling resistance in the future without the need to sacrifice traction (safety) or tread life (durability). Suppliers all generally stated that rolling resistance levels could be reduced by 20 percent relative to today's tires by MY 2017. As such, the agencies agreed, based on these discussions, to consider ROLL2 as initially available for purposes of this analysis in MY 2017, but not widespread in the marketplace until MYs 2022-2023. In alignment with introduction of new technology, the agencies limited the phase-in schedule to 15 percent of a manufacturer's fleet starting in 2017, and did not allow complete application (100 percent of a manufacturer's fleet) until 2023. The agencies believe that this schedule aligns with the necessary efforts for production implementation, such as system and electronic system calibration and verification.

ROLL2 technology does not yet exist in the marketplace today, making cost estimation challenging without disclosing potentially confidential business information. To develop a transparent cost estimate, the agencies relied on ROLL1 history, costs, market implementation, and information provided by the 2010 NAS report. The agencies assumed low rolling resistance technology ("ROLL1") first entered the marketplace in the 1993 time frame with more widespread adoption being achieved in recent years, yielding approximately 15 years to maturity and widespread adoption.

Then, using MY 2017 as the starting point for market entry for ROLL2 and taking into account the advances in industry knowledge and an assumed increase in demand for improvements in this technology, the agencies interpolated DMC for ROLL2 at $10 (2010$) per tire, or $40 ($2010) per vehicle. This estimate is generally fairly consistent with CBI suggestions by tire suppliers. The agencies have not included a cost for the spare tire because we believe manufacturers are not likely to include a ROLL2 as a spare given the $10 DMC. In some cases and when possible pending any state-level requirements, manufacturers have removed spare tires replacing them with tire repair kits to reduce both cost and weight associated with a spare tire.[346] The agencies

[345] As noted elsewhere in this chapter, we show dollar values to the nearest dollar. However, dollars and cents are carried through each agency's respective analysis. Thus, while the cost for lower rolling resistance tires in the 2012-2016 final rule was shown as $5, the specific value used in that rule was $5.15 (2007$) and is now $5.40 (2010$). We show $5 for presentation simplicity.

[346] "The Disappearing Spare Tire" Edmunds.com, May 11, 2011; http://www.edmunds.com/car-buying/the-disappearing-spare-tire.html (last accessed 9/6/2011)

consider this estimated cost for ROLL2 to be applicable in MY 2021. Further, the agencies consider ROLL2 technology to be on the steep portion of the learning curve where costs would be reduced quickly in a relative short period of time. The agencies have applied a low complexity ICM of 1.24 through 2024, and switching to a long-term ICM of 1.19 thereafter. The ICM timing for ROLL2 is different from that for ROLL1 because ROLL2 is brand-new for this rulemaking and is not yet being implemented in the fleet. The resultant costs are shown in Table V-117. Note that both ROLL1 and ROLL2 are incremental to the baseline system, so ROLL2 is not incremental to ROLL1.

Table V-117 Costs for Lower Rolling Resistance Tires Levels 1 & 2 (2010$)

Cost type	Lower Rolling Resistance Tire Technology	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	Level 1	$5	$5	$5	$5	$5	$5	$5	$5	$5
DMC	Level 2	$63	$63	$51	$51	$40	$39	$38	$37	$35
IC	Level 1	$1	$1	$1	$1	$1	$1	$1	$1	$1
IC	Level 2	$10	$10	$10	$10	$10	$10	$10	$10	$8
TC	Level 1	$7	$7	$6	$6	$6	$6	$6	$6	$6
TC	Level 2	$73	$73	$60	$60	$50	$49	$48	$47	$43

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost
Note that both levels of lower rolling resistance tires are incremental to today's baseline tires.

Given that the final standards cover such a long timeframe, the agencies also considered introducing a third level of rolling resistance reduction ("ROLL3"), defined as a 30 percent reduction in rolling resistance. The agencies evaluated the potential of ROLL3 entering the marketplace during this proposed rulemaking timeframe.

Tire technologies that enable improvements of 10 and 20 percent have been in existence for many years. Achieving improvements up to 20 percent involves optimizing and integrating multiple technologies, with a primary contributor being the adoption of a silica tread technology.[347] This approach was based on the use of a new silica along with a specific polymer and coupling agent combination. The use of the polymer, coupling agent and silica was known to reduce tire rolling resistance at the expense of tread wear, but new approach using novel silica reduced the tread wear tradeoff.

Tire suppliers have indicated there are one or more innovations/inventions that they expect to occur in order to move the industry to the next quantum reduction of rolling resistance. However, based on the historical development and integration of tire technologies, there appears

[347] see U.S Patent 5,227,425, Rauline to Michelin, July 13, 1993

to be little evidence supporting improvements beyond ROLL2 by 2025. Therefore, the agencies decided not to incorporate ROLL3 at this time.

NHTSA sought comment on whether we should consider application of a 30 percent reduction from today's rolling resistance levels being available for mass production implementation by MY 2025 or sooner. We also sought comment on the viability of this technology, maturity by MY 2025, as well as market introduction timing and the technological ways that this level of rolling resistance improvement will be achieved without any tradeoffs in terms of vehicle handling capability and tire life from what consumers expect today. Finally, we sought cost information regarding the potential incorporation of ROLL3 relative to today's costs as well as during the timeframe covered by this final rule. No comments were submitted on any of these topics.

Front or secondary axle disconnect for four-wheel drive systems (SAX)

Energy is required to continually drive the front, or secondary, axle in a four-wheel drive system even when the system is not required during most operating conditions. This energy loss directly results in increased fuel consumption. Many part-time four-wheel drive systems use some type of front axle disconnect to provide shift-on-the-fly capabilities. The front axle disconnect is normally part of the front differential assembly. As part of a shift-on-the-fly four-wheel drive system, the front axles disconnect serves two basic purposes. First, in two-wheel drive mode, it disengages the front axle from the front driveline so the front wheels do not turn the front driveline at road speed, saving wear and tear. Second, when shifting from two- to four-wheel drive "on the fly" (while moving), the front axle disconnect couples the front axle to the front differential side gear only when the transfer case's synchronizing mechanism has spun the front driveshaft up to the same speed as the rear driveshaft. Four-wheel drive systems that have a front axle disconnect typically do not have either manual- or automatic-locking hubs. To isolate the front wheels from the rest of the front driveline, front axle disconnects use a sliding sleeve to connect or disconnect an axle shaft from the front differential side gear. NHTSA and EPA are not aware of any manufacturer offering this technology in the U.S. today on unibody frame vehicles; however, it is possible this technology could be introduced by manufacturers within the MYs 2017-2025 time period.

The MYs 2012-2016 final rule estimated an effectiveness improvement of 1.0 to 1.5 percent for axle disconnect. Based on the 2011 Ricardo report, NHTSA and EPA refined this range to 1.2 to 1.4 percent for this analysis.

In the MYs 2012-2016 final rule, the agencies estimated the DMC at $78 (2007$) which was considered applicable to MY 2015. This DMC becomes $82 (updated to 2010$) for this analysis. The agencies consider secondary axle disconnect technology to be on the flat portion of the learning curve and have applied a low complexity ICM of 1.24 through 2018, and then a long-term ICM of 1.19 thereafter. The resultant costs are shown in Table V-118.

Table V-118 Costs for Secondary Axle Disconnect (2010$)

Cost type	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	$78	$76	$75	$73	$72	$70	$69	$68	$66
IC	$20	$20	$16	$16	$16	$16	$16	$16	$16
TC	$98	$96	$91	$89	$88	$86	$85	$83	$82

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost

Aerodynamic Drag Reduction Level 1 and Level 2 (AERO1 and AERO2)

Many factors affect a vehicle's aerodynamic drag and the resulting power required to move it through the air. The overall drag effect can be simplified as proportional to vehicle's frontal area, vehicle's drag coefficient, air density and the second order of vehicle's velocity. Therefore reducing vehicle's frontal area and drag coefficient can reduce fuel consumption. Although frontal areas tend to be relatively similar within a vehicle class (mostly due to market-competitive size requirements), significant variations in drag coefficient can be observed. Significant changes to a vehicle's aerodynamic performance may need to be implemented during a redesign (*e.g.*, changes in vehicle shape). However, shorter-term aerodynamic reductions, with a somewhat lower effectiveness, may be achieved through the use of revised exterior components (typically at a model refresh in mid-cycle) and add-on devices that are currently being applied. The latter list would include revised front and rear fascias, modified front air dams and rear valances, addition of rear deck lips and underbody panels, and lower aerodynamic drag exterior mirrors.

In the MYs 2012-2016 final rule, we estimated that a fleet average of 10 to 20 percent total aerodynamic drag reduction is attainable which equates to incremental reductions in fuel consumption of 2 to 3 percent for both cars and trucks. These numbers are generally supported by the Ricardo study and public technical literature and therefore NHTSA and EPA are retaining these estimates, as confirmed by joint review, for the purposes of this final rule, consistent with the proposal. Importantly, the effectiveness values presented here represent two-cycle effectiveness. Because active aerodynamic technologies (i.e., aero level 2) provide additional off-cycle benefits, both agencies apply an off-cycle credit value to the technology. Off-cycle credits are discussed in Chapter 5 of the Joint TSD.

For this final rule, consistent with the proposal, the agencies considered two levels of aero improvements. The first level is that discussed in MYs 2012-2016 final rule and the 2010 TAR and includes such body features as air dams, tire spats, and perhaps one underbody panel. In the

2012-2016 final rule, the agencies estimated the DMC of aero-level 1 at $39 (2007$). This DMC becomes $41 (updated to 2010$) for this analysis, applicable in MY 2015. The agencies consider aero-level 1 technology to be on the flat portion of the learning curve and have applied a low complexity ICM of 1.24 through 2018, and then a long-term ICM of 1.19 thereafter.

The second level of aero—level 2, which includes such body features as active grille shutters, rear visors, larger under body panels or low-profile roof racks —was discussed in the 2010 TAR where the agencies estimated the DMC at $120 (2008$) incremental to the baseline vehicle. The agencies inadvertently used that cost as inclusive of aero-level 1 technologies when it should have been incremental to aero-1 technologies. As a result, the agencies now consider the TAR cost to more appropriately be incremental to aero-level 1, with a DMC for this analysis of $123 (2010$). The agencies consider this cost to be applicable in MY 2015. Further, the agencies consider aero-level 2 technology to be on the flat portion of the learning curve. The agencies have applied a medium complexity ICM of 1.39 through 2024, and then a long-term ICM of 1.29 thereafter. The timing of the aero-level 2 ICMs is different than that for the level 1 technology because the level 2 technology is newer and not yet being implemented in the fleet. The resultant costs are shown in Table V-119.

Table V-119 Costs for Aerodynamic Drag Improvements – Levels 1 & 2 (2010$)

Cost type	Aero Technology	Incremental to	2017	2018	2019	2020	2021	2022	2023	2024	2025
DMC	Level 1	Baseline	$39	$38	$37	$37	$36	$35	$35	$34	$33
DMC	Level 2	Aero-level 1	$117	$115	$112	$110	$108	$106	$104	$102	$100
IC	Level 1	Baseline	$10	$10	$8	$8	$8	$8	$8	$8	$8
IC	Level 2	Aero-level 1	$47	$47	$47	$47	$47	$47	$47	$47	$35
TC	Level 1	Baseline	$49	$48	$45	$45	$44	$43	$42	$42	$41
TC	Level 2	Aero-level 1	$164	$162	$160	$157	$155	$153	$150	$148	$135
TC	Level 2	Baseline	$213	$210	$205	$202	$199	$196	$193	$190	$176

DMC=Direct manufacturing cost; IC=Indirect cost; TC=Total cost

Because a large percent of the performance vehicles already have some level of aerodynamic treatments, the CAFE model only applies level 1 of aerodynamic treatment to these vehicles. Also for specific vehicles, such as Toyota Prius, which already have extensive aerodynamic treatment, the level of the aerodynamic that could be further applied by CAFE model is limited in the market input file.

Technologies considered but not included in the final rule analysis

Lean-Burn Gasoline Direct Injection Technology

Direct injection, especially with diesel-like "spray-guided" injection systems, enables operation with excess air in a stratified or partially-stratified fuel-air mixture, as a way of reducing the amount of intake throttling. Also, with higher-pressure fuel injection systems, the fuel may be added late enough during the compression stroke so as to delay the onset of auto-ignition, even with higher engine compression ratios or with boosted intake pressure. Taken together, an optimized "lean-burn" direct injection gasoline engine may achieve high engine thermal efficiency which approaches that of a diesel engine. European gasoline direct-injection engines have implemented stratified-charge lean-burn GDI, although at higher NOx emissions levels than are allowed at under U.S. Federal Tier 2 emissions standards. Fuel system improvements, changes in combustion chamber design and repositioning of the injectors have allowed for better air/fuel mixing and combustion efficiency. There is currently a shift from wall-guided injection to spray guided injection, which improves injection precision and targeting towards the spark plug, increasing lean combustion stability. Combined with advances in NOx after-treatment, lean-burn GDI engines may eventually be a possibility in North America.

EPA and NHTSA's current assessment is that the availability of ultra-low sulfur (ULS less than 15 ppm sulfur) gasoline is a key technical requirement for lean-burn GDI engines to meet EPA's Tier 2 NOx emissions standards. Since we do not believe that ULS gasoline will be available during the model years applicable to these rules, the technology was not applied in EPA or NHTSA analyses.

Homogeneous Charge Compression Ignition

Gasoline homogeneous charge compression ignition (HCCI), also referred to as controlled autoignition (CAI), is an alternate engine operating mode that does not rely on a spark event to initiate combustion. The principles are more closely aligned with a diesel combustion cycle, in which the compressed charge exceeds a temperature and pressure necessary for spontaneous autoignition although it differs from diesel by having a homogenous fuel/air charge rather than being a diffusion controlled combustion event. The subsequent combustion event is much shorter in duration with higher thermal efficiency.

An HCCI engine has inherent advantages in its overall efficiency for two main reasons:

- The engine is operated with a higher compression ratio, and with a shorter combustion duration, resulting in a higher thermodynamic efficiency, and
- The engine can be operated virtually unthrottled, even at light loads.

Combined, these effects have shown an increase in engine brake efficiency (typically 25-28 percent) to greater than 35 percent at the high end of the HCCI operating range.[348]
Criteria pollutant emissions are very favorable during HCCI operation. Lower peak in-cylinder temperatures (due to high dilution) keep engine-out NOx emissions to a minimum – realistically below Tier 2 levels without aftertreatment – and particulates are low due to the homogeneous nature of the premixed charge.

Due to the inherent difficulty in maintaining combustion stability without encountering engine knock, HCCI is difficult to control, requiring feedback from in-cylinder pressure sensors and rapid engine control logic to optimize combustion timing, especially considering the transient nature of operating conditions seen in a vehicle. Due to the highly dilute conditions under which gasoline-HCCI combustion is stable, the range of engine loads achievable in a naturally-aspirated engine is somewhat limited. Because of this, it is likely that any commercial application would operate in a "dual-mode" strategy between HCCI and spark ignition combustion modes, in which HCCI would be utilized for best efficiency at light engine loads and spark ignition would be used at higher loads and at idle. This type of dual-mode strategy has already been employed in diesel HCCI engines in Europe and Asia (notably the Toyota Avensis D-Cat and the Nissan light-duty "MK" combustion diesels).

Until recently, gasoline-HCCI technology was considered to still be in the research phase. However, most manufacturers have made public statements about the viability of incorporating HCCI into light-duty passenger vehicles, and have significant vehicle demonstration programs aimed at producing a viable product within the next 5-10 years.

There is widespread opinion as to the fuel consumption reduction potential for HCCI in the literature. Based on confidential manufacturer information, EPA and NHTSA believe that a gasoline HCCI / GDI dual-mode engine might achieve 10-12% reduction in fuel consumption, compared to a comparable SI engine. Despite its promise, application of HCCI in light duty vehicles is not yet ready for the market. It is not anticipated to be seen in volume for at least the next 5-10 years, which is concurrent with many manufacturers' public estimates. NHTSA also noted in its MY 2011 CAFE final rule that the technology will not be available within the time frame considered based on a review of confidential product plan information.

Electric Assist Turbocharging

The Alliance commented in prior rulemakings that global development of electric assist turbo-charging has not demonstrated the fuel efficiency effectiveness of a 12V EAT up to 2kW power levels since the 2004 NESCCAF study, and stated that it saw remote probability of its

[348] "An HCCI Engine Power Plant for a Hybrid Vehicle," Sun, R., R. Thomas and C. Gray, Jr., SAE Technical Paper No. 2004-01-0933, 2004.

application over the next decade. While hybrid vehicles lower the incremental hardware requirements for higher-voltage, higher-power EAT systems, NHTSA and EPA agree that significant developmental work is required to demonstrate effective systems and that implementation in significant volumes will not occur in the time frame considered in this rulemaking. Thus, this technology was not included in the FRM, consistent with the NPRM.

Fuel cell electric vehicles

Fuel cell electric vehicles (FCEVs) – utilize a full electric drive platform but consume electricity generated by an on-board fuel cell and hydrogen fuel. Fuel cells are electro-chemical devices that directly convert reactants (hydrogen and oxygen via air) into electricity, with the potential of achieving more than twice the efficiency of conventional internal combustion engines. High pressure gaseous hydrogen storage tanks are used by most automakers for FCEVs that are currently under development. The high pressure tanks are similar to those used for compressed gas storage in more than 10 million CNG vehicles worldwide, except that they are designed to operate at a higher pressure (350 bar or 700 bar vs. 250 bar for CNG). Due to the uncertainty of the future availability for this technology, FCEVs were not included in any OMEGA or CAFE model runs.

Cost and effectiveness tables

The following tables representing the CAFE model input files for MY 2017 incremental technology costs by vehicle subclass are presented below. The tables have been divided into passenger cars, performance passenger cars, and light trucks to make them easier to read.

Table V-120 Technology Incremental Cost Estimates, Passenger Cars, 2008 Baseline

VEHICLE TECHNOLOGY ICM COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS - PASSENGER CARS					
		Subcompact Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Low Friction Lubricants - Level 1	LUB1	$4.02	$4.02	$4.02	$4.02
Engine Friction Reduction - Level 1	EFR1	$60.50	$60.50	$60.50	$60.50
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	$62.84	$62.84	$62.84	$62.84
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	$46.34	$46.34	$46.34	$92.69
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	$163.08	$163.08	$163.08	$163.08
Cylinder Deactivation on SOHC	DEACS	$32.47	$32.47	$32.47	$32.47
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	$46.34	$46.34	$46.34	$92.69
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	$44.26	$44.26	$44.26	$88.52
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	$163.08	$163.08	$163.08	$163.08
Continuously Variable Valve Lift (CVVL)	CVVL	$262.52	$262.52	$262.52	$262.52
Cylinder Deactivation on DOHC	DEACD	$32.47	$32.47	$32.47	$32.47
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$268.45	$268.45	$268.45	$268.45
Cylinder Deactivation on OHV	DEACO	$207.75	$207.75	$207.75	$207.75
Variable Valve Actuation - CCP and DVVL on OHV	VVA	$51.93	$51.93	$51.93	$103.86
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	$268.45	$268.45	$268.45	$268.45
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	$493.60	$493.60	$493.60	$493.60
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	$19.39	$19.39	$19.39	$19.39
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	$620.79	$620.79	$620.79	$620.79
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	$26.06	$26.06	$26.06	$26.06
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	$262.37	$262.37	$262.37	$262.37
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	$442.27	$442.27	$442.27	$442.27
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	-$299.93	-$299.93	-$299.93	-$299.93
Advanced Diesel - Small Displacement	ADSL_SD	$888.62	$888.62	$888.62	$888.62
Advanced Diesel - Medium Displacement	ADSL_MD	$854.97	$854.97	$854.97	$854.97
Advanced Diesel - Large Displacement	ADSL_LD	$1,709.99	$1,709.99	$1,709.99	$1,709.99
6-Speed Manual/Improved Internals	6MAN	$279.19	$279.19	$279.19	$279.19
High Efficiency Gearbox (Manual)	HETRANSM	$250.87	$250.87	$250.87	$250.87

Improved Auto. Trans. Controls/Externals	IATC	$62.25	$62.25	$62.25	$62.25
6-Speed Trans with Improved Internals (Auto)	NAUTO	-$39.06	-$39.06	-$39.06	-$39.06
6-speed DCT	DCT	-$108.65	-$108.65	-$74.51	-$74.51
8-Speed Trans (Auto or DCT)	8SPD	$257.36	$257.36	$257.36	$257.36
High Efficiency Gearbox (Auto or DCT)	HETRANS	$250.87	$250.87	$250.87	$250.87
Shift Optimizer	SHFTOPT	$1.67	$1.67	$1.67	$1.67
Electric Power Steering	EPS	$109.42	$109.42	$109.42	$109.42
Improved Accessories - Level 1	IACC1	$88.99	$88.99	$88.99	$88.99
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	$54.17	$54.17	$54.17	$54.17
12V Micro-Hybrid (Stop-Start)	MHEV	$324.53	$351.07	$385.46	$414.00
Integrated Starter Generator	ISG	$975.85	$975.85	$975.85	$975.85
Strong Hybrid - Level 1	SHEV1	$1,910.10	$1,910.10	$2,290.00	$2,962.35
Conversion from SHEV1 to SHEV2	SHEV1_2	$1,222.53	$1,222.53	$1,222.53	$1,490.27
Strong Hybrid - Level 2	SHEV2	$1,898.75	$1,898.75	$2,290.00	$2,962.35
Plug-in Hybrid - 30 mi range	PHEV1	$10,797.73	$10,797.73	$13,060.13	$17,995.66
Plug-in Hybrid	PHEV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$2,292.75	$2,292.75	$3,577.34	$4,405.48
Electric Vehicle (Early Adopter) - 100 mile range	EV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 150 mile range	EV3	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Broad Market) - 150 mile range	EV4	$8,323.23	$8,323.23	$10,525.89	$9,581.94
Fuel Cell Vehicle	FCV	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 1	MR1	$0.00	$0.00	$0.08	$0.08
Mass Reduction - Level 2	MR2	$0.00	$0.00	$0.27	$0.48
Mass Reduction - Level 3	MR3	$0.00	$0.00	$0.00	$0.94
Mass Reduction - Level 4	MR4	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 5	MR5	$0.00	$0.00	$0.00	$0.00
Low Rolling Resistance Tires - Level 1	ROLL1	$6.71	$6.71	$6.71	$6.71
Low Rolling Resistance Tires - Level 2	ROLL2	$73.16	$73.16	$73.16	$73.16
Low Rolling Resistance Tires - Level 3	ROLL3	$0.00	$0.00	$0.00	$0.00
Low Drag Brakes	LDB	$73.77	$73.77	$73.77	$73.77
Secondary Axle Disconnect	SAX	$97.67	$97.67	$97.67	$97.67
Aero Drag Reduction, Level 1	AERO1	$48.92	$48.92	$48.92	$48.92
Aero Drag Reduction, Level 2	AERO2	$164.44	$164.44	$164.44	$164.44

Table V-121 Technology Incremental Cost Estimates, Passenger Cars, 2010 Baseline

VEHICLE TECHNOLOGY ICM COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS - PASSENGER CARS					
		Subcompact Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Low Friction Lubricants - Level 1	LUB1	$4.02	$4.02	$4.02	$4.02
Engine Friction Reduction - Level 1	EFR1	$60.50	$60.50	$60.50	$60.50
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	$62.84	$62.84	$62.84	$62.84
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	$46.34	$46.34	$46.34	$92.69
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	$163.08	$163.08	$163.08	$163.08
Cylinder Deactivation on SOHC	DEACS	$32.47	$32.47	$32.47	$32.47
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	$46.34	$46.34	$46.34	$92.69
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	$44.26	$44.26	$44.26	$88.52
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	$163.08	$163.08	$163.08	$163.08
Continuously Variable Valve Lift (CVVL)	CVVL	$262.52	$262.52	$262.52	$262.52
Cylinder Deactivation on DOHC	DEACD	$32.47	$32.47	$32.47	$32.47
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$268.45	$268.45	$268.45	$268.45
Cylinder Deactivation on OHV	DEACO	$207.75	$207.75	$207.75	$207.75
Variable Valve Actuation - CCP and DVVL on OHV	VVA	$51.93	$51.93	$51.93	$103.86
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	$268.45	$268.45	$268.45	$268.45
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	$493.60	$493.60	$493.60	$493.60
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	$19.39	$19.39	$19.39	$19.39
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	$620.79	$620.79	$620.79	$620.79
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	$26.06	$26.06	$26.06	$26.06
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	$262.37	$262.37	$262.37	$262.37
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	$442.27	$442.27	$442.27	$442.27
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	-$299.93	-$299.93	-$299.93	-$299.93
Advanced Diesel - Small Displacement	ADSL_SD	$888.62	$888.62	$888.62	$888.62
Advanced Diesel - Medium Displacement	ADSL_MD	$854.97	$854.97	$854.97	$854.97
Advanced Diesel - Large Displacement	ADSL_LD	$1,709.99	$1,709.99	$1,709.99	$1,709.99
6-Speed Manual/Improved Internals	6MAN	$279.19	$279.19	$279.19	$279.19

High Efficiency Gearbox (Manual)	HETRANSM	$250.87	$250.87	$250.87	$250.87
Improved Auto. Trans. Controls/Externals	IATC	$62.25	$62.25	$62.25	$62.25
6-Speed Trans with Improved Internals (Auto)	NAUTO	-$39.06	-$39.06	-$39.06	-$39.06
6-speed DCT	DCT	-$108.65	-$108.65	-$74.51	-$74.51
8-Speed Trans (Auto or DCT)	8SPD	$257.36	$257.36	$257.36	$257.36
High Efficiency Gearbox (Auto or DCT)	HETRANS	$250.87	$250.87	$250.87	$250.87
Shift Optimizer	SHFTOPT	$1.67	$1.67	$1.67	$1.67
Electric Power Steering	EPS	$109.42	$109.42	$109.42	$109.42
Improved Accessories - Level 1	IACC1	$88.99	$88.99	$88.99	$88.99
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	$54.17	$54.17	$54.17	$54.17
12V Micro-Hybrid (Stop-Start)	MHEV	$324.53	$351.07	$385.46	$414.00
Integrated Starter Generator	ISG	$975.85	$975.85	$975.85	$975.85
Strong Hybrid - Level 1	SHEV1	$1,932.10	$1,932.10	$2,333.75	$3,053.73
Conversion from SHEV1 to SHEV2	SHEV1_2	$1,222.53	$1,222.53	$1,222.53	$1,490.27
Strong Hybrid - Level 2	SHEV2	$1,920.65	$1,920.65	$2,333.75	$3,053.73
Plug-in Hybrid - 30 mi range	PHEV1	$11,042.77	$11,042.77	$13,448.66	$18,538.03
Plug-in Hybrid	PHEV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$2,416.11	$2,416.11	$3,711.27	$4,614.46
Electric Vehicle (Early Adopter) - 100 mile range	EV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 150 mile range	EV3	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Broad Market) - 150 mile range	EV4	$8,646.39	$8,646.39	$10,648.50	$9,894.33
Fuel Cell Vehicle	FCV	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 1	MR1	$0.00	$0.00	$0.08	$0.08
Mass Reduction - Level 2	MR2	$0.00	$0.00	$0.27	$0.48
Mass Reduction - Level 3	MR3	$0.00	$0.00	$0.00	$0.94
Mass Reduction - Level 4	MR4	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 5	MR5	$0.00	$0.00	$0.00	$0.00
Low Rolling Resistance Tires - Level 1	ROLL1	$6.71	$6.71	$6.71	$6.71
Low Rolling Resistance Tires - Level 2	ROLL2	$73.16	$73.16	$73.16	$73.16
Low Rolling Resistance Tires - Level 3	ROLL3	$0.00	$0.00	$0.00	$0.00
Low Drag Brakes	LDB	$73.77	$73.77	$73.77	$73.77
Secondary Axle Disconnect	SAX	$97.67	$97.67	$97.67	$97.67
Aero Drag Reduction, Level 1	AERO1	$48.92	$48.92	$48.92	$48.92
Aero Drag Reduction, Level 2	AERO2	$164.44	$164.44	$164.44	$164.44

Table V-122 Technology Incremental Cost Estimates, Performance Passenger Cars, 2008 Baseline

VEHICLE TECHNOLOGY ICM COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS - PERFORMANCE PASSENGER CARS					
		Performance Subcompact Car	Performance Compact Car	Performance Midsize Car	Performance Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Low Friction Lubricants - Level 1	LUB1	$4.02	$4.02	$4.02	$4.02
Engine Friction Reduction - Level 1	EFR1	$60.50	$90.75	$90.75	$121.00
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	$62.84	$94.26	$94.26	$125.68
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	$46.34	$92.69	$92.69	$92.69
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	$163.08	$244.61	$244.61	$326.15
Cylinder Deactivation on SOHC	DEACS	$32.47	$32.47	$32.47	$32.47
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	$46.34	$92.69	$92.69	$92.69
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	$44.26	$88.52	$88.52	$88.52
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	$163.08	$244.61	$244.61	$326.15
Continuously Variable Valve Lift (CVVL)	CVVL	$262.52	$393.78	$393.78	$525.04
Cylinder Deactivation on DOHC	DEACD	$32.47	$32.47	$32.47	$32.47
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$268.45	$402.68	$402.68	$536.91
Cylinder Deactivation on OHV	DEACO	$207.75	$207.75	$207.75	$207.75
Variable Valve Actuation - CCP and DVVL on OHV	VVA	$51.93	$103.86	$103.86	$103.86
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	$268.45	$402.68	$402.68	$536.91
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	$493.60	$493.60	$493.60	$493.60
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	$19.39	$19.39	$19.39	$19.39
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	$620.79	$620.79	$620.79	$620.79
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	$26.06	$26.06	$26.06	$26.06
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	$262.37	$262.37	$262.37	$262.37
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	$442.27	$442.27	$442.27	$442.27
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	-$299.93	-$299.93	-$299.93	-$299.93
Advanced Diesel - Small Displacement	ADSL_SD	$888.62	$888.62	$888.62	$888.62
Advanced Diesel - Medium Displacement	ADSL_MD	$854.97	$854.97	$854.97	$854.97
Advanced Diesel - Large Displacement	ADSL_LD	$1,709.99	$1,709.99	$1,709.99	$1,709.99
6-Speed Manual/Improved Internals	6MAN	$279.19	$279.19	$279.19	$279.19

High Efficiency Gearbox (Manual)	HETRA NSM	$250.87	$250.87	$250.87	$250.87
Improved Auto. Trans. Controls/Externals	IATC	$62.25	$62.25	$62.25	$62.25
6-Speed Trans with Improved Internals (Auto)	NAUT O	-$39.06	-$39.06	-$39.06	-$39.06
6-speed DCT	DCT	-$74.51	-$74.51	-$74.51	-$74.51
8-Speed Trans (Auto or DCT)	8SPD	$257.36	$257.36	$257.36	$257.36
High Efficiency Gearbox (Auto or DCT)	HETRA NS	$250.87	$250.87	$250.87	$250.87
Shift Optimizer	SHFTO PT	$1.67	$1.67	$1.67	$1.67
Electric Power Steering	EPS	$109.42	$109.42	$109.42	$109.42
Improved Accessories - Level 1	IACC1	$88.99	$88.99	$88.99	$88.99
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	$54.17	$54.17	$54.17	$54.17
12V Micro-Hybrid (Stop-Start)	MHEV	$324.53	$351.07	$385.46	$414.00
Integrated Starter Generator	ISG	$975.85	$975.85	$975.85	$975.85
Strong Hybrid - Level 1	SHEV1	$1,910.10	$1,910.10	$2,290.00	$2,962.35
Conversion from SHEV1 to SHEV2	SHEV1 _2	$1,222.53	$1,490.27	$1,490.27	$876.90
Strong Hybrid - Level 2	SHEV2	$1,898.75	$1,898.75	$2,290.00	$2,962.35
Plug-in Hybrid - 30 mi range	PHEV1	$10,797.73	$10,797.73	$13,060.13	$17,995.66
Plug-in Hybrid	PHEV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$2,292.75	$2,292.75	$3,577.34	$4,405.48
Electric Vehicle (Early Adopter) - 100 mile range	EV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 150 mile range	EV3	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Broad Market) - 150 mile range	EV4	$8,323.23	$8,323.23	$10,525.89	$9,581.94
Fuel Cell Vehicle	FCV	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 1	MR1	$0.00	$0.00	$0.08	$0.08
Mass Reduction - Level 2	MR2	$0.00	$0.00	$0.27	$0.48
Mass Reduction - Level 3	MR3	$0.00	$0.00	$0.00	$0.94
Mass Reduction - Level 4	MR4	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 5	MR5	$0.00	$0.00	$0.00	$0.00
Low Rolling Resistance Tires - Level 1	ROLL1	$6.71	$6.71	$6.71	$6.71
Low Rolling Resistance Tires - Level 2	ROLL2	$73.16	$73.16	$73.16	$73.16
Low Rolling Resistance Tires - Level 3	ROLL3	$0.00	$0.00	$0.00	$0.00
Low Drag Brakes	LDB	$73.77	$73.77	$73.77	$73.77
Secondary Axle Disconnect	SAX	$97.67	$97.67	$97.67	$97.67
Aero Drag Reduction, Level 1	AERO1	$48.92	$48.92	$48.92	$48.92
Aero Drag Reduction, Level 2	AERO2	$164.44	$164.44	$164.44	$164.44

Table V-123 Technology Incremental Cost Estimates, Performance Passenger Cars, 2010 Baseline

VEHICLE TECHNOLOGY ICM COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS - PERFORMANCE PASSENGER CARS					
		Performance Subcompact Car	Performance Compact Car	Performance Midsize Car	Performance Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Low Friction Lubricants - Level 1	LUB1	$4.02	$4.02	$4.02	$4.02
Engine Friction Reduction - Level 1	EFR1	$60.50	$90.75	$90.75	$121.00
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	$62.84	$94.26	$94.26	$125.68
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	$46.34	$92.69	$92.69	$92.69
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	$163.08	$244.61	$244.61	$326.15
Cylinder Deactivation on SOHC	DEACS	$32.47	$32.47	$32.47	$32.47
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	$46.34	$92.69	$92.69	$92.69
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	$44.26	$88.52	$88.52	$88.52
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	$163.08	$244.61	$244.61	$326.15
Continuously Variable Valve Lift (CVVL)	CVVL	$262.52	$393.78	$393.78	$525.04
Cylinder Deactivation on DOHC	DEACD	$32.47	$32.47	$32.47	$32.47
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$268.45	$402.68	$402.68	$536.91
Cylinder Deactivation on OHV	DEACO	$207.75	$207.75	$207.75	$207.75
Variable Valve Actuation - CCP and DVVL on OHV	VVA	$51.93	$103.86	$103.86	$103.86
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	$268.45	$402.68	$402.68	$536.91
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	$493.60	$493.60	$493.60	$493.60
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	$19.39	$19.39	$19.39	$19.39
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	$620.79	$620.79	$620.79	$620.79
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	$26.06	$26.06	$26.06	$26.06
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	$262.37	$262.37	$262.37	$262.37
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	$442.27	$442.27	$442.27	$442.27
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	-$299.93	-$299.93	-$299.93	-$299.93
Advanced Diesel - Small Displacement	ADSL_SD	$888.62	$888.62	$888.62	$888.62
Advanced Diesel - Medium Displacement	ADSL_MD	$854.97	$854.97	$854.97	$854.97
Advanced Diesel - Large Displacement	ADSL_LD	$1,709.99	$1,709.99	$1,709.99	$1,709.99
6-Speed Manual/Improved Internals	6MAN	$279.19	$279.19	$279.19	$279.19

High Efficiency Gearbox (Manual)	HETRANSM	$250.87	$250.87	$250.87	$250.87
Improved Auto. Trans. Controls/Externals	IATC	$62.25	$62.25	$62.25	$62.25
6-Speed Trans with Improved Internals (Auto)	NAUTO	-$39.06	-$39.06	-$39.06	-$39.06
6-speed DCT	DCT	-$74.51	-$74.51	-$74.51	-$74.51
8-Speed Trans (Auto or DCT)	8SPD	$257.36	$257.36	$257.36	$257.36
High Efficiency Gearbox (Auto or DCT)	HETRANS	$250.87	$250.87	$250.87	$250.87
Shift Optimizer	SHFTOPT	$1.67	$1.67	$1.67	$1.67
Electric Power Steering	EPS	$109.42	$109.42	$109.42	$109.42
Improved Accessories - Level 1	IACC1	$88.99	$88.99	$88.99	$88.99
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	$54.17	$54.17	$54.17	$54.17
12V Micro-Hybrid (Stop-Start)	MHEV	$324.53	$351.07	$385.46	$414.00
Integrated Starter Generator	ISG	$975.85	$975.85	$975.85	$975.85
Strong Hybrid - Level 1	SHEV1	$1,932.10	$1,932.10	$2,333.75	$3,053.73
Conversion from SHEV1 to SHEV2	SHEV1_2	$1,222.53	$1,490.27	$1,490.27	$876.90
Strong Hybrid - Level 2	SHEV2	$1,920.65	$1,920.65	$2,333.75	$3,053.73
Plug-in Hybrid - 30 mi range	PHEV1	$11,042.77	$11,042.77	$13,448.66	$18,538.03
Plug-in Hybrid	PHEV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$2,416.11	$2,416.11	$3,711.27	$4,614.46
Electric Vehicle (Early Adopter) - 100 mile range	EV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 150 mile range	EV3	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Broad Market) - 150 mile range	EV4	$8,646.39	$8,646.39	$10,648.50	$9,894.33
Fuel Cell Vehicle	FCV	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 1	MR1	$0.00	$0.00	$0.08	$0.08
Mass Reduction - Level 2	MR2	$0.00	$0.00	$0.27	$0.48
Mass Reduction - Level 3	MR3	$0.00	$0.00	$0.00	$0.94
Mass Reduction - Level 4	MR4	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 5	MR5	$0.00	$0.00	$0.00	$0.00
Low Rolling Resistance Tires - Level 1	ROLL1	$6.71	$6.71	$6.71	$6.71
Low Rolling Resistance Tires - Level 2	ROLL2	$73.16	$73.16	$73.16	$73.16
Low Rolling Resistance Tires - Level 3	ROLL3	$0.00	$0.00	$0.00	$0.00
Low Drag Brakes	LDB	$73.77	$73.77	$73.77	$73.77
Secondary Axle Disconnect	SAX	$97.67	$97.67	$97.67	$97.67
Aero Drag Reduction, Level 1	AERO1	$48.92	$48.92	$48.92	$48.92
Aero Drag Reduction, Level 2	AERO2	$164.44	$164.44	$164.44	$164.44

Table V-124 Technology Incremental Cost Estimates, Light Trucks, 2008 Baseline

VEHICLE TECHNOLOGY ICM COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS - LIGHT TRUCKS					
		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Low Friction Lubricants - Level 1	LUB1	$4.02	$4.02	$4.02	$4.02
Engine Friction Reduction - Level 1	EFR1	$90.75	$60.50	$90.75	$121.00
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	$94.26	$62.84	$94.26	$125.68
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	$92.69	$46.34	$92.69	$92.69
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	$244.61	$163.08	$244.61	$326.15
Cylinder Deactivation on SOHC	DEACS	$32.47	$32.47	$32.47	$32.47
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	$92.69	$46.34	$92.69	$92.69
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	$88.52	$44.26	$88.52	$88.52
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	$244.61	$163.08	$244.61	$326.15
Continuously Variable Valve Lift (CVVL)	CVVL	$393.78	$262.52	$393.78	$525.04
Cylinder Deactivation on DOHC	DEACD	$32.47	$32.47	$32.47	$32.47
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$402.68	$268.45	$402.68	$536.91
Cylinder Deactivation on OHV	DEACO	$207.75	$207.75	$207.75	$207.75
Variable Valve Actuation - CCP and DVVL on OHV	VVA	$103.86	$51.93	$103.86	$103.86
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	$402.68	$268.45	$402.68	$536.91
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	$493.60	$493.60	$493.60	$493.60
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	$19.39	$19.39	$19.39	$19.39
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	$620.79	$620.79	$620.79	$620.79
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	$26.06	$26.06	$26.06	$26.06
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	$262.37	$262.37	$262.37	$262.37
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	$442.27	$442.27	$442.27	$442.27
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	-$299.93	-$299.93	-$299.93	-$299.93
Advanced Diesel - Small Displacement	ADSL_SD	$888.62	$888.62	$888.62	$888.62
Advanced Diesel - Medium Displacement	ADSL_MD	$854.97	$854.97	$854.97	$854.97
Advanced Diesel - Large Displacement	ADSL_LD	$1,709.99	$1,709.99	$1,709.99	$1,709.99
6-Speed Manual/Improved Internals	6MAN	$279.19	$279.19	$279.19	$279.19

High Efficiency Gearbox (Manual)	HETRANSM	$250.87	$250.87	$250.87	$250.87
Improved Auto. Trans. Controls/Externals	IATC	$62.25	$62.25	$62.25	$62.25
6-Speed Trans with Improved Internals (Auto)	NAUTO	-$39.06	-$39.06	-$39.06	-$39.06
6-speed DCT	DCT	$0.00	-$74.51	$0.00	$0.00
8-Speed Trans (Auto or DCT)	8SPD	$80.32	$257.36	$80.32	$80.32
High Efficiency Gearbox (Auto or DCT)	HETRANS	$250.87	$250.87	$250.87	$250.87
Shift Optimizer	SHFTOPT	$1.67	$1.67	$1.67	$1.67
Electric Power Steering	EPS	$109.42	$109.42	$109.42	$109.42
Improved Accessories - Level 1	IACC1	$88.99	$88.99	$88.99	$88.99
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	$54.17	$54.17	$54.17	$54.17
12V Micro-Hybrid (Stop-Start)	MHEV	$414.00	$366.17	$424.17	$479.57
Integrated Starter Generator	ISG	$975.85	$975.85	$975.85	$975.85
Strong Hybrid - Level 1	SHEV1	$2,689.41	$2,141.46	$2,689.41	$3,069.02
Conversion from SHEV1 to SHEV2	SHEV1_2	$1,490.27	$1,222.53	$1,490.27	$876.90
Strong Hybrid - Level 2	SHEV2	$2,689.41	$2,141.46	$2,689.41	$3,069.02
Plug-in Hybrid - 30 mi range	PHEV1	$0.00	$12,373.67	$0.00	$0.00
Plug-in Hybrid	PHEV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$0.00	$2,288.55	$0.00	$0.00
Electric Vehicle (Early Adopter) - 100 mile range	EV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 150 mile range	EV3	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Broad Market) - 150 mile range	EV4	$0.00	$11,602.07	$0.00	$0.00
Fuel Cell Vehicle	FCV	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 1	MR1	$0.08	$0.08	$0.08	$0.08
Mass Reduction - Level 2	MR2	$0.48	$0.48	$0.48	$0.48
Mass Reduction - Level 3	MR3	$0.94	$0.94	$0.94	$0.94
Mass Reduction - Level 4	MR4	$1.50	$1.50	$1.50	$1.50
Mass Reduction - Level 5	MR5	$2.10	$2.10	$2.10	$2.10
Low Rolling Resistance Tires - Level 1	ROLL1	$6.71	$6.71	$6.71	$6.71
Low Rolling Resistance Tires - Level 2	ROLL2	$73.16	$73.16	$73.16	$73.16
Low Rolling Resistance Tires - Level 3	ROLL3	$0.00	$0.00	$0.00	$0.00
Low Drag Brakes	LDB	$73.77	$73.77	$73.77	$73.77
Secondary Axle Disconnect	SAX	$97.67	$97.67	$97.67	$97.67
Aero Drag Reduction, Level 1	AERO1	$48.92	$48.92	$48.92	$48.92
Aero Drag Reduction, Level 2	AERO2	$164.44	$164.44	$164.44	$164.44

Table V-125 Technology Incremental Cost Estimates, Light Trucks, 2010 Baseline

VEHICLE TECHNOLOGY ICM COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS - LIGHT TRUCKS					
		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Low Friction Lubricants - Level 1	LUB1	$4.02	$4.02	$4.02	$4.02
Engine Friction Reduction - Level 1	EFR1	$90.75	$60.50	$90.75	$121.00
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	$94.26	$62.84	$94.26	$125.68
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	$92.69	$46.34	$92.69	$92.69
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	$244.61	$163.08	$244.61	$326.15
Cylinder Deactivation on SOHC	DEACS	$32.47	$32.47	$32.47	$32.47
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	$92.69	$46.34	$92.69	$92.69
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	$88.52	$44.26	$88.52	$88.52
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	$244.61	$163.08	$244.61	$326.15
Continuously Variable Valve Lift (CVVL)	CVVL	$393.78	$262.52	$393.78	$525.04
Cylinder Deactivation on DOHC	DEACD	$32.47	$32.47	$32.47	$32.47
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$402.68	$268.45	$402.68	$536.91
Cylinder Deactivation on OHV	DEACO	$207.75	$207.75	$207.75	$207.75
Variable Valve Actuation - CCP and DVVL on OHV	VVA	$103.86	$51.93	$103.86	$103.86
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	$402.68	$268.45	$402.68	$536.91
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	$493.60	$493.60	$493.60	$493.60
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	$19.39	$19.39	$19.39	$19.39
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	$620.79	$620.79	$620.79	$620.79
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	$26.06	$26.06	$26.06	$26.06
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	$262.37	$262.37	$262.37	$262.37
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	$442.27	$442.27	$442.27	$442.27
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	$302.18	$302.18	$302.18	$302.18
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	$524.75	$524.75	$524.75	$524.75
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	-$299.93	-$299.93	-$299.93	-$299.93
Advanced Diesel - Small Displacement	ADSL_SD	$888.62	$888.62	$888.62	$888.62
Advanced Diesel - Medium Displacement	ADSL_MD	$854.97	$854.97	$854.97	$854.97
Advanced Diesel - Large Displacement	ADSL_LD	$1,709.99	$1,709.99	$1,709.99	$1,709.99
6-Speed Manual/Improved Internals	6MAN	$279.19	$279.19	$279.19	$279.19

High Efficiency Gearbox (Manual)	HETRANSM	$250.87	$250.87	$250.87	$250.87
Improved Auto. Trans. Controls/Externals	IATC	$62.25	$62.25	$62.25	$62.25
6-Speed Trans with Improved Internals (Auto)	NAUTO	-$39.06	-$39.06	-$39.06	-$39.06
6-speed DCT	DCT	$0.00	-$74.51	$0.00	$0.00
8-Speed Trans (Auto or DCT)	8SPD	$80.32	$257.36	$80.32	$80.32
High Efficiency Gearbox (Auto or DCT)	HETRANS	$250.87	$250.87	$250.87	$250.87
Shift Optimizer	SHFTOPT	$1.67	$1.67	$1.67	$1.67
Electric Power Steering	EPS	$109.42	$109.42	$109.42	$109.42
Improved Accessories - Level 1	IACC1	$88.99	$88.99	$88.99	$88.99
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	$54.17	$54.17	$54.17	$54.17
12V Micro-Hybrid (Stop-Start)	MHEV	$414.00	$366.17	$424.17	$479.57
Integrated Starter Generator	ISG	$975.85	$975.85	$975.85	$975.85
Strong Hybrid - Level 1	SHEV1	$2,723.05	$2,204.77	$2,723.05	$3,110.95
Conversion from SHEV1 to SHEV2	SHEV1_2	$1,490.27	$1,222.53	$1,490.27	$876.90
Strong Hybrid - Level 2	SHEV2	$2,723.05	$2,204.77	$2,723.05	$3,110.95
Plug-in Hybrid - 30 mi range	PHEV1	$0.00	$12,828.40	$0.00	$0.00
Plug-in Hybrid	PHEV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$0.00	$2,207.55	$0.00	$0.00
Electric Vehicle (Early Adopter) - 100 mile range	EV2	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Early Adopter) - 150 mile range	EV3	$0.00	$0.00	$0.00	$0.00
Electric Vehicle (Broad Market) - 150 mile range	EV4	$0.00	$11,739.32	$0.00	$0.00
Fuel Cell Vehicle	FCV	$0.00	$0.00	$0.00	$0.00
Mass Reduction - Level 1	MR1	$0.08	$0.08	$0.08	$0.08
Mass Reduction - Level 2	MR2	$0.48	$0.48	$0.48	$0.48
Mass Reduction - Level 3	MR3	$0.94	$0.94	$0.94	$0.94
Mass Reduction - Level 4	MR4	$1.50	$1.50	$1.50	$1.50
Mass Reduction - Level 5	MR5	$2.10	$2.10	$2.10	$2.10
Low Rolling Resistance Tires - Level 1	ROLL1	$6.71	$6.71	$6.71	$6.71
Low Rolling Resistance Tires - Level 2	ROLL2	$73.16	$73.16	$73.16	$73.16
Low Rolling Resistance Tires - Level 3	ROLL3	$0.00	$0.00	$0.00	$0.00
Low Drag Brakes	LDB	$73.77	$73.77	$73.77	$73.77
Secondary Axle Disconnect	SAX	$97.67	$97.67	$97.67	$97.67
Aero Drag Reduction, Level 1	AERO1	$48.92	$48.92	$48.92	$48.92
Aero Drag Reduction, Level 2	AERO2	$164.44	$164.44	$164.44	$164.44

The tables representing the CAFE model input files for incremental technology effectiveness values by vehicle subclass are presented below. The tables have been divided into passenger cars, performance passenger cars, and light trucks to make them easier to read.

Table V-126 Technology Incremental Effectiveness Estimates, Passenger Cars

VEHICLE TECHNOLOGY INCREMENTAL FUEL CONSUMPTION REDUCTION (-%) BY VEHICLE SUBCLASS - PASSENGER CARS					
		Subcompact Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Low Friction Lubricants - Level 1	LUB1	0.50%	0.50%	0.70%	0.80%
Engine Friction Reduction - Level 1	EFR1	2.00%	2.00%	2.60%	2.70%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	1.04%	1.04%	1.26%	1.37%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	4.15%	4.15%	5.03%	5.36%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	2.81%	2.81%	3.64%	3.88%
Cylinder Deactivation on SOHC	DEACS	0.44%	0.44%	0.69%	0.69%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2.18%	2.18%	2.62%	2.73%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	2.01%	2.01%	2.47%	2.70%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	2.81%	2.81%	3.64%	3.88%
Continuously Variable Valve Lift (CVVL)	CVVL	3.57%	3.57%	4.63%	4.88%
Cylinder Deactivation on DOHC	DEACD	0.44%	0.44%	0.69%	0.69%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	1.56%	1.56%	1.50%	1.51%
Cylinder Deactivation on OHV	DEACO	4.66%	4.66%	5.86%	6.30%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	2.72%	2.72%	3.45%	3.59%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1.56%	1.56%	1.50%	1.51%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	7.20%	7.20%	8.29%	8.61%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	6.70%	6.70%	7.49%	7.79%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	6.70%	6.70%	7.49%	7.79%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	2.92%	2.92%	3.54%	3.71%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	2.92%	2.92%	3.54%	3.71%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displ.	TRBDS2_LD	2.92%	2.92%	3.54%	3.71%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	3.63%	3.63%	3.54%	3.46%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3.63%	3.63%	3.54%	3.46%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	3.63%	3.63%	3.54%	3.46%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	1.04%	1.04%	1.36%	1.38%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1.04%	1.04%	1.36%	1.38%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1.04%	1.04%	1.36%	1.38%
Advanced Diesel - Small Displacement	ADSL_SD	5.53%	5.53%	2.75%	2.89%
Advanced Diesel - Medium Displacement	ADSL_MD	5.53%	5.53%	2.75%	2.89%
Advanced Diesel - Large Displacement	ADSL_LD	5.53%	5.53%	2.75%	2.89%
6-Speed Manual/Improved Internals	6MAN	2.02%	2.02%	2.39%	2.34%
High Efficiency Gearbox (Manual)	HETRANSM	3.44%	3.44%	4.08%	3.85%
Improved Auto. Trans. Controls/Externals	IATC	2.30%	2.30%	3.00%	3.10%
6-Speed Trans with Improved Internals (Auto)	NAUTO	1.89%	1.89%	2.04%	2.04%
6-speed DCT	DCT	4.01%	4.01%	4.06%	3.75%
8-Speed Trans (Auto or DCT)	8SPD	3.85%	3.85%	4.57%	4.56%
High Efficiency Gearbox (Auto or DCT)	HETRANS	2.17%	2.17%	2.68%	2.56%
Shift Optimizer	SHFTOPT	3.27%	3.27%	4.08%	4.31%
Electric Power Steering	EPS	1.50%	1.50%	1.30%	1.10%
Improved Accessories - Level 1	IACC1	1.22%	1.22%	1.22%	1.01%
Improved Accessories - Level 2	IACC2	1.85%	1.85%	2.36%	2.55%
12V Micro-Hybrid (Stop-Start)	MHEV	1.68%	1.68%	2.10%	2.20%
Integrated Starter Generator	ISG	7.45%	7.45%	6.55%	6.43%
Strong Hybrid - Level 1	SHEV1	7.82%	7.82%	5.30%	6.14%
Conversion from SHEV1 to SHEV2	SHEV1_2	10.05%	10.05%	12.46%	12.63%
Strong Hybrid - Level 2	SHEV2	3.01%	3.01%	0.11%	0.63%
Plug-in Hybrid - 30 mi range	PHEV1	40.65%	40.65%	40.65%	40.65%
Plug-in Hybrid	PHEV2	0.00%	0.00%	0.00%	0.00%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	68.54%	68.54%	68.54%	68.54%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0.00%	0.00%	0.00%	0.00%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0.00%	0.00%	0.00%	0.00%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0.00%	0.00%	0.00%	0.00%

Fuel Cell Vehicle	FCV	0.00%	0.00%	0.00%	0.00%
Mass Reduction - Level 1	MR1	0.00%	0.00%	0.53%	0.53%
Mass Reduction - Level 2	MR2	0.00%	0.00%	0.70%	3.32%
Mass Reduction - Level 3	MR3	0.00%	0.00%	0.00%	1.33%
Mass Reduction - Level 4	MR4	0.00%	0.00%	0.00%	0.00%
Mass Reduction - Level 5	MR5	0.00%	0.00%	0.00%	0.00%
Low Rolling Resistance Tires - Level 1	ROLL1	1.90%	1.90%	1.90%	1.90%
Low Rolling Resistance Tires - Level 2	ROLL2	2.04%	2.04%	2.04%	2.04%
Low Rolling Resistance Tires - Level 3	ROLL3	0.00%	0.00%	0.00%	0.00%
Low Drag Brakes	LDB	0.80%	0.80%	0.80%	0.80%
Secondary Axle Disconnect	SAX	1.40%	1.40%	1.40%	1.30%
Aero Drag Reduction, Level 1	AERO1	2.30%	2.30%	2.30%	2.30%
Aero Drag Reduction, Level 2	AERO2	2.46%	2.46%	2.46%	2.46%

Table V-127 Technology Incremental Effectiveness Estimates, Performance Cars

VEHICLE TECHNOLOGY INCREMENTAL FUEL CONSUMPTION REDUCTION (-%) BY VEHICLE SUBCLASS - PERFORMANCE PASSENGER CARS					
		Performance Subcompact Car	Performance Compact Car	Performance Midsize Car	Performance Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Low Friction Lubricants - Level 1	LUB1	0.50%	0.50%	0.70%	0.80%
Engine Friction Reduction - Level 1	EFR1	2.00%	2.00%	2.60%	2.70%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	1.04%	1.04%	1.26%	1.37%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	4.15%	4.15%	5.03%	5.36%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	2.81%	2.81%	3.64%	3.88%
Cylinder Deactivation on SOHC	DEACS	0.44%	0.44%	0.69%	0.69%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2.18%	2.18%	2.62%	2.73%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	2.01%	2.01%	2.47%	2.70%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	2.81%	2.81%	3.64%	3.88%
Continuously Variable Valve Lift (CVVL)	CVVL	3.57%	3.57%	4.63%	4.88%
Cylinder Deactivation on DOHC	DEACD	0.44%	0.44%	0.69%	0.69%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	1.56%	1.56%	1.50%	1.51%
Cylinder Deactivation on OHV	DEACO	4.66%	4.66%	5.86%	6.30%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	2.72%	2.72%	3.45%	3.59%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1.56%	1.56%	1.50%	1.51%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	7.20%	7.20%	8.29%	8.61%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	6.70%	6.70%	7.49%	7.79%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	6.70%	6.70%	7.49%	7.79%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	2.92%	2.92%	3.54%	3.71%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	2.92%	2.92%	3.54%	3.71%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displ.	TRBDS2_LD	2.92%	2.92%	3.54%	3.71%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	3.63%	3.63%	3.54%	3.46%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3.63%	3.63%	3.54%	3.46%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	3.63%	3.63%	3.54%	3.46%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	1.04%	1.04%	1.36%	1.38%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1.04%	1.04%	1.36%	1.38%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1.04%	1.04%	1.36%	1.38%
Advanced Diesel - Small Displacement	ADSL_SD	5.53%	5.53%	2.75%	2.89%
Advanced Diesel - Medium Displacement	ADSL_MD	5.53%	5.53%	2.75%	2.89%
Advanced Diesel - Large Displacement	ADSL_LD	5.53%	5.53%	2.75%	2.89%
6-Speed Manual/Improved Internals	6MAN	2.02%	2.02%	2.39%	2.34%
High Efficiency Gearbox (Manual)	HETRANSM	3.44%	3.44%	4.08%	3.85%
Improved Auto. Trans. Controls/Externals	IATC	2.30%	2.30%	3.00%	3.10%
6-Speed Trans with Improved Internals (Auto)	NAUTO	1.89%	1.89%	2.04%	2.04%
6-speed DCT	DCT	3.38%	3.38%	4.06%	3.75%
8-Speed Trans (Auto or DCT)	8SPD	4.48%	4.48%	4.57%	4.56%
High Efficiency Gearbox (Auto or DCT)	HETRANS	2.17%	2.17%	2.68%	2.56%
Shift Optimizer	SHFTOPT	3.27%	3.27%	4.08%	4.31%
Electric Power Steering	EPS	1.50%	1.50%	1.30%	1.10%
Improved Accessories - Level 1	IACC1	1.22%	1.22%	1.22%	1.01%
Improved Accessories - Level 2	IACC2	1.85%	1.85%	2.36%	2.55%
12V Micro-Hybrid (Stop-Start)	MHEV	1.68%	1.68%	2.10%	2.20%
Integrated Starter Generator	ISG	7.45%	7.45%	6.55%	6.43%
Strong Hybrid - Level 1	SHEV1	7.82%	7.82%	5.30%	6.14%
Conversion from SHEV1 to SHEV2	SHEV1_2	10.05%	10.05%	12.46%	12.63%
Strong Hybrid - Level 2	SHEV2	3.01%	3.01%	0.11%	0.63%
Plug-in Hybrid - 30 mi range	PHEV1	40.65%	40.65%	40.65%	40.65%
Plug-in Hybrid	PHEV2	0.00%	0.00%	0.00%	0.00%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	68.54%	68.54%	68.54%	68.54%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0.00%	0.00%	0.00%	0.00%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0.00%	0.00%	0.00%	0.00%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0.00%	0.00%	0.00%	0.00%
Fuel Cell Vehicle	FCV	0.00%	0.00%	0.00%	0.00%
Mass Reduction - Level 1	MR1	0.00%	0.00%	0.53%	0.53%
Mass Reduction - Level 2	MR2	0.00%	0.00%	0.70%	3.32%

Mass Reduction - Level 3	MR3	0.00%	0.00%	0.00%	1.33%
Mass Reduction - Level 4	MR4	0.00%	0.00%	0.00%	0.00%
Mass Reduction - Level 5	MR5	0.00%	0.00%	0.00%	0.00%
Low Rolling Resistance Tires - Level 1	ROLL1	1.90%	1.90%	1.90%	1.90%
Low Rolling Resistance Tires - Level 2	ROLL2	2.04%	2.04%	2.04%	2.04%
Low Rolling Resistance Tires - Level 3	ROLL3	0.00%	0.00%	0.00%	0.00%
Low Drag Brakes	LDB	0.80%	0.80%	0.80%	0.80%
Secondary Axle Disconnect	SAX	1.40%	1.40%	1.40%	1.30%
Aero Drag Reduction, Level 1	AERO1	2.30%	2.30%	2.30%	2.30%
Aero Drag Reduction, Level 2	AERO2	2.46%	2.46%	2.46%	2.46%

Table V-128 Technology Incremental Effectiveness Estimates, Light Trucks

VEHICLE TECHNOLOGY INCREMENTAL FUEL CONSUMPTION REDUCTION (-%) BY VEHICLE SUBCLASS - LIGHT TRUCKS					
		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Low Friction Lubricants - Level 1	LUB1	0.70%	0.60%	0.70%	0.70%
Engine Friction Reduction - Level 1	EFR1	2.60%	2.00%	2.60%	2.40%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	1.26%	0.83%	1.26%	1.15%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	5.03%	4.14%	5.03%	4.80%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	3.53%	2.81%	3.53%	3.40%
Cylinder Deactivation on SOHC	DEACS	0.69%	0.44%	0.69%	0.57%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2.51%	2.17%	2.51%	2.51%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	2.58%	2.01%	2.58%	2.36%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	3.53%	2.81%	3.53%	3.40%
Continuously Variable Valve Lift (CVVL)	CVVL	4.52%	3.56%	4.52%	4.28%
Cylinder Deactivation on DOHC	DEACD	0.69%	0.44%	0.69%	0.57%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	1.50%	1.56%	1.50%	1.48%
Cylinder Deactivation on OHV	DEACO	5.86%	4.66%	5.86%	5.53%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3.34%	2.71%	3.34%	3.20%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1.50%	1.56%	1.50%	1.48%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	8.74%	7.08%	8.74%	7.96%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	7.94%	6.58%	7.94%	7.30%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	7.94%	6.58%	7.94%	7.30%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	3.43%	2.91%	3.43%	3.38%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	3.43%	2.91%	3.43%	3.38%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	3.43%	2.91%	3.43%	3.38%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	3.55%	3.63%	3.55%	3.62%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3.55%	3.63%	3.55%	3.62%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	3.55%	3.63%	3.55%	3.62%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	1.09%	1.04%	1.09%	1.21%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1.09%	1.04%	1.09%	1.21%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1.09%	1.04%	1.09%	1.21%
Advanced Diesel - Small Displacement	ADSL_SD	3.44%	5.31%	3.44%	3.48%
Advanced Diesel - Medium Displacement	ADSL_MD	3.44%	5.31%	3.44%	3.48%
Advanced Diesel - Large Displacement	ADSL_LD	3.44%	5.31%	3.44%	3.48%
6-Speed Manual/Improved Internals	6MAN	2.24%	2.21%	2.24%	2.52%
High Efficiency Gearbox (Manual)	HETRANSM	3.71%	3.90%	3.71%	4.45%
Improved Auto. Trans. Controls/Externals	IATC	2.90%	2.40%	2.90%	2.90%
6-Speed Trans with Improved Internals (Auto)	NAUTO	2.03%	2.00%	2.03%	2.13%
6-speed DCT	DCT	0.00%	3.81%	0.00%	0.00%
8-Speed Trans (Auto or DCT)	8SPD	4.90%	4.18%	4.90%	5.34%
High Efficiency Gearbox (Auto or DCT)	HETRANS	3.14%	2.52%	3.14%	3.72%
Shift Optimizer	SHFTOPT	4.05%	3.29%	4.05%	3.86%
Electric Power Steering	EPS	1.00%	1.20%	1.00%	0.80%
Improved Accessories - Level 1	IACC1	0.91%	1.01%	0.91%	1.61%
Improved Accessories - Level 2	IACC2	2.34%	1.74%	2.34%	2.15%
12V Micro-Hybrid (Stop-Start)	MHEV	2.09%	1.77%	2.09%	2.09%
Integrated Starter Generator	ISG	5.65%	6.14%	5.65%	2.99%
Strong Hybrid - Level 1	SHEV1	-0.33%	8.24%	-0.33%	1.06%
Conversion from SHEV1 to SHEV2	SHEV1_2	17.13%	10.93%	17.13%	17.87%
Strong Hybrid - Level 2	SHEV2	-0.33%	4.25%	-0.33%	1.59%
Plug-in Hybrid - 30 mi range	PHEV1	40.65%	40.65%	40.65%	40.65%
Plug-in Hybrid	PHEV2	0.00%	0.00%	0.00%	0.00%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	68.54%	68.54%	68.54%	68.54%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0.00%	0.00%	0.00%	0.00%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0.00%	0.00%	0.00%	0.00%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0.00%	0.00%	0.00%	0.00%
Fuel Cell Vehicle	FCV	0.00%	0.00%	0.00%	0.00%
Mass Reduction - Level 1	MR1	0.53%	0.53%	0.53%	0.53%
Mass Reduction - Level 2	MR2	3.32%	3.32%	3.32%	3.32%
Mass Reduction - Level 3	MR3	1.33%	1.33%	1.33%	1.33%

Mass Reduction - Level 4	MR4	2.69%	2.69%	2.69%	2.69%
Mass Reduction - Level 5	MR5	2.76%	2.76%	2.76%	2.76%
Low Rolling Resistance Tires - Level 1	ROLL1	1.90%	1.90%	1.90%	1.90%
Low Rolling Resistance Tires - Level 2	ROLL2	2.04%	2.04%	2.04%	2.04%
Low Rolling Resistance Tires - Level 3	ROLL3	0.00%	0.00%	0.00%	0.00%
Low Drag Brakes	LDB	0.80%	0.80%	0.80%	0.80%
Secondary Axle Disconnect	SAX	1.30%	1.40%	1.30%	1.60%
Aero Drag Reduction, Level 1	AERO1	2.30%	2.30%	2.30%	2.30%
Aero Drag Reduction, Level 2	AERO2	2.46%	2.46%	2.46%	2.46%

The following tables representing the CAFE model input files for MY 2017, MY 2021 and MY 2025 approximate net (accumulated) technology costs by vehicle subclass are presented below. The tables have been divided into passenger cars, performance passenger cars, and light trucks to make them easier to read.

Table V-129 MY 2017 Approximate Net (Accumulated) Technology Costs, Passenger Cars, 2008 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Subcompact Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$638	$638	$638	$961
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$1,131	$1,131	$1,131	$981
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,157	$1,157	$1,157	$1,243
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,460	$1,460	$1,460	$1,545
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,984	$1,984	$1,984	$2,070
Advanced Diesel	ADSL	$2,873	$2,873	$2,873	$2,925
6-speed DCT	DCT	($85)	($85)	($51)	($51)
8-Speed Trans (Auto or DCT)	8SPD	$172	$172	$206	$206
Shift Optimizer	SHFTOPT	$424	$424	$459	$459
12V Micro-Hybrid (Stop-Start)	MHEV	$577	$604	$638	$667
Mild Hybrid (Integrated Starter Generator)	ISG	$1,553	$1,579	$1,614	$1,642
Strong Hybrid - Level 2	SHEV2	$5,860	$5,887	$6,347	$7,134
Plug-in Hybrid - 30 mi range	PHEV1	$16,658	$16,685	$19,407	$25,129
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$18,951	$18,977	$22,984	$29,535
Electric Vehicle (Broad Market) - 150 mile range	EV4	$27,274	$27,301	$33,510	$39,117

Table V-130 MY 2017 Approximate Net (Accumulated) Technology Costs, Passenger Cars, 2010 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Subcompact Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$638	$638	$638	$961
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$1,131	$1,131	$1,131	$981
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,157	$1,157	$1,157	$1,243
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,460	$1,460	$1,460	$1,545
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,984	$1,984	$1,984	$2,070

Advanced Diesel	ADSL	$2,873	$2,873	$2,873	$2,925
6-speed DCT	DCT	($85)	($85)	($51)	($51)
8-Speed Trans (Auto or DCT)	8SPD	$172	$172	$206	$206
Shift Optimizer	SHFTOPT	$424	$424	$459	$459
12V Micro-Hybrid (Stop-Start)	MHEV	$577	$604	$638	$667
Mild Hybrid (Integrated Starter Generator)	ISG	$1,553	$1,579	$1,614	$1,642
Strong Hybrid - Level 2	SHEV2	$5,882	$5,909	$6,391	$7,225
Plug-in Hybrid - 30 mi range	PHEV1	$16,925	$16,952	$19,839	$25,763
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$19,341	$19,368	$23,550	$30,377
Electric Vehicle (Broad Market) - 150 mile range	EV4	$27,988	$28,014	$34,199	$40,272

Table V-131 MY 2017 Approximate Net (Accumulated) Technology Costs, Performance Passenger Cars, 2008 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Performance Subcompact Car	Performance Compact Car	Performance Midsize Car	Performance Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$638	$961	$961	$1,239
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$1,131	$981	$981	$1,860
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,157	$1,243	$1,243	$2,302
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,460	$1,545	$1,545	$2,604
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,984	$2,070	$2,070	$2,304
Advanced Diesel	ADSL	$2,873	$2,925	$2,925	$4,014
6-speed DCT	DCT	($51)	($51)	($51)	($51)
8-Speed Trans (Auto or DCT)	8SPD	$206	$206	$206	$206
Shift Optimizer	SHFTOPT	$459	$459	$459	$459
12V Micro-Hybrid (Stop-Start)	MHEV	$577	$604	$638	$667
Mild Hybrid (Integrated Starter Generator)	ISG	$1,553	$1,579	$1,614	$1,642
Strong Hybrid - Level 2	SHEV2	$5,895	$6,007	$6,433	$7,368
Plug-in Hybrid - 30 mi range	PHEV1	$16,692	$16,805	$19,493	$25,363
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$18,985	$19,097	$23,070	$29,769
Electric Vehicle (Broad Market) - 150 mile range	EV4	$27,308	$27,421	$33,596	$39,351

Table V-132 MY 2017 Approximate Net (Accumulated) Technology Costs, Performance Passenger Cars, 2010 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Performance Subcompact Car	Performance Compact Car	Performance Midsize Car	Performance Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$638	$961	$961	$1,239
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$1,131	$981	$981	$1,860
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,157	$1,243	$1,243	$2,302
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,460	$1,545	$1,545	$2,604
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,984	$2,070	$2,070	$2,304
Advanced Diesel	ADSL	$2,873	$2,925	$2,925	$4,014
6-speed DCT	DCT	($51)	($51)	($51)	($51)
8-Speed Trans (Auto or DCT)	8SPD	$206	$206	$206	$206
Shift Optimizer	SHFTOPT	$459	$459	$459	$459
12V Micro-Hybrid (Stop-Start)	MHEV	$577	$604	$638	$667
Mild Hybrid (Integrated Starter Generator)	ISG	$1,553	$1,579	$1,614	$1,642
Strong Hybrid - Level 2	SHEV2	$5,916	$6,029	$6,476	$7,459
Plug-in Hybrid - 30 mi range	PHEV1	$16,959	$17,072	$19,925	$25,997
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$19,375	$19,488	$23,636	$30,611
Electric Vehicle (Broad Market) - 150 mile range	EV4	$28,022	$28,134	$34,285	$40,506

Table V-133 MY 2017 Approximate Net (Accumulated) Technology Costs, Light Trucks, 2008 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$961	$638	$961	$1,239
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$981	$1,131	$981	$1,860
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,243	$1,157	$1,243	$2,302
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,545	$1,460	$1,545	$2,604
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$2,070	$1,984	$2,070	$2,304
Advanced Diesel	ADSL	$2,925	$2,873	$2,925	$4,014
6-speed DCT	DCT	$23	($51)	$23	$23
8-Speed Trans (Auto or DCT)	8SPD	$104	$206	$104	$104

Shift Optimizer	SHFTOPT	$356	$459	$356	$356
12V Micro-Hybrid (Stop-Start)	MHEV	$667	$619	$677	$732
Mild Hybrid (Integrated Starter Generator)	ISG	$1,642	$1,595	$1,653	$1,708
Strong Hybrid - Level 2	SHEV2	$6,758	$6,179	$6,768	$7,437
Plug-in Hybrid - 30 mi range	PHEV1	-	$18,553	-	-
Electric Vehicle (Early Adopter) - 75 mile range	EV1	-	$20,841	-	-
Electric Vehicle (Broad Market) - 150 mile range	EV4	-	$32,443	-	-

Table V-134 MY 2017 Approximate Net (Accumulated) Technology Costs, Light Trucks, 2010 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2017 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$961	$638	$961	$1,239
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$981	$1,131	$981	$1,860
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,243	$1,157	$1,243	$2,302
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,545	$1,460	$1,545	$2,604
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$2,070	$1,984	$2,070	$2,304
Advanced Diesel	ADSL	$2,925	$2,873	$2,925	$4,014
6-speed DCT	DCT	$23	($51)	$23	$23
8-Speed Trans (Auto or DCT)	8SPD	$104	$206	$104	$104
Shift Optimizer	SHFTOPT	$356	$459	$356	$356
12V Micro-Hybrid (Stop-Start)	MHEV	$667	$619	$677	$732
Mild Hybrid (Integrated Starter Generator)	ISG	$1,642	$1,595	$1,653	$1,708
Strong Hybrid - Level 2	SHEV2	$6,792	$6,242	$6,802	$7,479
Plug-in Hybrid - 30 mi range	PHEV1	-	$19,071	-	-
Electric Vehicle (Early Adopter) - 75 mile range	EV1	-	$21,278	-	-
Electric Vehicle (Broad Market) - 150 mile range	EV4	-	$33,018	-	-

Table V-135 MY 2021 Approximate Net (Accumulated) Technology Costs, Passenger Cars, 2008 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2021 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES				
Final technology (as compared to baseline vehicle prior to technology application)	Subcompact Car	Compact Car	Midsize Car	Large Car

Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$569	$569	$569	$859
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$989	$989	$989	$830
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,009	$1,009	$1,009	$1,077
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,295	$1,295	$1,295	$1,362
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,790	$1,790	$1,790	$1,858
Advanced Diesel	ADSL	$2,701	$2,701	$2,701	$2,785
6-speed DCT	DCT	($98)	($98)	($61)	($61)
8-Speed Trans (Auto or DCT)	8SPD	$126	$126	$162	$162
Shift Optimizer	SHFTOPT	$355	$355	$391	$391
12V Micro-Hybrid (Stop-Start)	MHEV	$502	$525	$554	$578
Mild Hybrid (Integrated Starter Generator)	ISG	$1,397	$1,419	$1,448	$1,472
Strong Hybrid - Level 2	SHEV2	$5,042	$5,065	$5,459	$6,115
Plug-in Hybrid - 30 mi range	PHEV1	$13,090	$13,113	$15,185	$19,528
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$14,594	$14,616	$17,841	$22,958
Electric Vehicle (Broad Market) - 150 mile range	EV4	$20,668	$20,691	$25,522	$29,950

Table V-136 MY 2021 Approximate Net (Accumulated) Technology Costs, Passenger Cars, 2010 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2021 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Subcompact Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$569	$569	$569	$859
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$989	$989	$989	$830
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,009	$1,009	$1,009	$1,077
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,295	$1,295	$1,295	$1,362
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,790	$1,790	$1,790	$1,858
Advanced Diesel	ADSL	$2,701	$2,701	$2,701	$2,785
6-speed DCT	DCT	($98)	($98)	($61)	($61)
8-Speed Trans (Auto or DCT)	8SPD	$126	$126	$162	$162
Shift Optimizer	SHFTOPT	$355	$355	$391	$391
12V Micro-Hybrid (Stop-Start)	MHEV	$502	$525	$554	$578
Mild Hybrid (Integrated Starter Generator)	ISG	$1,397	$1,419	$1,448	$1,472
Strong Hybrid - Level 2	SHEV2	$5,061	$5,083	$5,496	$6,191
Plug-in Hybrid - 30 mi range	PHEV1	$13,292	$13,315	$15,515	$20,013
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$14,899	$14,921	$18,293	$23,628

Electric Vehicle (Broad Market) - 150 mile range	EV4	$21,209	$21,231	$26,064	$30,848

Table V-137 MY 2021 Approximate Net (Accumulated) Technology Costs, Performance Passenger Cars, 2008 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2021 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Performance Subcompact Car	Performance Compact Car	Performance Midsize Car	Performance Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$569	$859	$859	$1,107
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$989	$830	$830	$1,630
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,009	$1,077	$1,077	$2,048
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,295	$1,362	$1,362	$2,333
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,790	$1,858	$1,858	$2,036
Advanced Diesel	ADSL	$2,701	$2,785	$2,785	$3,848
6-speed DCT	DCT	($61)	($61)	($61)	($61)
8-Speed Trans (Auto or DCT)	8SPD	$162	$162	$162	$162
Shift Optimizer	SHFTOPT	$391	$391	$391	$391
12V Micro-Hybrid (Stop-Start)	MHEV	$502	$525	$554	$578
Mild Hybrid (Integrated Starter Generator)	ISG	$1,397	$1,419	$1,448	$1,472
Strong Hybrid - Level 2	SHEV2	$5,078	$5,169	$5,527	$6,294
Plug-in Hybrid - 30 mi range	PHEV1	$13,126	$13,217	$15,253	$19,707
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$14,630	$14,720	$17,909	$23,136
Electric Vehicle (Broad Market) - 150 mile range	EV4	$20,705	$20,795	$25,590	$30,129

Table V-138 MY 2021 Approximate Net (Accumulated) Technology Costs, Performance Passenger Cars, 2010 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2021 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Performance Subcompact Car	Performance Compact Car	Performance Midsize Car	Performance Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$569	$859	$859	$1,107
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$989	$830	$830	$1,630
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,009	$1,077	$1,077	$2,048
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,295	$1,362	$1,362	$2,333
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,790	$1,858	$1,858	$2,036

Advanced Diesel	ADSL	$2,701	$2,785	$2,785	$3,848
6-speed DCT	DCT	($61)	($61)	($61)	($61)
8-Speed Trans (Auto or DCT)	8SPD	$162	$162	$162	$162
Shift Optimizer	SHFTOPT	$391	$391	$391	$391
12V Micro-Hybrid (Stop-Start)	MHEV	$502	$525	$554	$578
Mild Hybrid (Integrated Starter Generator)	ISG	$1,397	$1,419	$1,448	$1,472
Strong Hybrid - Level 2	SHEV2	$5,097	$5,188	$5,563	$6,370
Plug-in Hybrid - 30 mi range	PHEV1	$13,329	$13,419	$15,583	$20,192
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$14,935	$15,025	$18,361	$23,807
Electric Vehicle (Broad Market) - 150 mile range	EV4	$21,245	$21,335	$26,132	$31,027

Table V-139 MY 2021 Approximate Net (Accumulated) Technology Costs, Light Trucks, 2008 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2021 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$859	$569	$859	$1,107
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$830	$989	$830	$1,630
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,077	$1,009	$1,077	$2,048
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,362	$1,295	$1,362	$2,333
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,858	$1,790	$1,858	$2,036
Advanced Diesel	ADSL	$2,785	$2,701	$2,785	$3,848
6-speed DCT	DCT	$18	($61)	$18	$18
8-Speed Trans (Auto or DCT)	8SPD	$88	$162	$88	$88
Shift Optimizer	SHFTOPT	$317	$391	$317	$317
12V Micro-Hybrid (Stop-Start)	MHEV	$578	$538	$587	$633
Mild Hybrid (Integrated Starter Generator)	ISG	$1,472	$1,432	$1,481	$1,528
Strong Hybrid - Level 2	SHEV2	$5,811	$5,320	$5,819	$6,374
Plug-in Hybrid - 30 mi range	PHEV1	-	$14,527	-	-
Electric Vehicle (Early Adopter) - 75 mile range	EV1	-	$15,864	-	-
Electric Vehicle (Broad Market) - 150 mile range	EV4	-	$24,331	-	-

Table V-140 MY 2021 Approximate Net (Accumulated) Technology Costs, Light Trucks, 2010 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2021 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES

Final technology (as compared to baseline vehicle prior to technology application)		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$859	$569	$859	$1,107
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$830	$989	$830	$1,630
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,077	$1,009	$1,077	$2,048
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,362	$1,295	$1,362	$2,333
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,858	$1,790	$1,858	$2,036
Advanced Diesel	ADSL	$2,785	$2,701	$2,785	$3,848
6-speed DCT	DCT	$18	($61)	$18	$18
8-Speed Trans (Auto or DCT)	8SPD	$88	$162	$88	$88
Shift Optimizer	SHFTOPT	$317	$391	$317	$317
12V Micro-Hybrid (Stop-Start)	MHEV	$578	$538	$587	$633
Mild Hybrid (Integrated Starter Generator)	ISG	$1,472	$1,432	$1,481	$1,528
Strong Hybrid - Level 2	SHEV2	$5,838	$5,372	$5,847	$6,409
Plug-in Hybrid - 30 mi range	PHEV1	-	$14,922	-	-
Electric Vehicle (Early Adopter) - 75 mile range	EV1	-	$16,230	-	-
Electric Vehicle (Broad Market) - 150 mile range	EV4	-	$24,797	-	-

Table V-141 MY 2025 Approximate Net (Accumulated) Technology Costs, Passenger Cars, 2008 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2025 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Subcompact Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$540	$540	$540	$815
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$938	$938	$938	$797
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$943	$943	$943	$1,011
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,190	$1,190	$1,190	$1,258
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,618	$1,618	$1,618	$1,686
Advanced Diesel	ADSL	$2,320	$2,320	$2,320	$2,415
6-speed DCT	DCT	($84)	($84)	($52)	($52)
8-Speed Trans (Auto or DCT)	8SPD	$126	$126	$158	$158
Shift Optimizer	SHFTOPT	$330	$330	$362	$362
12V Micro-Hybrid (Stop-Start)	MHEV	$461	$482	$508	$530
Mild Hybrid (Integrated Starter Generator)	ISG	$1,186	$1,206	$1,233	$1,255
Strong Hybrid - Level 2	SHEV2	$4,512	$4,532	$4,882	$5,472
Plug-in Hybrid - 30 mi range	PHEV1	$10,933	$10,954	$12,654	$16,240
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$11,374	$11,394	$13,842	$17,701
Electric Vehicle (Broad Market) - 150 mile range	EV4	$15,834	$15,854	$19,482	$22,835

Table V-142 MY 2025 Approximate Net (Accumulated) Technology Costs, Passenger Cars, 2010 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2025 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Subcompact Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$540	$540	$540	$815
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$938	$938	$938	$797
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$943	$943	$943	$1,011
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,190	$1,190	$1,190	$1,258
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,618	$1,618	$1,618	$1,686
Advanced Diesel	ADSL	$2,320	$2,320	$2,320	$2,415
6-speed DCT	DCT	($84)	($84)	($52)	($52)
8-Speed Trans (Auto or DCT)	8SPD	$126	$126	$158	$158
Shift Optimizer	SHFTOPT	$330	$330	$362	$362
12V Micro-Hybrid (Stop-Start)	MHEV	$461	$482	$508	$530
Mild Hybrid (Integrated Starter Generator)	ISG	$1,186	$1,206	$1,233	$1,255
Strong Hybrid - Level 2	SHEV2	$4,528	$4,549	$4,914	$5,540
Plug-in Hybrid - 30 mi range	PHEV1	$11,099	$11,120	$12,929	$16,648
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$11,603	$11,623	$14,184	$18,206
Electric Vehicle (Broad Market) - 150 mile range	EV4	$16,235	$16,256	$19,889	$23,508

Table V-143 MY 2025 Approximate Net (Accumulated) Technology Costs, Performance Passenger Cars, 2008 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2025 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Perf. Subcompact Car	Perf. Compact Car	Perf. Midsize Car	Perf. Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$540	$815	$815	$1,050
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$938	$797	$797	$1,543
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$943	$1,011	$1,011	$1,904
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,190	$1,258	$1,258	$2,151
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,618	$1,686	$1,686	$1,862
Advanced Diesel	ADSL	$2,320	$2,415	$2,415	$3,364
6-speed DCT	DCT	($52)	($52)	($52)	($52)
8-Speed Trans (Auto or DCT)	8SPD	$158	$158	$158	$158

Shift Optimizer	SHFTOPT	$362	$362	$362	$362
12V Micro-Hybrid (Stop-Start)	MHEV	$461	$482	$508	$530
Mild Hybrid (Integrated Starter Generator)	ISG	$1,186	$1,206	$1,233	$1,255
Strong Hybrid - Level 2	SHEV2	$4,544	$4,633	$4,950	$5,647
Plug-in Hybrid - 30 mi range	PHEV1	$10,965	$11,054	$12,722	$16,416
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$11,406	$11,495	$13,910	$17,876
Electric Vehicle (Broad Market) - 150 mile range	EV4	$15,866	$15,955	$19,550	$23,011

Table V-144 MY 2025 Approximate Net (Accumulated) Technology Costs, Performance Passenger Cars, 2010 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2025 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Perf. Subcompact Car	Perf. Compact Car	Perf. Midsize Car	Perf. Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$540	$815	$815	$1,050
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$938	$797	$797	$1,543
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$943	$1,011	$1,011	$1,904
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,190	$1,258	$1,258	$2,151
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,618	$1,686	$1,686	$1,862
Advanced Diesel	ADSL	$2,320	$2,415	$2,415	$3,364
6-speed DCT	DCT	($52)	($52)	($52)	($52)
8-Speed Trans (Auto or DCT)	8SPD	$158	$158	$158	$158
Shift Optimizer	SHFTOPT	$362	$362	$362	$362
12V Micro-Hybrid (Stop-Start)	MHEV	$461	$482	$508	$530
Mild Hybrid (Integrated Starter Generator)	ISG	$1,186	$1,206	$1,233	$1,255
Strong Hybrid - Level 2	SHEV2	$4,560	$4,649	$4,982	$5,716
Plug-in Hybrid - 30 mi range	PHEV1	$11,132	$11,220	$12,997	$16,824
Electric Vehicle (Early Adopter) - 75 mile range	EV1	$11,635	$11,723	$14,252	$18,382
Electric Vehicle (Broad Market) - 150 mile range	EV4	$16,267	$16,356	$19,957	$23,683

Table V-145 MY 2025 Approximate Net (Accumulated) Technology Costs, Light Trucks, 2008 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2025 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$815	$540	$815	$1,050

Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$797	$938	$797	$1,543
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,011	$943	$1,011	$1,904
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,258	$1,190	$1,258	$2,151
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,686	$1,618	$1,686	$1,862
Advanced Diesel	ADSL	$2,415	$2,320	$2,415	$3,364
6-speed DCT	DCT	$18	($52)	$18	$18
8-Speed Trans (Auto or DCT)	8SPD	$84	$158	$84	$84
Shift Optimizer	SHFTOPT	$287	$362	$287	$287
12V Micro-Hybrid (Stop-Start)	MHEV	$530	$493	$538	$581
Mild Hybrid (Integrated Starter Generator)	ISG	$1,255	$1,218	$1,263	$1,305
Strong Hybrid - Level 2	SHEV2	$5,195	$4,756	$5,202	$5,699
Plug-in Hybrid - 30 mi range	PHEV1	-	$12,092	-	-
Electric Vehicle (Early Adopter) - 75 mile range	EV1	-	$12,285	-	-
Electric Vehicle (Broad Market) - 150 mile range	EV4	-	$18,501	-	-

Table V-146 MY 2025 Approximate Net (Accumulated) Technology Costs, Light Trucks, 2010 Baseline

APPROXIMATE ICM NET COSTS PER VEHICLE (for MY 2025 in 2010 dollars) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	$815	$540	$815	$1,050
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	$797	$938	$797	$1,543
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	$1,011	$943	$1,011	$1,904
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	$1,258	$1,190	$1,258	$2,151
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	$1,686	$1,618	$1,686	$1,862
Advanced Diesel	ADSL	$2,415	$2,320	$2,415	$3,364
6-speed DCT	DCT	$18	($52)	$18	$18
8-Speed Trans (Auto or DCT)	8SPD	$84	$158	$84	$84
Shift Optimizer	SHFTOPT	$287	$362	$287	$287
12V Micro-Hybrid (Stop-Start)	MHEV	$530	$493	$538	$581
Mild Hybrid (Integrated Starter Generator)	ISG	$1,255	$1,218	$1,263	$1,305
Strong Hybrid - Level 2	SHEV2	$5,220	$4,803	$5,228	$5,731
Plug-in Hybrid - 30 mi range	PHEV1	-	$12,420	-	-
Electric Vehicle (Early Adopter) - 75 mile range	EV1	-	$12,568	-	-
Electric Vehicle (Broad Market) - 150 mile range	EV4	-	$18,858	-	-

The following tables representing the CAFE model input files for approximate net (accumulated) technology effectiveness values by vehicle subclass are presented below. The tables have been divided into passenger cars, performance passenger cars, and light trucks to make them easier to read.

Table V-147 Approximate Net Technology Effectiveness, Passenger Cars

APPROXIMATE NET EFFECTIVENESS ESTIMATES (FC REDUCTION) PER VEHILCE (-%) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Subcompact Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	11.9%	11.9%	14.5%	15.3%
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	17.8%	17.8%	20.9%	21.9%
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	20.2%	20.2%	23.7%	24.8%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	23.1%	23.1%	26.4%	27.4%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	23.9%	23.9%	27.4%	28.4%
Advanced Diesel	ADSL	28.1%	28.1%	29.4%	30.5%
6-speed DCT	DCT	8.0%	8.0%	8.8%	8.6%
8-Speed Trans (Auto or DCT)	8SPD	11.5%	11.5%	13.0%	12.8%
Shift Optimizer	SHFTOPT	16.3%	16.3%	18.8%	18.7%
12V Micro-Hybrid (Stop-Start)	MHEV	6.1%	6.1%	6.8%	6.7%
Mild Hybrid (Integrated Starter Generator)	ISG	13.1%	13.1%	12.9%	12.7%
Strong Hybrid - Level 2	SHEV2	46.3%	46.3%	48.7%	49.5%
Plug-in Hybrid - 30 mi range	PHEV1	68.1%	68.1%	69.6%	70.0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	90.0%	90.0%	90.4%	90.6%
Electric Vehicle (Broad Market) - 150 mile range	EV4	90.0%	90.0%	90.4%	90.6%

Table V-148 Approximate Net Technology Effectiveness, Performance Passenger Cars

APPROXIMATE NET EFFECTIVENESS ESTIMATES (FC REDUCTION) PER VEHILCE (-%) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Perf. Subcompact Car	Perf. Compact Car	Perf. Midsize Car	Perf. Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	11.9%	11.9%	14.5%	15.3%
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	17.8%	17.8%	20.9%	21.9%
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	20.2%	20.2%	23.7%	24.8%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	23.1%	23.1%	26.4%	27.4%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	23.9%	23.9%	27.4%	28.4%
Advanced Diesel	ADSL	28.1%	28.1%	29.4%	30.5%

6-speed DCT	DCT	7.4%	7.4%	8.8%	8.6%
8-Speed Trans (Auto or DCT)	8SPD	11.5%	11.5%	13.0%	12.8%
Shift Optimizer	SHFTOPT	16.3%	16.3%	18.8%	18.7%
12V Micro-Hybrid (Stop-Start)	MHEV	6.1%	6.1%	6.8%	6.7%
Mild Hybrid (Integrated Starter Generator)	ISG	13.1%	13.1%	12.9%	12.7%
Strong Hybrid - Level 2	SHEV2	46.3%	46.3%	48.7%	49.5%
Plug-in Hybrid - 30 mi range	PHEV1	68.1%	68.1%	69.6%	70.0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	90.0%	90.0%	90.4%	90.6%
Electric Vehicle (Broad Market) - 150 mile range	EV4	90.0%	90.0%	90.4%	90.6%

Table V-149 Approximate Net Technology Effectiveness, Light Trucks

APPROXIMATE NET EFFECTIVENESS ESTIMATES (FC REDUCTION) PER VEHILCE (-%) BY VEHICLE SUBCLASS TO KEY TECHNOLOGIES					
Final technology (as compared to baseline vehicle prior to technology application)		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	14.4%	11.8%	14.4%	13.7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP)	TRBDS1	21.2%	17.6%	21.2%	20.0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP)	TRBDS2	23.9%	20.0%	23.9%	22.7%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP)	CEGR1	26.6%	22.9%	26.6%	25.5%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP)	CEGR2	27.4%	23.7%	27.4%	26.4%
Advanced Diesel	ADSL	29.9%	27.8%	29.9%	29.0%
6-speed DCT	DCT	4.9%	8.0%	4.9%	5.0%
8-Speed Trans (Auto or DCT)	8SPD	9.5%	11.8%	9.5%	10.0%
Shift Optimizer	SHFTOPT	15.9%	16.9%	15.9%	16.7%
12V Micro-Hybrid (Stop-Start)	MHEV	6.2%	5.6%	6.2%	6.5%
Mild Hybrid (Integrated Starter Generator)	ISG	11.5%	11.4%	11.5%	9.3%
Strong Hybrid - Level 2	SHEV2	45.8%	46.2%	45.8%	45.3%
Plug-in Hybrid - 30 mi range	PHEV1	-	68.1%	-	-
Electric Vehicle (Early Adopter) - 75 mile range	EV1	-	90.0%	-	-
Electric Vehicle (Broad Market) - 150 mile range	EV4	-	90.0%	-	-

Penetration of Technologies by Alternative

Preferred Alternative **- Passenger Cars - 2008 Baseline** shows the penetration of technologies by alternative for passenger cars, Table V-151 shows the penetration of technologies for light trucks for the alternatives and Table V-152 shows the penetration of technologies by alternative for the combined passenger car and light truck fleet. These tables are for the whole fleet combined, not by specific manufacturers. The application rate only includes technologies that the model applied. The penetration rate includes technologies that the model applies and technologies that were already present in the base fleet/base vehicle. They allow the reader to see the progression of technologies used as the alternatives get stricter.

Table V-150 Penetration Rate of New Technologies to Passenger Cars, by Baseline Model Year and Alternative,

Preferred Alternative - Passenger Cars - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	89%	89%	89%	89%	89%	89%	89%	88%	87%
Engine Friction Reduction - Level 1	EFR1	77%	80%	87%	88%	88%	88%	88%	88%	87%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	16%	26%	40%	44%	48%	51%	57%	59%	61%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	4%	5%	11%	10%	11%	11%	10%	11%	10%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	11%	11%	11%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	1%	1%	1%	1%	1%	1%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	5%	5%	4%	3%	3%	3%	3%	3%	3%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	73%	73%	74%	75%	75%	75%	75%	74%	74%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	51%	54%	54%	56%	57%	57%	56%	56%	56%
Continuously Variable Valve Lift (CVVL)	CVVL	10%	12%	15%	16%	16%	16%	17%	17%	17%
Cylinder Deactivation on DOHC	DEACD	5%	4%	4%	4%	4%	5%	4%	4%	4%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	44%	51%	57%	61%	70%	75%	75%	84%	83%
Cylinder Deactivation on OHV	DEACO	3%	1%	1%	1%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	3%	4%	5%	5%	5%	5%	5%	5%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	0%	1%	2%	4%	5%	5%	5%	5%	5%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	23%	26%	27%	25%	34%	31%	28%	33%	29%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	11%	16%	16%	18%	15%	14%	10%	9%	6%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	3%	3%	3%	4%	3%	3%	2%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	1%	2%	2%	2%	2%	2%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	1%	1%	1%	1%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	1%	1%	4%	8%	8%	15%	18%	21%	26%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	3%	5%	6%	8%	9%	13%	14%	16%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%

CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	1%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	3%	3%	3%	3%	3%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	1%	2%	2%	3%	3%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	2%	3%	4%	6%	8%	8%	8%	8%	9%
Improved Auto. Trans. Controls/Externals	IATC	9%	7%	4%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	13%	7%	5%	2%	1%	0%	0%	0%	0%
6-speed DCT	DCT	30%	24%	18%	12%	5%	3%	1%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	26%	29%	28%	21%	12%	8%	3%	2%	2%
High Efficiency Gearbox (Auto or DCT)	HETRANS	5%	17%	29%	43%	57%	66%	72%	74%	73%
Shift Optimizer	SHFTOPT	7%	20%	34%	45%	56%	72%	81%	84%	83%
Electric Power Steering	EPS	80%	84%	93%	94%	95%	95%	95%	95%	95%
Improved Accessories - Level 1	IACC1	61%	64%	68%	77%	80%	82%	85%	92%	92%
Improved Accessories - Level 2	IACC2	19%	26%	39%	46%	54%	63%	65%	76%	78%
12V Micro-Hybrid (Stop-Start)	MHEV	6%	6%	9%	12%	14%	14%	15%	13%	12%
Integrated Starter Generator	ISG	1%	2%	2%	7%	7%	10%	11%	17%	24%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	3%	3%	3%	3%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	1%	2%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	45%	49%	52%	53%	53%	52%	53%	52%	52%
Mass Reduction - Level 2	MR2	26%	32%	44%	47%	47%	47%	49%	49%	49%
Mass Reduction - Level 3	MR3	10%	12%	13%	15%	15%	15%	16%	17%	18%
Mass Reduction - Level 4	MR4	4%	4%	5%	5%	5%	5%	6%	7%	9%
Mass Reduction - Level 5	MR5	1%	1%	2%	3%	3%	4%	4%	5%	8%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	96%	99%	99%	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	20%	33%	53%	66%	75%	83%	86%	87%	88%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	91%	92%	92%	92%	92%	92%	92%	92%	92%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	97%	99%	99%	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	47%	59%	71%	81%	88%	89%	89%	89%	89%

Preferred Alternative - Passenger Cars - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	100%	100 %	100%	100 %	100 %	100 %	100%
Engine Friction Reduction - Level 1	EFR1	75%	79%	81%	80%	81%	81%	81%	80%	80%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	9%	12%	15%	19%	24%	31%	37%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	15%	15%	15%	15%	15%	15%	15%	15%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	14%	14%	15%	16%	16%	16%	16%	16%	15%
Cylinder Deactivation on SOHC	DEACS	5%	4%	4%	3%	2%	2%	2%	1%	1%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	5%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	66%	68%	68%	68%	68%	68%	68%	68%	68%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	36%	37%	38%	38%	39%	40%	40%	40%	40%
Continuously Variable Valve Lift (CVVL)	CVVL	24%	25%	27%	27%	27%	27%	27%	27%	27%
Cylinder Deactivation on DOHC	DEACD	7%	7%	5%	4%	3%	3%	3%	2%	2%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	46%	56%	69%	73%	82%	86%	86%	89%	89%
Cylinder Deactivation on OHV	DEACO	3%	1%	1%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	2%	3%	3%	3%	3%	3%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1%	3%	3%	3%	3%	3%	3%	3%	3%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	28%	35%	40%	42%	46%	46%	41%	39%	34%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	12%	16%	19%	20%	19%	19%	19%	18%	13%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	2%	3%	3%	3%	3%	3%	2%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	2%	2%	2%	3%	3%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	2%	2%	2%	2%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	3%	4%	7%	10%	16%	21%	25%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	1%	2%	2%	2%	2%	3%	3%	5%	8%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1%	1%	1%	1%	1%	1%	1%	1%	3%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	1%	2%	2%	3%	4%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	1%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	3%	2%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	2%	3%	4%	4%	4%	4%
Improved Auto. Trans. Controls/Externals	IATC	24%	22%	12%	6%	4%	2%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	25%	24%	15%	9%	7%	6%	1%	0%	0%
6-speed DCT	DCT	35%	35%	29%	19%	21%	15%	11%	8%	7%
8-Speed Trans (Auto or DCT)	8SPD	11%	15%	24%	24%	21%	19%	16%	5%	5%

High Efficiency Gearbox (Auto or DCT)	HETRANS	0%	3%	12%	24%	31%	40%	49%	59%	61%
Shift Optimizer	SHFTOPT	0%	0%	8%	17%	30%	36%	54%	62%	65%
Electric Power Steering	EPS	76%	82%	90%	92%	93%	93%	95%	97%	97%
Improved Accessories - Level 1	IACC1	53%	62%	74%	80%	81%	82%	85%	89%	94%
Improved Accessories - Level 2	IACC2	5%	13%	19%	29%	38%	44%	51%	65%	68%
12V Micro-Hybrid (Stop-Start)	MHEV	5%	5%	6%	5%	6%	6%	7%	7%	7%
Integrated Starter Generator	ISG	1%	2%	2%	4%	5%	6%	6%	10%	12%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	46%	50%	59%	59%	60%	60%	61%	60%	61%
Mass Reduction - Level 2	MR2	16%	27%	37%	41%	46%	48%	51%	58%	59%
Mass Reduction - Level 3	MR3	7%	8%	8%	10%	12%	12%	15%	18%	19%
Mass Reduction - Level 4	MR4	2%	2%	3%	3%	3%	3%	3%	4%	5%
Mass Reduction - Level 5	MR5	0%	0%	1%	1%	1%	1%	1%	2%	3%
Low Rolling Resistance Tires - Level 1	ROLL1	91%	97%	98%	99%	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	21%	29%	52%	62%	72%	79%	83%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	92%	92%	92%	93%	93%	93%	93%	94%	94%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	91%	97%	99%	99%	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	42%	56%	70%	80%	87%	88%	88%	90%	91%

2% Annual Increase - Passenger Cars - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	89%	89%	89%	89%	89%	89%	89%	89%	89%
Engine Friction Reduction - Level 1	EFR1	83%	88%	88%	88%	88%	88%	88%	88%	88%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	12%	26%	39%	47%	53%	56%	61%	63%	67%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	4%	4%	4%	4%	4%	4%	4%	4%	4%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	11%	11%	11%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	1%	1%	1%	1%	1%	1%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	14%	9%	7%	5%	5%	5%	5%	5%	5%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	63%	68%	71%	73%	73%	73%	73%	73%	73%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	46%	49%	50%	52%	53%	53%	52%	52%	53%
Continuously Variable Valve Lift (CVVL)	CVVL	10%	13%	16%	20%	20%	20%	20%	20%	20%
Cylinder Deactivation on DOHC	DEACD	4%	5%	5%	5%	5%	5%	5%	5%	4%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	40%	42%	43%	45%	46%	46%	48%	52%	53%
Cylinder Deactivation on OHV	DEACO	3%	2%	2%	3%	2%	2%	1%	1%	1%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	3%	3%	4%	3%	3%	3%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	0%	0%	0%	0%	0%	0%	1%	1%	1%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	20%	20%	21%	21%	22%	21%	23%	26%	25%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	11%	12%	13%	13%	13%	12%	14%	13%	14%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	3%	2%	2%	3%	3%	2%	2%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	1%	1%	1%	1%	1%	2%	2%	3%	5%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	3%	3%	4%	4%	5%	5%	6%	6%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	1%	2%	2%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	3%	4%	6%	8%	8%	8%	8%	9%
Improved Auto. Trans. Controls/Externals	IATC	15%	9%	5%	3%	3%	1%	3%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	10%	11%	12%	12%	11%	10%	9%	1%	0%
6-speed DCT	DCT	36%	32%	27%	22%	16%	13%	10%	19%	17%
8-Speed Trans (Auto or DCT)	8SPD	15%	17%	21%	16%	14%	17%	15%	12%	12%
High Efficiency Gearbox (Auto or DCT)	HETRANS	3%	12%	17%	26%	35%	39%	47%	52%	54%
Shift Optimizer	SHFTOPT	5%	9%	18%	24%	28%	31%	37%	37%	37%
Electric Power Steering	EPS	79%	85%	90%	91%	91%	91%	91%	95%	95%
Improved Accessories - Level 1	IACC1	55%	56%	56%	60%	63%	68%	73%	84%	87%
Improved Accessories - Level 2	IACC2	11%	15%	17%	23%	29%	33%	39%	56%	60%
12V Micro-Hybrid (Stop-Start)	MHEV	6%	6%	6%	6%	6%	6%	6%	6%	6%
Integrated Starter Generator	ISG	1%	2%	2%	3%	3%	3%	3%	5%	6%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	3%	3%	3%	3%	3%	3%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%

Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	1%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	45%	49%	52%	53%	52%	52%	53%	52%	52%
Mass Reduction - Level 2	MR2	24%	29%	40%	42%	42%	44%	49%	51%	51%
Mass Reduction - Level 3	MR3	10%	10%	11%	13%	13%	13%	15%	16%	16%
Mass Reduction - Level 4	MR4	3%	4%	4%	4%	4%	5%	5%	5%	5%
Mass Reduction - Level 5	MR5	0%	1%	1%	1%	1%	1%	1%	1%	3%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	96%	98%	99%	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	20%	33%	48%	60%	72%	81%	84%	87%	87%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	91%	92%	92%	92%	92%	92%	92%	92%	92%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	96%	99%	99%	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	47%	59%	71%	81%	88%	89%	89%	88%	88%

2% Annual Increase - Passenger Cars - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	100%	100 %	100%	100 %	100 %	100 %	100%
Engine Friction Reduction - Level 1	EFR1	76%	80%	80%	81%	81%	81%	81%	80%	80%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	9%	21%	25%	27%	31%	42%	45%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	15%	15%	15%	15%	15%	15%	15%	15%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	14%	14%	15%	16%	16%	16%	16%	16%	16%
Cylinder Deactivation on SOHC	DEACS	5%	5%	5%	5%	5%	5%	5%	5%	5%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	7%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	66%	69%	69%	69%	69%	69%	69%	69%	69%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	32%	33%	34%	36%	39%	40%	40%	40%	40%
Continuously Variable Valve Lift (CVVL)	CVVL	19%	20%	26%	26%	29%	28%	28%	28%	28%
Cylinder Deactivation on DOHC	DEACD	7%	8%	10%	11%	11%	11%	12%	12%	12%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	31%	40%	41%	44%	50%	51%	51%	55%	56%
Cylinder Deactivation on OHV	DEACO	3%	3%	3%	3%	3%	3%	3%	3%	3%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	2%	3%	3%	3%	3%	3%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	0%	1%	1%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	15%	22%	23%	25%	31%	32%	32%	36%	37%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	6%	7%	7%	9%	9%	9%	9%	8%	6%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	2%	2%	2%	2%	2%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	1%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	1%	1%	1%	1%	1%	1%	2%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	1%	2%	2%	2%	2%	2%	2%	3%	5%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	0%	0%	1%	1%	1%	1%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	2%	2%	4%	4%	4%	4%
Improved Auto. Trans. Controls/Externals	IATC	25%	22%	20%	15%	15%	15%	16%	19%	18%
6-Speed Trans with Improved Internals (Auto)	NAUTO	27%	21%	18%	12%	18%	19%	23%	25%	25%
6-speed DCT	DCT	31%	32%	24%	14%	13%	9%	4%	5%	5%
8-Speed Trans (Auto or DCT)	8SPD	9%	13%	14%	18%	15%	14%	18%	19%	19%
High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	3%	10%	17%	23%	25%	28%	28%	28%
Shift Optimizer	SHFTOPT	0%	0%	11%	17%	19%	24%	26%	27%	27%
Electric Power Steering	EPS	72%	79%	85%	86%	90%	92%	92%	92%	92%
Improved Accessories - Level 1	IACC1	38%	40%	42%	45%	53%	58%	63%	75%	75%
Improved Accessories - Level 2	IACC2	2%	3%	7%	9%	14%	16%	24%	33%	34%
12V Micro-Hybrid (Stop-Start)	MHEV	5%	5%	5%	5%	5%	5%	4%	4%	4%
Integrated Starter Generator	ISG	1%	2%	2%	2%	2%	2%	2%	4%	4%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%

Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	40%	47%	57%	59%	59%	59%	61%	60%	61%
Mass Reduction - Level 2	MR2	15%	22%	29%	32%	37%	39%	46%	56%	57%
Mass Reduction - Level 3	MR3	7%	7%	8%	8%	10%	10%	12%	15%	16%
Mass Reduction - Level 4	MR4	1%	1%	1%	1%	1%	1%	2%	4%	5%
Mass Reduction - Level 5	MR5	0%	0%	0%	0%	1%	1%	1%	4%	4%
Low Rolling Resistance Tires - Level 1	ROLL1	91%	96%	98%	100 %	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	20%	37%	45%	58%	71%	82%	83%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	91%	91%	92%	92%	93%	93%	93%	93%	93%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	90%	96%	98%	100 %	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	42%	56%	70%	80%	87%	88%	88%	90%	90%

3% Annual Increase - Passenger Cars - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	89%	89%	89%	89%	89%	89%	89%	88%	88%
Engine Friction Reduction - Level 1	EFR1	83%	87%	87%	88%	88%	88%	88%	88%	87%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	13%	27%	38%	46%	53%	61%	64%	66%	67%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	4%	4%	4%	4%	6%	6%	6%	10%	10%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	11%	11%	11%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	1%	1%	1%	1%	1%	1%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	8%	6%	6%	5%	5%	4%	4%	3%	3%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	69%	72%	72%	73%	73%	74%	74%	75%	74%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	49%	52%	53%	55%	56%	56%	56%	56%	56%
Continuously Variable Valve Lift (CVVL)	CVVL	10%	12%	15%	17%	17%	17%	17%	17%	17%
Cylinder Deactivation on DOHC	DEACD	4%	4%	3%	4%	4%	4%	3%	2%	2%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	42%	45%	51%	56%	57%	62%	64%	65%	65%
Cylinder Deactivation on OHV	DEACO	3%	1%	1%	1%	1%	1%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	3%	3%	5%	4%	4%	4%	5%	5%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	0%	1%	1%	3%	4%	3%	4%	4%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	21%	23%	27%	27%	28%	29%	28%	26%	24%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	11%	15%	15%	18%	16%	14%	16%	16%	16%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	3%	2%	2%	3%	2%	2%	1%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	1%	1%	2%	3%	3%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	1%	1%	1%	2%	2%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	1%	1%	1%	3%	3%	6%	6%	8%	10%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	3%	3%	4%	7%	8%	8%	11%	11%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	2%	2%	2%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	2%	3%	4%	6%	8%	8%	8%	8%	9%
Improved Auto. Trans. Controls/Externals	IATC	10%	8%	4%	1%	2%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	14%	9%	6%	3%	0%	0%	0%	0%	0%
6-speed DCT	DCT	31%	24%	19%	13%	10%	6%	6%	6%	6%
8-Speed Trans (Auto or DCT)	8SPD	24%	25%	25%	18%	8%	7%	6%	6%	6%
High Efficiency Gearbox (Auto or DCT)	HETRANS	3%	19%	30%	44%	55%	61%	63%	63%	62%
Shift Optimizer	SHFTOPT	7%	21%	35%	47%	55%	60%	70%	75%	74%
Electric Power Steering	EPS	79%	85%	90%	91%	95%	95%	95%	95%	95%
Improved Accessories - Level 1	IACC1	54%	56%	60%	64%	71%	73%	76%	76%	76%
Improved Accessories - Level 2	IACC2	14%	24%	28%	32%	34%	41%	46%	51%	54%
12V Micro-Hybrid (Stop-Start)	MHEV	5%	5%	5%	6%	6%	6%	6%	6%	6%
Integrated Starter Generator	ISG	1%	2%	2%	4%	4%	5%	5%	6%	10%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	3%	3%	3%	3%	3%	3%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%

Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	45%	49%	52%	53%	52%	52%	53%	52%	52%
Mass Reduction - Level 2	MR2	26%	33%	44%	47%	46%	47%	50%	51%	51%
Mass Reduction - Level 3	MR3	10%	12%	13%	15%	15%	15%	15%	15%	17%
Mass Reduction - Level 4	MR4	4%	4%	5%	5%	5%	6%	5%	6%	8%
Mass Reduction - Level 5	MR5	0%	1%	2%	3%	3%	4%	4%	4%	6%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	96%	99%	99%	99%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	20%	35%	52%	64%	74%	82%	85%	85%	87%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	91%	92%	92%	92%	92%	92%	92%	92%	92%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	97%	99%	99%	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	47%	59%	71%	81%	88%	89%	89%	88%	88%

3% Annual Increase - Passenger Cars - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	100%	100 %	100%	100 %	100 %	100 %	100%
Engine Friction Reduction - Level 1	EFR1	75%	79%	81%	81%	81%	81%	81%	80%	80%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	5%	9%	11%	12%	14%	20%	22%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	15%	15%	15%	15%	15%	15%	15%	15%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	14%	14%	15%	16%	16%	16%	16%	16%	16%
Cylinder Deactivation on SOHC	DEACS	5%	5%	4%	3%	3%	3%	2%	3%	3%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	5%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	66%	68%	68%	68%	68%	68%	68%	68%	68%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	35%	36%	37%	38%	38%	39%	39%	39%	39%
Continuously Variable Valve Lift (CVVL)	CVVL	24%	25%	27%	28%	28%	29%	29%	29%	29%
Cylinder Deactivation on DOHC	DEACD	8%	9%	9%	5%	5%	5%	4%	2%	2%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	38%	47%	63%	67%	70%	76%	78%	81%	82%
Cylinder Deactivation on OHV	DEACO	3%	3%	3%	2%	2%	2%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	2%	3%	3%	3%	3%	3%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	0%	1%	1%	1%	1%	1%	3%	3%	3%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	19%	22%	27%	29%	32%	36%	40%	44%	41%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	9%	10%	13%	17%	16%	16%	19%	18%	14%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	2%	3%	3%	3%	2%	2%	2%	2%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	1%	1%	2%	2%	5%	6%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	2%	2%	2%	2%	5%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	4%	4%	4%	4%	4%	4%	6%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	1%	2%	2%	2%	2%	2%	3%	4%	5%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	0%	1%	1%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	3%	2%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	2%	3%	4%	4%	4%	4%
Improved Auto. Trans. Controls/Externals	IATC	25%	22%	13%	11%	6%	4%	3%	1%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	26%	21%	13%	6%	4%	5%	4%	2%	4%
6-speed DCT	DCT	36%	37%	34%	25%	29%	26%	23%	18%	17%
8-Speed Trans (Auto or DCT)	8SPD	11%	18%	27%	32%	28%	29%	23%	15%	11%
High Efficiency Gearbox (Auto or DCT)	HETRANS	0%	3%	8%	16%	23%	26%	34%	49%	55%
Shift Optimizer	SHFTOPT	0%	0%	3%	14%	21%	23%	32%	45%	51%
Electric Power Steering	EPS	73%	79%	89%	92%	92%	92%	92%	93%	93%
Improved Accessories - Level 1	IACC1	50%	56%	66%	74%	74%	75%	76%	76%	77%
Improved Accessories - Level 2	IACC2	3%	4%	8%	12%	16%	24%	24%	28%	29%
12V Micro-Hybrid (Stop-Start)	MHEV	5%	5%	4%	5%	5%	5%	5%	5%	5%
Integrated Starter Generator	ISG	2%	2%	2%	2%	2%	3%	3%	4%	5%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	1%	1%

Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	46%	50%	59%	60%	61%	60%	61%	60%	61%
Mass Reduction - Level 2	MR2	16%	27%	38%	42%	47%	49%	50%	56%	58%
Mass Reduction - Level 3	MR3	7%	7%	8%	10%	11%	11%	12%	15%	17%
Mass Reduction - Level 4	MR4	1%	1%	2%	2%	2%	3%	3%	4%	7%
Mass Reduction - Level 5	MR5	0%	0%	0%	0%	1%	1%	1%	2%	5%
Low Rolling Resistance Tires - Level 1	ROLL1	91%	97%	99%	100 %	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	20%	37%	44%	56%	74%	82%	85%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	92%	92%	92%	93%	93%	93%	93%	93%	93%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	90%	97%	99%	100 %	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	42%	56%	70%	80%	87%	88%	88%	90%	91%

4% Annual Increase - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	78%	78%	78%	77%	77%	76%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	89%	89%	89%	89%	89%	89%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	11%	23%	38%	52%	66%	72%	77%	82%	84%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	14%	13%	13%	13%	13%	13%	13%	13%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	12%	12%	12%	12%	12%	12%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	2%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	58%	58%	58%	59%	60%	61%	62%	62%	62%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	41%	40%	41%	42%	43%	43%	44%	44%	44%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	7%	7%	6%	6%	5%	4%	1%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	68%	69%	70%	70%	74%	76%	79%	81%	81%
Cylinder Deactivation on OHV	DEACO	12%	12%	3%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	19%	17%	17%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	11%	12%	15%	20%	19%	18%	17%	17%	17%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	10%	10%	9%	7%	7%	4%	4%	2%	1%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	50%	50%	50%	45%	39%	35%	32%	26%	22%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	9%	9%	17%	18%	14%	11%	13%	13%	13%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	1%	1%	1%	1%	1%	3%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	2%	9%	9%	10%	12%	13%	16%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	1%	1%	4%	4%	5%	5%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	5%	6%	8%	15%	19%	21%	25%	27%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	0%	0%	3%	3%	3%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	1%	1%	1%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	1%	1%	4%	7%	7%	7%	7%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	1%	1%	1%	2%	2%	2%	2%	2%
Improved Auto. Trans. Controls/Externals	IATC	13%	6%	5%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	32%	24%	12%	6%	3%	3%	1%	1%	1%
6-speed DCT	DCT	5%	5%	4%	2%	1%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	34%	40%	40%	34%	17%	14%	9%	5%	5%

High Efficiency Gearbox (Auto or DCT)	HETRANS	8%	15%	31%	45%	60%	64%	71%	75%	75%
Shift Optimizer	SHFTOPT	11%	19%	34%	49%	66%	74%	81%	93%	94%
Electric Power Steering	EPS	79%	83%	92%	92%	92%	92%	92%	93%	93%
Improved Accessories - Level 1	IACC1	51%	53%	56%	63%	69%	71%	75%	85%	87%
Improved Accessories - Level 2	IACC2	7%	8%	11%	15%	24%	28%	32%	35%	43%
12V Micro-Hybrid (Stop-Start)	MHEV	3%	3%	3%	3%	6%	7%	7%	7%	7%
Integrated Starter Generator	ISG	0%	0%	0%	1%	1%	2%	2%	4%	9%
Strong Hybrid - Level 1	SHEV1	2%	2%	1%	2%	2%	2%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	87%	88%	93%	98%	99%	100 %	100 %	100 %	100%
Mass Reduction - Level 2	MR2	30%	39%	54%	64%	77%	82%	84%	87%	88%
Mass Reduction - Level 3	MR3	16%	18%	22%	29%	34%	38%	44%	49%	52%
Mass Reduction - Level 4	MR4	9%	10%	12%	17%	25%	28%	33%	41%	46%
Mass Reduction - Level 5	MR5	0%	0%	2%	5%	8%	9%	11%	17%	21%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100 %	100%	100 %	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	13%	28%	48%	66%	71%	76%	85%	89%	90%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	81%	82%	83%	84%	84%	84%	84%	84%	84%
Secondary Axle Disconnect	SAX	34%	38%	39%	44%	43%	43%	43%	43%	43%
Aero Drag Reduction, Level 1	AERO1	100%	100 %	99%	100 %	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	61%	69%	86%	93%	95%	98%	100 %	100 %	100%

4% Annual Increase - Passenger Cars - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	100%	100 %	100%	100 %	100 %	100 %	99%
Engine Friction Reduction - Level 1	EFR1	75%	79%	81%	81%	81%	81%	81%	80%	80%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	4%	10%	11%	13%	18%	29%	30%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	15%	14%	14%	14%	15%	15%	15%	14%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	14%	14%	14%	15%	15%	15%	15%	15%	15%
Cylinder Deactivation on SOHC	DEACS	5%	5%	5%	3%	2%	2%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	5%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	66%	68%	68%	68%	68%	68%	68%	68%	68%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	34%	37%	37%	39%	39%	39%	39%	39%	39%
Continuously Variable Valve Lift (CVVL)	CVVL	25%	26%	28%	28%	28%	28%	28%	28%	28%
Cylinder Deactivation on DOHC	DEACD	9%	9%	7%	3%	2%	1%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	52%	59%	73%	77%	86%	87%	90%	92%	92%
Cylinder Deactivation on OHV	DEACO	3%	1%	1%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	2%	3%	3%	3%	3%	3%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	0%	2%	2%	3%	3%	3%	3%	3%	3%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	33%	38%	47%	47%	51%	48%	44%	37%	32%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	8%	11%	14%	19%	20%	20%	21%	20%	16%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	2%	3%	3%	3%	3%	3%	3%	2%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	2%	2%	2%	2%	2%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	1%	1%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	2%	3%	7%	11%	14%	22%	28%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	4%	4%	4%	6%	6%	6%	8%	10%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	2%	2%	2%	3%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	1%	1%	1%	1%	1%	1%	1%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	3%	2%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	2%	3%	4%	4%	4%	4%
Improved Auto. Trans. Controls/Externals	IATC	27%	21%	11%	8%	3%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	29%	25%	15%	8%	3%	1%	0%	0%	0%
6-speed DCT	DCT	33%	35%	30%	20%	19%	15%	7%	2%	2%
8-Speed Trans (Auto or DCT)	8SPD	11%	15%	22%	24%	23%	23%	25%	18%	16%
High Efficiency Gearbox (Auto or DCT)	HETRANS	0%	4%	16%	24%	30%	35%	37%	47%	46%
Shift Optimizer	SHFTOPT	0%	0%	8%	23%	40%	46%	52%	54%	60%
Electric Power Steering	EPS	77%	84%	92%	94%	96%	96%	96%	96%	97%
Improved Accessories - Level 1	IACC1	54%	64%	76%	82%	86%	90%	91%	91%	94%
Improved Accessories - Level 2	IACC2	5%	14%	22%	30%	38%	43%	54%	62%	65%
12V Micro-Hybrid (Stop-Start)	MHEV	5%	5%	7%	7%	8%	10%	11%	11%	10%
Integrated Starter Generator	ISG	1%	2%	3%	7%	7%	8%	9%	11%	18%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	1%

Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	46%	50%	59%	61%	61%	61%	61%	61%	61%
Mass Reduction - Level 2	MR2	16%	25%	36%	40%	45%	47%	51%	53%	53%
Mass Reduction - Level 3	MR3	7%	8%	10%	13%	15%	15%	18%	19%	20%
Mass Reduction - Level 4	MR4	2%	2%	3%	3%	4%	4%	4%	5%	9%
Mass Reduction - Level 5	MR5	0%	0%	1%	1%	2%	3%	3%	3%	7%
Low Rolling Resistance Tires - Level 1	ROLL1	92%	97%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	21%	37%	54%	61%	71%	78%	84%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	92%	92%	92%	93%	93%	93%	94%	94%	94%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	91%	97%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	42%	56%	70%	79%	85%	86%	87%	89%	91%

5% Annual Increase - Passenger Cars - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	89%	89%	89%	88%	88%	88%	88%	87%	85%
Engine Friction Reduction - Level 1	EFR1	83%	87%	87%	87%	87%	87%	87%	86%	85%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	15%	27%	36%	40%	43%	47%	49%	51%	51%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	6%	7%	11%	10%	10%	10%	10%	10%	10%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	11%	11%	11%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	1%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	6%	6%	5%	3%	3%	3%	3%	3%	3%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	72%	72%	73%	74%	75%	72%	70%	68%	66%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	52%	55%	55%	57%	57%	57%	56%	54%	52%
Continuously Variable Valve Lift (CVVL)	CVVL	14%	14%	15%	15%	15%	15%	15%	15%	15%
Cylinder Deactivation on DOHC	DEACD	5%	3%	2%	2%	2%	2%	2%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	52%	62%	70%	75%	84%	82%	82%	83%	81%
Cylinder Deactivation on OHV	DEACO	2%	1%	1%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	3%	4%	5%	5%	5%	5%	4%	4%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1%	3%	4%	5%	5%	5%	5%	4%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	30%	36%	37%	35%	35%	26%	21%	9%	7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	14%	18%	21%	18%	16%	14%	10%	5%	5%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	3%	3%	3%	3%	3%	2%	2%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	3%	3%	5%	5%	5%	3%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	2%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	1%	1%	2%	8%	11%	19%	22%	33%	35%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	3%	4%	8%	8%	10%	13%	17%	18%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	4%	4%	4%	4%	4%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	1%	4%	5%	7%	9%	9%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	2%	2%	2%	3%	3%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	3%	5%	6%	7%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	4%	3%	3%	1%	1%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	2%	3%	4%	6%	8%	8%	8%	8%	9%
Improved Auto. Trans. Controls/Externals	IATC	5%	2%	2%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	8%	5%	4%	1%	0%	0%	0%	0%	0%
6-speed DCT	DCT	42%	31%	22%	12%	3%	1%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	20%	20%	19%	12%	8%	6%	5%	4%	3%
High Efficiency Gearbox (Auto or DCT)	HETRANS	9%	24%	38%	51%	58%	61%	62%	61%	60%
Shift Optimizer	SHFTOPT	12%	31%	47%	60%	79%	86%	87%	83%	80%
Electric Power Steering	EPS	85%	89%	93%	94%	95%	95%	95%	95%	95%
Improved Accessories - Level 1	IACC1	60%	62%	66%	75%	88%	89%	95%	95%	95%
Improved Accessories - Level 2	IACC2	15%	28%	34%	42%	53%	63%	70%	79%	82%
12V Micro-Hybrid (Stop-Start)	MHEV	8%	8%	11%	18%	23%	29%	33%	31%	27%
Integrated Starter Generator	ISG	2%	3%	5%	11%	15%	19%	24%	32%	40%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	3%	3%	3%	3%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	4%	5%

Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	1%	1%	1%	1%	2%	4%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	1%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	47%	52%	52%	53%	53%	52%	53%	52%	52%
Mass Reduction - Level 2	MR2	26%	32%	44%	48%	47%	48%	52%	52%	51%
Mass Reduction - Level 3	MR3	10%	13%	14%	18%	18%	18%	18%	19%	19%
Mass Reduction - Level 4	MR4	4%	4%	6%	9%	9%	9%	9%	9%	9%
Mass Reduction - Level 5	MR5	1%	2%	3%	8%	8%	8%	8%	9%	9%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	96%	99%	99%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	18%	33%	53%	66%	74%	83%	88%	88%	89%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	91%	92%	92%	92%	92%	92%	92%	92%	92%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	97%	99%	99%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	47%	59%	71%	81%	88%	89%	89%	89%	89%

5% Annual Increase - Passenger Cars - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	100%	99%	99%	99%	99%	99%	95%
Engine Friction Reduction - Level 1	EFR1	76%	79%	81%	81%	81%	80%	80%	80%	77%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	2%	6%	6%	7%	7%	14%	19%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	15%	14%	14%	14%	14%	14%	14%	14%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	14%	14%	14%	14%	14%	14%	14%	14%	14%
Cylinder Deactivation on SOHC	DEACS	4%	4%	4%	3%	2%	2%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	5%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	66%	68%	68%	68%	68%	65%	64%	64%	61%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	35%	38%	38%	38%	38%	36%	36%	36%	35%
Continuously Variable Valve Lift (CVVL)	CVVL	25%	26%	27%	27%	28%	27%	28%	27%	27%
Cylinder Deactivation on DOHC	DEACD	5%	5%	3%	2%	1%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	57%	67%	78%	82%	87%	85%	85%	88%	85%
Cylinder Deactivation on OHV	DEACO	2%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	2%	3%	3%	3%	3%	3%	3%	2%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1%	3%	3%	3%	3%	3%	3%	3%	2%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	38%	43%	50%	48%	47%	40%	32%	20%	17%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	12%	16%	18%	19%	17%	16%	16%	15%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	2%	3%	3%	4%	3%	3%	3%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	2%	2%	2%	2%	2%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	2%	2%	2%	2%	2%	2%	2%	2%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	3%	6%	10%	14%	18%	32%	34%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	1%	2%	2%	4%	6%	8%	8%	11%	13%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1%	1%	1%	1%	2%	2%	2%	2%	3%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	1%	2%	2%	3%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	1%	1%	1%	4%	5%	5%	5%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	3%	2%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	2%	3%	4%	4%	4%	4%
Improved Auto. Trans. Controls/Externals	IATC	25%	19%	8%	3%	2%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	27%	23%	12%	6%	2%	1%	0%	0%	0%
6-speed DCT	DCT	37%	33%	24%	13%	9%	4%	3%	1%	0%
8-Speed Trans (Auto or DCT)	8SPD	13%	22%	22%	22%	17%	13%	6%	4%	3%
High Efficiency Gearbox (Auto or DCT)	HETRANS	0%	6%	23%	35%	42%	47%	51%	55%	52%
Shift Optimizer	SHFTOPT	0%	0%	24%	40%	63%	75%	83%	86%	84%
Electric Power Steering	EPS	78%	85%	93%	94%	97%	97%	97%	97%	97%
Improved Accessories - Level 1	IACC1	55%	66%	79%	84%	92%	95%	95%	97%	97%
Improved Accessories - Level 2	IACC2	6%	18%	22%	31%	43%	51%	59%	77%	80%
12V Micro-Hybrid (Stop-Start)	MHEV	10%	11%	14%	16%	20%	20%	24%	24%	24%
Integrated Starter Generator	ISG	2%	3%	5%	11%	12%	13%	19%	28%	29%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%

Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	2%	3%	5%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	1%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	1%	1%	1%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	46%	50%	59%	61%	61%	61%	61%	61%	61%
Mass Reduction - Level 2	MR2	16%	28%	45%	49%	55%	56%	59%	60%	60%
Mass Reduction - Level 3	MR3	7%	8%	9%	12%	15%	15%	18%	20%	22%
Mass Reduction - Level 4	MR4	2%	2%	3%	4%	4%	4%	5%	7%	10%
Mass Reduction - Level 5	MR5	0%	0%	2%	2%	3%	4%	4%	6%	10%
Low Rolling Resistance Tires - Level 1	ROLL1	92%	97%	99%	100 %	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	22%	41%	52%	62%	69%	80%	85%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	92%	92%	93%	93%	94%	94%	94%	94%	94%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	91%	97%	99%	100 %	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	42%	56%	70%	79%	86%	87%	87%	89%	91%

6% Annual Increase - Passenger Cars - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	89%	89%	89%	89%	88%	86%	84%	82%	78%
Engine Friction Reduction - Level 1	EFR1	83%	87%	87%	88%	86%	83%	82%	80%	75%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	18%	30%	40%	46%	46%	46%	48%	56%	55%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	9%	10%	11%	10%	10%	10%	10%	10%	9%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	11%	11%	11%	11%	11%	11%	11%	11%	10%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	1%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	4%	4%	4%	3%	3%	3%	3%	3%	3%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	73%	74%	74%	74%	71%	67%	66%	63%	60%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	55%	56%	56%	56%	54%	53%	51%	47%	46%
Continuously Variable Valve Lift (CVVL)	CVVL	14%	14%	14%	15%	15%	15%	15%	15%	14%
Cylinder Deactivation on DOHC	DEACD	3%	1%	0%	1%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	60%	70%	76%	80%	83%	81%	81%	77%	73%
Cylinder Deactivation on OHV	DEACO	2%	1%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	4%	4%	5%	5%	5%	5%	5%	5%	4%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	2%	4%	4%	5%	5%	5%	5%	5%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	33%	39%	40%	35%	34%	27%	23%	11%	9%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	17%	21%	24%	21%	17%	15%	14%	7%	6%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	3%	3%	3%	3%	2%	2%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	2%	2%	3%	3%	3%	1%	1%	1%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	1%	1%	3%	12%	15%	17%	17%	23%	21%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	4%	4%	6%	10%	10%	11%	12%	11%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	1%	1%	2%	6%	9%	14%	14%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	3%	3%	5%	6%	9%	8%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	3%	3%	3%	4%	4%	3%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	1%	2%	2%	3%	3%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	1%	2%	2%	2%	2%	2%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	4%	3%	3%	1%	1%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	2%	3%	4%	6%	8%	8%	8%	8%	9%
Improved Auto. Trans. Controls/Externals	IATC	5%	2%	2%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	8%	6%	4%	0%	0%	0%	0%	0%	0%
6-speed DCT	DCT	38%	28%	19%	11%	2%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	23%	23%	22%	14%	8%	5%	4%	4%	3%
High Efficiency Gearbox (Auto or DCT)	HETRANS	9%	25%	38%	49%	54%	56%	57%	56%	49%
Shift Optimizer	SHFTOPT	12%	34%	53%	68%	79%	81%	81%	78%	69%
Electric Power Steering	EPS	82%	87%	93%	95%	95%	95%	95%	95%	95%
Improved Accessories - Level 1	IACC1	65%	68%	75%	84%	87%	87%	93%	96%	96%
Improved Accessories - Level 2	IACC2	20%	30%	40%	52%	64%	69%	80%	86%	87%
12V Micro-Hybrid (Stop-Start)	MHEV	13%	18%	25%	31%	42%	40%	39%	38%	31%
Integrated Starter Generator	ISG	4%	7%	10%	16%	19%	24%	28%	39%	39%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	2%	2%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	1%	1%	1%	3%	3%	3%	3%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	1%	1%	1%	1%	5%

Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	2%	5%	6%	7%	9%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	1%	1%	2%	5%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	47%	52%	52%	53%	53%	52%	53%	52%	52%
Mass Reduction - Level 2	MR2	26%	33%	45%	49%	49%	49%	52%	52%	51%
Mass Reduction - Level 3	MR3	10%	12%	14%	17%	17%	17%	17%	19%	19%
Mass Reduction - Level 4	MR4	4%	4%	6%	6%	6%	6%	6%	8%	8%
Mass Reduction - Level 5	MR5	1%	1%	3%	5%	6%	6%	6%	7%	7%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	96%	99%	100 %	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	18%	35%	52%	67%	74%	83%	86%	89%	89%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	91%	92%	92%	92%	92%	92%	92%	92%	92%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	97%	99%	100 %	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	47%	59%	71%	81%	88%	89%	89%	89%	89%

6% Annual Increase - Passenger Cars - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	100%	99%	98%	98%	96%	94%	92%
Engine Friction Reduction - Level 1	EFR1	77%	79%	80%	80%	79%	79%	77%	76%	74%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	3%	5%	5%	6%	10%	15%	17%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	15%	14%	14%	14%	14%	14%	14%	14%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	14%	14%	14%	14%	14%	14%	14%	14%	14%
Cylinder Deactivation on SOHC	DEACS	4%	3%	2%	2%	1%	1%	1%	1%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	5%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	66%	68%	67%	66%	65%	63%	61%	60%	58%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	34%	38%	37%	36%	36%	35%	34%	32%	31%
Continuously Variable Valve Lift (CVVL)	CVVL	25%	26%	27%	27%	27%	27%	25%	25%	24%
Cylinder Deactivation on DOHC	DEACD	4%	4%	3%	2%	1%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	51%	63%	78%	77%	84%	83%	81%	78%	77%
Cylinder Deactivation on OHV	DEACO	2%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	2%	3%	3%	3%	3%	3%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1%	3%	3%	3%	2%	2%	2%	2%	2%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	27%	33%	40%	38%	39%	35%	28%	16%	13%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	14%	19%	22%	21%	19%	18%	16%	12%	6%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	3%	3%	3%	2%	2%	2%	1%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	1%	1%	1%	1%	1%	1%	1%	1%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	2%	2%	2%	2%	2%	2%	2%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	3%	4%	8%	10%	16%	18%	23%	29%	31%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	2%	2%	3%	3%	6%	7%	7%	9%	12%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	1%	1%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1%	1%	1%	1%	1%	1%	3%	3%	3%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	1%	2%	3%	3%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	2%	3%	4%	5%	5%	7%	7%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	2%	2%	2%	2%	2%	2%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	4%	3%	2%	2%	1%	1%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	2%	3%	4%	4%	4%	4%
Improved Auto. Trans. Controls/Externals	IATC	18%	16%	5%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	25%	17%	7%	2%	1%	0%	0%	0%	0%
6-speed DCT	DCT	39%	35%	27%	15%	7%	5%	3%	1%	0%
8-Speed Trans (Auto or DCT)	8SPD	21%	29%	29%	29%	19%	12%	5%	4%	3%
High Efficiency Gearbox (Auto or DCT)	HETRANS	0%	7%	25%	36%	41%	46%	46%	42%	40%
Shift Optimizer	SHFTOPT	0%	0%	21%	37%	59%	72%	83%	80%	78%
Electric Power Steering	EPS	80%	88%	97%	97%	97%	97%	97%	97%	97%
Improved Accessories - Level 1	IACC1	60%	67%	80%	81%	89%	91%	97%	97%	97%
Improved Accessories - Level 2	IACC2	9%	20%	34%	39%	51%	57%	69%	69%	71%
12V Micro-Hybrid (Stop-Start)	MHEV	11%	17%	31%	37%	47%	48%	45%	41%	37%
Integrated Starter Generator	ISG	4%	6%	8%	14%	21%	26%	32%	39%	40%

Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	1%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	1%	1%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	1%	3%	6%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	2%	2%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	1%	1%	1%	2%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	1%	1%	2%	3%	4%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	47%	51%	59%	60%	61%	60%	61%	60%	61%
Mass Reduction - Level 2	MR2	17%	28%	45%	49%	54%	55%	58%	59%	60%
Mass Reduction - Level 3	MR3	7%	8%	10%	11%	14%	15%	17%	19%	22%
Mass Reduction - Level 4	MR4	2%	2%	4%	4%	4%	4%	5%	5%	9%
Mass Reduction - Level 5	MR5	0%	0%	2%	3%	4%	4%	5%	5%	9%
Low Rolling Resistance Tires - Level 1	ROLL1	93%	97%	99%	99%	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	20%	38%	50%	59%	71%	77%	85%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	92%	92%	93%	93%	94%	94%	94%	94%	94%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	97%	99%	99%	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	42%	56%	70%	79%	86%	87%	87%	89%	91%

7% Annual Increase - Passenger Cars - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	89%	89%	89%	88%	88%	84%	84%	80%	78%
Engine Friction Reduction - Level 1	EFR1	87%	87%	87%	87%	85%	82%	81%	77%	75%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	18%	30%	40%	42%	43%	42%	45%	50%	50%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	9%	10%	10%	10%	8%	8%	8%	8%	8%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	11%	11%	11%	11%	9%	9%	9%	9%	8%
Cylinder Deactivation on SOHC	DEACS	2%	1%	1%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	4%	4%	4%	3%	3%	1%	1%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	73%	73%	73%	71%	64%	61%	60%	58%	57%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	55%	56%	55%	54%	49%	45%	45%	42%	42%
Continuously Variable Valve Lift (CVVL)	CVVL	14%	14%	14%	15%	14%	14%	14%	14%	13%
Cylinder Deactivation on DOHC	DEACD	5%	2%	1%	1%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	67%	78%	83%	84%	76%	72%	72%	69%	68%
Cylinder Deactivation on OHV	DEACO	1%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	4%	4%	5%	5%	4%	4%	4%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	3%	4%	5%	5%	5%	4%	4%	3%	3%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	38%	45%	42%	37%	29%	24%	19%	15%	13%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	19%	24%	26%	22%	19%	16%	13%	8%	7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	3%	3%	3%	3%	2%	2%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	1%	1%	1%	2%	2%	2%	2%	2%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	2%	3%	5%	11%	13%	15%	16%	18%	19%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	3%	4%	6%	7%	8%	9%	9%	10%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	3%	3%	4%	4%	8%	8%	7%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	1%	2%	3%	4%	5%	5%	5%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	3%	3%	3%	4%	3%	3%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	2%	6%	7%	7%	7%	7%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	3%	5%	5%	5%	5%	5%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	4%	3%	3%	1%	1%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	2%	3%	4%	6%	8%	8%	8%	8%	9%
Improved Auto. Trans. Controls/Externals	IATC	7%	6%	2%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	10%	4%	2%	0%	0%	0%	0%	0%	0%
6-speed DCT	DCT	39%	28%	19%	10%	1%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	23%	23%	22%	13%	7%	5%	4%	4%	2%
High Efficiency Gearbox (Auto or DCT)	HETRANS	11%	26%	37%	50%	56%	57%	57%	53%	51%
Shift Optimizer	SHFTOPT	12%	34%	56%	73%	82%	80%	79%	72%	68%
Electric Power Steering	EPS	87%	91%	94%	95%	95%	95%	95%	95%	95%
Improved Accessories - Level 1	IACC1	63%	74%	86%	93%	93%	95%	96%	96%	96%
Improved Accessories - Level 2	IACC2	23%	41%	50%	61%	72%	81%	84%	84%	85%
12V Micro-Hybrid (Stop-Start)	MHEV	20%	28%	37%	41%	44%	40%	39%	34%	31%
Integrated Starter Generator	ISG	6%	10%	13%	20%	29%	34%	38%	36%	39%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	2%	2%	0%	0%	0%	0%

Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	1%	1%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	1%	1%	4%	6%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	3%	7%	7%	8%	9%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	1%	1%	1%	1%	2%	3%	6%	7%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	49%	53%	53%	53%	53%	52%	53%	52%	52%
Mass Reduction - Level 2	MR2	27%	36%	49%	52%	52%	51%	52%	51%	51%
Mass Reduction - Level 3	MR3	10%	12%	14%	16%	16%	17%	17%	17%	19%
Mass Reduction - Level 4	MR4	4%	4%	6%	6%	6%	7%	6%	7%	9%
Mass Reduction - Level 5	MR5	2%	2%	4%	6%	6%	6%	6%	7%	9%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	96%	99%	99%	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	18%	33%	52%	66%	75%	84%	88%	88%	88%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	92%	92%	92%	92%	92%	92%	92%	92%	92%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	97%	99%	99%	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	47%	59%	71%	81%	88%	89%	89%	89%	89%

7% Annual Increase - Passenger Cars - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	99%	99%	98%	95%	92%	90%	88%
Engine Friction Reduction - Level 1	EFR1	78%	79%	80%	80%	80%	79%	77%	75%	73%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	3%	6%	6%	6%	9%	15%	17%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	15%	15%	15%	15%	15%	15%	14%	14%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	14%	14%	15%	14%	14%	14%	14%	14%	13%
Cylinder Deactivation on SOHC	DEACS	4%	3%	2%	2%	1%	1%	1%	1%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	5%	2%	2%	2%	2%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	66%	68%	67%	66%	65%	61%	54%	53%	51%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	35%	38%	37%	37%	37%	35%	30%	29%	27%
Continuously Variable Valve Lift (CVVL)	CVVL	25%	26%	27%	26%	26%	26%	25%	24%	24%
Cylinder Deactivation on DOHC	DEACD	6%	5%	3%	2%	1%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	63%	74%	85%	83%	84%	82%	76%	73%	71%
Cylinder Deactivation on OHV	DEACO	2%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	2%	3%	3%	2%	2%	2%	2%	2%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1%	2%	3%	3%	3%	2%	2%	2%	2%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	41%	46%	51%	48%	46%	42%	34%	22%	15%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	12%	17%	21%	20%	18%	18%	17%	12%	6%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	2%	3%	3%	3%	2%	2%	2%	2%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	1%	1%	1%	1%	0%	0%	0%	0%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	3%	4%	5%	8%	8%	9%	8%	15%	17%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	4%	4%	5%	8%	8%	9%	10%	14%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	3%	4%	4%	4%	4%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	1%	2%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	1%	2%	3%	5%	9%	10%	10%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	2%	2%	2%	2%	2%	2%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	4%	3%	2%	2%	1%	1%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	2%	3%	4%	4%	4%	4%
Improved Auto. Trans. Controls/Externals	IATC	18%	16%	6%	1%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	25%	17%	6%	0%	0%	0%	0%	0%	0%
6-speed DCT	DCT	40%	34%	25%	13%	5%	3%	1%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	22%	31%	31%	31%	21%	14%	6%	4%	3%
High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	7%	25%	34%	40%	43%	44%	42%	38%
Shift Optimizer	SHFTOPT	0%	0%	24%	44%	64%	72%	81%	76%	71%
Electric Power Steering	EPS	79%	88%	96%	97%	97%	97%	97%	97%	97%
Improved Accessories - Level 1	IACC1	60%	71%	86%	92%	95%	97%	97%	97%	97%
Improved Accessories - Level 2	IACC2	13%	27%	41%	44%	53%	57%	58%	60%	61%
12V Micro-Hybrid (Stop-Start)	MHEV	27%	38%	53%	53%	53%	49%	45%	36%	32%
Integrated Starter Generator	ISG	6%	11%	13%	17%	30%	35%	36%	37%	37%

Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	2%	8%	11%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	1%	1%	2%	3%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	1%	1%	1%	5%	6%	7%	9%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	48%	52%	59%	61%	61%	61%	61%	61%	61%
Mass Reduction - Level 2	MR2	17%	29%	47%	50%	55%	56%	58%	59%	60%
Mass Reduction - Level 3	MR3	8%	8%	10%	12%	15%	15%	17%	19%	22%
Mass Reduction - Level 4	MR4	2%	3%	4%	4%	4%	4%	4%	7%	10%
Mass Reduction - Level 5	MR5	0%	0%	2%	2%	3%	4%	4%	6%	10%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	97%	99%	99%	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	21%	38%	48%	58%	69%	79%	86%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	91%	92%	93%	94%	94%	94%	94%	94%	94%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	97%	99%	99%	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	42%	56%	70%	79%	86%	87%	87%	89%	91%

Max Net Benefits - Passenger Cars - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	89%	89%	88%	87%	87%	87%	87%	87%	86%
Engine Friction Reduction - Level 1	EFR1	87%	87%	86%	86%	86%	86%	86%	86%	85%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	20%	23%	29%	38%	55%	57%	67%	74%	75%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	10%	10%	10%	10%	10%	10%	10%	10%	10%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	11%	11%	11%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	1%	1%	1%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	4%	4%	4%	3%	3%	3%	3%	3%	3%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	71%	71%	70%	70%	71%	71%	70%	70%	70%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	55%	55%	54%	55%	55%	55%	55%	55%	55%
Continuously Variable Valve Lift (CVVL)	CVVL	14%	14%	14%	15%	15%	15%	15%	15%	15%
Cylinder Deactivation on DOHC	DEACD	4%	3%	2%	1%	1%	1%	1%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	70%	75%	75%	78%	82%	83%	83%	84%	84%
Cylinder Deactivation on OHV	DEACO	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	5%	5%	5%	5%	5%	5%	5%	4%	4%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	5%	5%	5%	5%	5%	5%	5%	4%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	38%	41%	38%	38%	31%	28%	23%	9%	5%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	20%	22%	21%	22%	22%	22%	20%	17%	17%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	3%	3%	3%	4%	4%	3%	3%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	1%	1%	1%	3%	9%	9%	11%	19%	18%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	1%	1%	1%	1%	1%	1%	1%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	4%	4%	6%	8%	12%	16%	18%	23%	26%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	5%	5%	6%	7%	8%	8%	10%	12%	12%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	0%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	1%	1%	2%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	2%	2%	3%	3%	3%	3%	3%	3%	3%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	5%	4%	3%	1%	1%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	2%	3%	4%	6%	8%	8%	8%	8%	8%
Improved Auto. Trans. Controls/Externals	IATC	6%	2%	2%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	7%	5%	2%	0%	0%	0%	0%	0%	0%
6-speed DCT	DCT	38%	26%	15%	6%	2%	1%	1%	1%	1%
8-Speed Trans (Auto or DCT)	8SPD	31%	31%	30%	22%	11%	8%	6%	6%	5%
High Efficiency Gearbox (Auto or DCT)	HETRANS	7%	24%	36%	50%	57%	59%	61%	59%	58%
Shift Optimizer	SHFTOPT	15%	27%	39%	53%	78%	81%	82%	79%	77%
Electric Power Steering	EPS	94%	94%	94%	94%	95%	95%	95%	95%	95%
Improved Accessories - Level 1	IACC1	76%	76%	76%	78%	82%	82%	83%	87%	90%
Improved Accessories - Level 2	IACC2	38%	42%	43%	48%	51%	52%	55%	59%	61%
12V Micro-Hybrid (Stop-Start)	MHEV	24%	26%	27%	26%	24%	24%	24%	22%	18%
Integrated Starter Generator	ISG	6%	8%	10%	14%	17%	18%	19%	25%	30%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	3%	3%	3%	3%	3%	3%

Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	3%	4%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	1%	2%	2%	2%	2%	3%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	53%	53%	53%	53%	52%	52%	53%	52%	52%
Mass Reduction - Level 2	MR2	27%	32%	43%	46%	46%	46%	50%	51%	51%
Mass Reduction - Level 3	MR3	11%	13%	14%	16%	16%	15%	16%	17%	18%
Mass Reduction - Level 4	MR4	5%	5%	6%	6%	6%	6%	6%	7%	7%
Mass Reduction - Level 5	MR5	3%	3%	4%	6%	6%	5%	5%	6%	7%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	96%	98%	99%	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	22%	33%	46%	58%	78%	85%	86%	87%	87%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	92%	92%	92%	92%	92%	92%	92%	92%	92%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	96%	99%	99%	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	47%	59%	71%	81%	88%	89%	89%	89%	89%

Max Net Benefits - Passenger Cars - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	98%	98%	98%	98%	98%	98%	97%
Engine Friction Reduction - Level 1	EFR1	79%	80%	78%	78%	79%	78%	78%	78%	77%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	1%	7%	12%	13%	16%	23%	27%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	15%	15%	14%	14%	14%	14%	14%	14%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	14%	14%	14%	13%	14%	14%	14%	14%	13%
Cylinder Deactivation on SOHC	DEACS	4%	3%	2%	2%	1%	1%	1%	1%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	67%	67%	66%	66%	66%	66%	66%	66%	65%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	34%	36%	34%	35%	35%	35%	35%	35%	35%
Continuously Variable Valve Lift (CVVL)	CVVL	27%	26%	25%	24%	24%	24%	24%	24%	24%
Cylinder Deactivation on DOHC	DEACD	4%	3%	1%	0%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	70%	76%	83%	83%	84%	85%	85%	85%	85%
Cylinder Deactivation on OHV	DEACO	3%	1%	1%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	2%	3%	3%	3%	3%	3%	2%	2%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1%	1%	3%	2%	3%	3%	3%	2%	2%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	44%	45%	50%	47%	45%	43%	34%	21%	17%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_M D	15%	20%	23%	24%	22%	21%	20%	19%	14%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	2%	2%	2%	2%	2%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_M D	0%	0%	0%	0%	0%	0%	0%	0%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	4%	5%	5%	6%	10%	12%	17%	31%	34%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	4%	4%	4%	6%	7%	8%	9%	13%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	3%	3%	4%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	1%	2%	2%	3%	3%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	3%	4%	4%	4%	4%	4%	5%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	4%	4%	3%	2%	2%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	2%	3%	4%	4%	4%	4%
Improved Auto. Trans. Controls/Externals	IATC	20%	18%	8%	3%	1%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	21%	17%	8%	2%	0%	0%	0%	0%	0%
6-speed DCT	DCT	43%	34%	23%	12%	9%	6%	5%	2%	1%
8-Speed Trans (Auto or DCT)	8SPD	21%	28%	33%	34%	31%	24%	18%	12%	13%
High Efficiency Gearbox (Auto or DCT)	HETRANS	0%	8%	22%	32%	37%	41%	50%	56%	56%
Shift Optimizer	SHFTOPT	0%	0%	15%	32%	45%	55%	63%	65%	65%
Electric Power Steering	EPS	92%	96%	97%	97%	97%	97%	97%	97%	97%
Improved Accessories - Level 1	IACC1	73%	77%	86%	90%	94%	94%	95%	95%	95%
Improved Accessories - Level 2	IACC2	12%	16%	26%	28%	43%	48%	53%	56%	58%
12V Micro-Hybrid (Stop-Start)	MHEV	27%	27%	27%	27%	29%	28%	26%	27%	24%
Integrated Starter Generator	ISG	7%	9%	10%	11%	12%	15%	18%	21%	27%

Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	1%	1%	1%	1%	1%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	1%	1%	1%	0%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	1%	1%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	2%	2%	2%	2%	2%	2%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	55%	57%	59%	60%	61%	60%	61%	60%	61%
Mass Reduction - Level 2	MR2	18%	26%	44%	47%	52%	52%	59%	59%	60%
Mass Reduction - Level 3	MR3	8%	8%	12%	14%	16%	16%	18%	19%	22%
Mass Reduction - Level 4	MR4	2%	3%	4%	4%	4%	4%	4%	7%	7%
Mass Reduction - Level 5	MR5	0%	0%	2%	3%	3%	4%	4%	4%	4%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	97%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	18%	34%	51%	61%	71%	82%	88%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	93%	93%	93%	94%	94%	94%	94%	94%	94%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	96%	98%	99%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	42%	55%	69%	78%	85%	86%	86%	89%	91%

Total Cost = Total Benefits - Passenger Cars - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	87%	87%	87%	86%	86%	86%	86%	85%	84%
Engine Friction Reduction - Level 1	EFR1	85%	85%	84%	85%	85%	85%	84%	84%	83%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	18%	21%	26%	33%	52%	57%	66%	75%	77%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	10%	10%	10%	10%	10%	10%	10%	10%	10%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	11%	11%	11%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	1%	1%	1%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	4%	4%	4%	3%	3%	3%	3%	3%	3%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	71%	70%	70%	69%	69%	69%	69%	69%	68%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	55%	55%	54%	55%	56%	56%	56%	55%	55%
Continuously Variable Valve Lift (CVVL)	CVVL	14%	14%	14%	14%	14%	14%	14%	14%	14%
Cylinder Deactivation on DOHC	DEACD	3%	2%	1%	1%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	78%	80%	81%	81%	82%	84%	84%	84%	83%
Cylinder Deactivation on OHV	DEACO	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	5%	5%	5%	5%	5%	4%	4%	4%	4%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	5%	5%	5%	5%	5%	4%	4%	4%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	46%	46%	43%	41%	30%	25%	20%	6%	3%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	21%	23%	22%	21%	20%	19%	15%	11%	9%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	3%	3%	3%	3%	3%	3%	2%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	3%	3%	3%	5%	5%	4%	3%	3%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	1%	1%	1%	1%	0%	0%	0%	2%	4%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	2%	3%	4%	6%	16%	23%	27%	38%	40%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	5%	5%	5%	7%	8%	11%	11%	12%	12%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	0%	1%	1%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	1%	3%	3%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	1%	2%	2%	2%	4%	4%	4%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	2%	2%	2%	3%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	1%	2%	2%	2%	2%	2%	2%
Advanced Diesel - Medium Displacement	ADSL_MD	1%	1%	1%	1%	1%	1%	1%	1%	1%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	5%	4%	3%	1%	1%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	2%	3%	4%	6%	8%	8%	8%	8%	9%
Improved Auto. Trans. Controls/Externals	IATC	4%	2%	2%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	7%	2%	2%	0%	0%	0%	0%	0%	0%
6-speed DCT	DCT	41%	29%	14%	6%	2%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	29%	29%	27%	18%	10%	8%	6%	6%	5%
High Efficiency Gearbox (Auto or DCT)	HETRANS	7%	23%	38%	55%	60%	64%	64%	62%	60%
Shift Optimizer	SHFTOPT	14%	25%	40%	56%	78%	83%	82%	78%	75%
Electric Power Steering	EPS	94%	94%	94%	94%	95%	95%	95%	95%	95%

Improved Accessories - Level 1	IACC1	76%	79%	82%	83%	85%	85%	91%	95%	96%
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	38%	43%	48%	55%	64%	65%	70%	73%	75%
12V Micro-Hybrid (Stop-Start)	MHEV	29%	30%	33%	32%	32%	33%	33%	30%	28%
Integrated Starter Generator	ISG	11%	13%	15%	18%	19%	24%	24%	26%	29%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	1%	1%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	2%	5%	7%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	2%	2%	3%	3%	3%	4%	4%	4%	5%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	1%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	53%	53%	53%	53%	53%	52%	53%	52%	52%
Mass Reduction - Level 2	MR2	27%	33%	44%	47%	47%	47%	51%	51%	51%
Mass Reduction - Level 3	MR3	11%	13%	13%	16%	17%	16%	16%	19%	19%
Mass Reduction - Level 4	MR4	5%	5%	5%	8%	7%	7%	7%	7%	7%
Mass Reduction - Level 5	MR5	3%	3%	3%	7%	7%	7%	6%	7%	7%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	96%	98%	99%	100%	100 %	100 %	100 %	100%
Low Rolling Resistance Tires - Level 2	ROLL2	22%	27%	39%	53%	76%	83%	85%	86%	88%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	92%	92%	92%	92%	92%	92%	92%	92%	92%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	96%	99%	99%	100%	100 %	100 %	100 %	100%
Aero Drag Reduction, Level 2	AERO2	47%	59%	71%	81%	88%	89%	89%	89%	89%

Total Cost = Total Benefits - Passenger Cars - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	98%	98%	98%	98%	96%	96%	96%
Engine Friction Reduction - Level 1	EFR1	80%	80%	79%	79%	78%	78%	77%	76%	76%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	1%	6%	12%	13%	14%	22%	25%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	15%	14%	14%	14%	14%	14%	14%	14%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	14%	14%	14%	14%	14%	14%	14%	14%	14%
Cylinder Deactivation on SOHC	DEACS	4%	3%	2%	2%	1%	1%	1%	1%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	67%	67%	67%	66%	65%	65%	64%	63%	63%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	34%	35%	34%	34%	34%	35%	35%	35%	34%
Continuously Variable Valve Lift (CVVL)	CVVL	27%	26%	25%	25%	25%	25%	24%	24%	24%
Cylinder Deactivation on DOHC	DEACD	4%	4%	2%	1%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	68%	74%	81%	82%	83%	84%	84%	84%	84%
Cylinder Deactivation on OHV	DEACO	3%	1%	1%	1%	1%	1%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	3%	2%	3%	3%	3%	3%	3%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	1%	1%	2%	2%	2%	2%	3%	3%	3%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	42%	44%	48%	48%	45%	39%	31%	18%	14%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	14%	19%	22%	21%	21%	20%	20%	17%	14%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	2%	2%	2%	3%	2%	2%	1%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	1%	1%	1%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	5%	5%	5%	7%	11%	17%	22%	32%	34%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	4%	4%	4%	6%	7%	7%	8%	10%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	1%	1%	1%	1%	1%	1%	1%	1%	1%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	1%	2%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	3%	3%	4%	4%	4%	4%	4%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	1%	1%	1%	1%	1%	1%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	4%	4%	3%	2%	2%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	0%	2%	3%	4%	4%	4%	4%
Improved Auto. Trans. Controls/Externals	IATC	18%	15%	6%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	20%	15%	6%	1%	0%	0%	0%	0%	0%
6-speed DCT	DCT	47%	37%	25%	13%	5%	3%	1%	1%	0%
8-Speed Trans (Auto or DCT)	8SPD	23%	31%	31%	31%	23%	14%	8%	5%	5%
High Efficiency Gearbox (Auto or DCT)	HETRANS	0%	8%	26%	39%	44%	45%	54%	56%	56%
Shift Optimizer	SHFTOPT	0%	0%	18%	35%	53%	68%	73%	79%	80%
Electric Power Steering	EPS	92%	97%	97%	97%	97%	97%	97%	97%	97%

Improved Accessories - Level 1	IACC1	76%	82%	90%	94%	94%	96%	96%	97%	97%
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	16%	26%	36%	37%	49%	54%	56%	60%	63%
12V Micro-Hybrid (Stop-Start)	MHEV	29%	30%	35%	34%	35%	33%	30%	25%	24%
Integrated Starter Generator	ISG	8%	10%	11%	13%	16%	20%	22%	26%	28%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	2%	6%	7%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	1%	1%	1%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	2%	2%	2%	2%	3%	3%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	1%	1%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	55%	57%	59%	61%	61%	61%	61%	61%	61%
Mass Reduction - Level 2	MR2	18%	30%	48%	51%	56%	56%	59%	59%	59%
Mass Reduction - Level 3	MR3	8%	8%	11%	13%	16%	16%	18%	19%	21%
Mass Reduction - Level 4	MR4	2%	2%	4%	4%	4%	4%	5%	6%	9%
Mass Reduction - Level 5	MR5	0%	0%	1%	2%	3%	4%	4%	6%	9%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	97%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	17%	35%	46%	58%	68%	84%	87%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	93%	93%	93%	94%	94%	94%	94%	94%	94%
Secondary Axle Disconnect	SAX	1%	1%	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction, Level 1	AERO1	92%	96%	98%	99%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	42%	55%	69%	78%	85%	86%	86%	89%	91%

* DOT has not yet been able to modify the CAFE model to explicitly estimate the extent to which manufacturers might respond to the proposed technology incentives by building greater numbers of HEVs, PHEVs, and/or EVs. Increased application of such technologies could result in reduced estimated application of some other technologies (*e.g.*, diesel engines).

Table V-151 Penetration Rate of New Technologies to Light Trucks, by Baseline Model Year and Alternative

Preferred Alternative - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	78%	78%	78%	77%	77%	77%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	89%	89%	89%	89%	89%	89%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	11%	19%	41%	49%	68%	74%	77%	83%	90%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	14%	13%	13%	13%	13%	13%	13%	13%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	12%	12%	12%	12%	12%	12%
Cylinder Deactivation on SOHC	DEACS	5%	5%	3%	2%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	58%	58%	58%	59%	60%	61%	62%	62%	62%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	41%	40%	41%	41%	43%	43%	44%	44%	44%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	28%	26%	24%	20%	17%	16%	16%	10%	9%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	42%	45%	49%	54%	61%	63%	64%	70%	72%
Cylinder Deactivation on OHV	DEACO	14%	14%	13%	11%	10%	9%	7%	7%	7%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	19%	17%	17%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	9%	9%	10%	12%	12%	11%	12%	12%	12%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	10%	10%	9%	8%	8%	7%	7%	8%	7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	27%	30%	34%	42%	44%	42%	43%	46%	43%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	7%	6%	6%	6%	8%	7%	7%	7%	6%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	1%	2%	2%	3%	6%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	1%	2%	2%	2%	2%	2%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	0%	0%	2%	2%	3%	5%	6%	8%	9%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	1%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	0%	1%	3%	4%	4%	4%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	2%	2%	1%	1%	1%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	2%	2%	2%	2%

Improved Auto. Trans. Controls/Externals	IATC	30%	23%	23%	16%	4%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	35%	28%	18%	11%	9%	5%	2%	0%	0%
6-speed DCT	DCT	2%	2%	3%	2%	2%	1%	1%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	14%	18%	19%	18%	16%	15%	14%	9%	2%
High Efficiency Gearbox (Auto or DCT)	HETRANS	5%	13%	28%	42%	63%	74%	78%	85%	92%
Shift Optimizer	SHFTOPT	10%	15%	30%	40%	54%	58%	66%	85%	92%
Electric Power Steering	EPS	74%	78%	80%	83%	86%	87%	88%	89%	96%
Improved Accessories - Level 1	IACC1	46%	49%	51%	53%	60%	61%	65%	77%	81%
Improved Accessories - Level 2	IACC2	7%	7%	9%	16%	24%	29%	36%	51%	71%
12V Micro-Hybrid (Stop-Start)	MHEV	3%	3%	3%	3%	3%	3%	3%	3%	2%
Integrated Starter Generator	ISG	0%	0%	0%	0%	0%	0%	0%	0%	4%
Strong Hybrid - Level 1	SHEV1	2%	2%	1%	1%	1%	1%	1%	1%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	82%	84%	93%	96%	99%	100%	100%	100%	100%
Mass Reduction - Level 2	MR2	35%	44%	56%	67%	76%	81%	83%	85%	88%
Mass Reduction - Level 3	MR3	14%	14%	17%	23%	36%	41%	46%	52%	59%
Mass Reduction - Level 4	MR4	7%	7%	8%	11%	21%	24%	25%	29%	42%
Mass Reduction - Level 5	MR5	0%	0%	0%	1%	1%	3%	3%	5%	18%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100%	100%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	12%	24%	48%	63%	79%	85%	90%	94%	98%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	76%	77%	80%	81%	82%	82%	82%	82%	82%
Secondary Axle Disconnect	SAX	27%	33%	34%	38%	38%	38%	38%	38%	37%
Aero Drag Reduction, Level 1	AERO1	99%	99%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	61%	69%	86%	93%	95%	98%	100%	100%	100%

Preferred Alternative - Light Trucks - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	100 %	100%	100 %	100 %	100 %	100%	100%
Engine Friction Reduction - Level 1	EFR1	71%	72%	72%	73%	73%	73%	75%	75%	75%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	8%	13%	25%	26%	35%	43%	44%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	26%	26%	26%	26%	24%	24%	24%	24%	24%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	22%	23%	23%	23%	23%	23%	24%	24%	23%
Cylinder Deactivation on SOHC	DEACS	19%	19%	17%	16%	5%	4%	3%	3%	3%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2%	2%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	46%	46%	48%	48%	48%	48%	48%	48%	48%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	17%	18%	20%	20%	20%	20%	20%	20%	20%
Continuously Variable Valve Lift (CVVL)	CVVL	11%	11%	11%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on DOHC	DEACD	15%	20%	15%	15%	13%	12%	12%	10%	8%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	28%	31%	41%	42%	54%	56%	58%	61%	62%
Cylinder Deactivation on OHV	DEACO	11%	11%	9%	3%	3%	3%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	16%	16%	16%	16%	16%	16%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	3%	3%	10%	16%	16%	16%	18%	18%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	11%	12%	13%	13%	12%	13%	13%	12%	12%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	18%	19%	27%	28%	30%	32%	32%	32%	33%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	1%	1%	9%	15%	26%	26%	29%	29%	29%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	3%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	0%	0%	0%	0%	1%	1%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	5%	5%	6%	4%	4%	5%	5%	5%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	1%	1%	1%	2%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	2%	2%	1%	1%	1%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	1%	1%	1%	1%
Improved Auto. Trans. Controls/Externals	IATC	52%	49%	36%	19%	5%	3%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	71%	68%	53%	32%	18%	13%	5%	0%	0%
6-speed DCT	DCT	5%	7%	6%	3%	3%	3%	3%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	7%	10%	13%	19%	16%	15%	13%	9%	9%

High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	2%	13%	24%	45%	54%	64%	71%	73%
Shift Optimizer	SHFTOPT	0%	0%	14%	27%	33%	38%	48%	62%	67%
Electric Power Steering	EPS	69%	73%	81%	86%	88%	90%	91%	92%	92%
Improved Accessories - Level 1	IACC1	57%	61%	66%	70%	79%	83%	84%	89%	90%
Improved Accessories - Level 2	IACC2	8%	10%	15%	16%	32%	36%	40%	47%	50%
12V Micro-Hybrid (Stop-Start)	MHEV	9%	9%	10%	13%	13%	12%	12%	12%	12%
Integrated Starter Generator	ISG	3%	3%	3%	4%	4%	4%	4%	4%	4%
Strong Hybrid - Level 1	SHEV1	1%	1%	1%	1%	1%	1%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	69%	76%	83%	91%	94%	95%	95%	99%	99%
Mass Reduction - Level 2	MR2	30%	36%	45%	48%	61%	64%	64%	68%	68%
Mass Reduction - Level 3	MR3	14%	14%	15%	17%	21%	23%	26%	30%	30%
Mass Reduction - Level 4	MR4	6%	7%	7%	8%	11%	12%	12%	15%	15%
Mass Reduction - Level 5	MR5	0%	0%	1%	2%	5%	6%	7%	9%	9%
Low Rolling Resistance Tires - Level 1	ROLL1	98%	98%	98%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	19%	26%	41%	49%	57%	76%	77%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	74%	76%	80%	82%	82%	83%	83%	83%	83%
Secondary Axle Disconnect	SAX	27%	29%	32%	33%	34%	36%	37%	37%	38%
Aero Drag Reduction, Level 1	AERO1	100%	100%	100%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	49%	56%	70%	84%	87%	89%	92%	95%	96%

2% Annual Increase - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	78%	78%	78%	77%	77%	77%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	89%	89%	89%	89%	89%	89%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	12%	20%	35%	47%	59%	64%	65%	69%	73%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	14%	13%	13%	13%	13%	13%	13%	13%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	12%	12%	12%	12%	12%	12%
Cylinder Deactivation on SOHC	DEACS	3%	3%	3%	3%	1%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	58%	58%	58%	59%	60%	61%	62%	62%	62%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	40%	40%	40%	41%	42%	43%	44%	44%	44%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	10%	10%	10%	10%	11%	11%	9%	9%	9%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	63%	63%	63%	64%	67%	68%	71%	71%	71%
Cylinder Deactivation on OHV	DEACO	13%	13%	13%	13%	12%	11%	10%	10%	10%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	18%	17%	16%	16%	15%	15%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	9%	9%	9%	10%	9%	9%	9%	9%	9%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	10%	10%	9%	9%	9%	9%	9%	9%	9%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	50%	49%	50%	51%	51%	51%	54%	54%	54%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	6%	6%	6%	6%	7%	8%	8%	8%	8%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	1%	1%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	0%	0%	0%	0%	1%	1%	1%	1%	1%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	1%	1%	1%	1%	1%	2%	2%	2%
Improved Auto. Trans. Controls/Externals	IATC	16%	12%	9%	3%	3%	3%	4%	6%	5%
6-Speed Trans with Improved Internals (Auto)	NAUTO	47%	41%	29%	22%	17%	11%	10%	17%	17%
6-speed DCT	DCT	4%	4%	5%	3%	3%	1%	1%	1%	1%
8-Speed Trans (Auto or DCT)	8SPD	16%	18%	21%	22%	19%	22%	21%	15%	11%
High Efficiency Gearbox (Auto or DCT)	HETRANS	3%	9%	19%	29%	42%	48%	52%	57%	62%
Shift Optimizer	SHFTOPT	8%	10%	23%	25%	26%	28%	28%	29%	29%
Electric Power Steering	EPS	70%	73%	74%	75%	76%	77%	78%	78%	84%
Improved Accessories - Level 1	IACC1	48%	50%	52%	55%	56%	56%	56%	56%	56%
Improved Accessories - Level 2	IACC2	4%	5%	5%	5%	8%	9%	10%	13%	13%
12V Micro-Hybrid (Stop-Start)	MHEV	3%	3%	3%	3%	3%	3%	3%	3%	3%
Integrated Starter Generator	ISG	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 1	SHEV1	2%	2%	1%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%

Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	78%	79%	85%	88%	88%	90%	91%	91%	91%
Mass Reduction - Level 2	MR2	34%	43%	54%	64%	70%	71%	74%	74%	78%
Mass Reduction - Level 3	MR3	16%	16%	19%	23%	23%	26%	32%	36%	37%
Mass Reduction - Level 4	MR4	8%	8%	9%	9%	10%	13%	13%	18%	18%
Mass Reduction - Level 5	MR5	0%	0%	0%	0%	0%	2%	2%	4%	4%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100 %	100 %	100%	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	12%	24%	41%	62%	79%	82%	83%	89%	91%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	74%	75%	77%	77%	78%	78%	78%	77%	77%
Secondary Axle Disconnect	SAX	26%	29%	32%	32%	33%	35%	35%	37%	37%
Aero Drag Reduction, Level 1	AERO1	99%	99%	99%	100%	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	61%	69%	86%	93%	95%	98%	100 %	100%	100%

2% Annual Increase - Light Trucks - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Engine Friction Reduction - Level 1	EFR1	71%	72%	72%	72%	72%	72%	74%	74%	74%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	7%	9%	13%	17%	22%	25%	25%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	24%	24%	24%	24%	24%	24%	24%	24%	24%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	22%	23%	23%	23%	23%	23%	23%	22%	22%
Cylinder Deactivation on SOHC	DEACS	8%	8%	7%	7%	7%	7%	7%	5%	5%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2%	2%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	46%	46%	48%	48%	48%	48%	48%	48%	48%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	18%	18%	20%	20%	20%	20%	20%	20%	20%
Continuously Variable Valve Lift (CVVL)	CVVL	10%	11%	11%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on DOHC	DEACD	12%	12%	9%	9%	8%	7%	6%	6%	6%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	50%	51%	56%	56%	57%	58%	59%	61%	61%
Cylinder Deactivation on OHV	DEACO	9%	9%	9%	9%	9%	9%	9%	9%	9%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	16%	16%	16%	16%	16%	16%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	10%	10%	10%	10%	10%	10%	10%	10%	10%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	9%	11%	12%	11%	11%	11%	11%	11%	11%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	33%	34%	37%	37%	38%	38%	39%	41%	41%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	14%	15%	16%	16%	16%	16%	16%	16%	16%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	4%	5%	5%	5%	5%	4%	4%	4%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	1%	1%	1%	2%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	1%	1%	1%	1%
Improved Auto. Trans. Controls/Externals	IATC	55%	52%	40%	24%	16%	14%	14%	19%	19%
6-Speed Trans with Improved Internals (Auto)	NAUTO	64%	62%	54%	35%	27%	25%	19%	19%	19%
6-speed DCT	DCT	7%	7%	5%	5%	5%	7%	7%	6%	6%
8-Speed Trans (Auto or DCT)	8SPD	6%	8%	8%	13%	20%	19%	20%	21%	21%
High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	2%	10%	21%	25%	28%	33%	33%	33%
Shift Optimizer	SHFTOPT	0%	0%	12%	18%	20%	21%	28%	28%	28%
Electric Power Steering	EPS	67%	69%	73%	74%	84%	88%	90%	90%	90%
Improved Accessories - Level 1	IACC1	55%	56%	58%	61%	65%	67%	73%	82%	81%
Improved Accessories - Level 2	IACC2	8%	10%	12%	12%	16%	16%	19%	24%	30%
12V Micro-Hybrid (Stop-Start)	MHEV	12%	12%	12%	13%	12%	12%	12%	12%	12%
Integrated Starter Generator	ISG	2%	2%	2%	3%	4%	4%	4%	4%	4%

Strong Hybrid - Level 1	SHEV1	1%	1%	1%	1%	1%	1%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	1%	1%	1%	1%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	69%	69%	75%	77%	83%	84%	84%	84%	84%
Mass Reduction - Level 2	MR2	30%	37%	44%	47%	57%	59%	59%	64%	63%
Mass Reduction - Level 3	MR3	15%	15%	15%	16%	16%	18%	21%	23%	24%
Mass Reduction - Level 4	MR4	6%	6%	7%	7%	7%	7%	8%	10%	11%
Mass Reduction - Level 5	MR5	0%	0%	1%	1%	1%	1%	1%	4%	4%
Low Rolling Resistance Tires - Level 1	ROLL1	98%	98%	98%	98%	98%	98%	98%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	17%	30%	39%	49%	60%	73%	74%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	70%	71%	74%	74%	82%	81%	81%	81%	81%
Secondary Axle Disconnect	SAX	27%	30%	32%	33%	33%	35%	35%	35%	35%
Aero Drag Reduction, Level 1	AERO1	94%	94%	94%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	49%	56%	70%	80%	83%	85%	88%	91%	91%

3% Annual Increase - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	78%	78%	78%	77%	77%	77%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	89%	89%	89%	89%	89%	89%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	12%	20%	35%	49%	61%	65%	69%	76%	83%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	14%	13%	13%	13%	13%	13%	13%	13%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	12%	12%	12%	12%	12%	12%
Cylinder Deactivation on SOHC	DEACS	3%	3%	3%	2%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	58%	58%	58%	59%	60%	61%	62%	62%	62%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	41%	40%	41%	42%	43%	43%	44%	44%	44%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	9%	9%	9%	9%	8%	7%	6%	5%	4%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	64%	65%	66%	67%	71%	73%	74%	76%	77%
Cylinder Deactivation on OHV	DEACO	13%	13%	8%	6%	6%	6%	4%	4%	4%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	19%	17%	17%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	9%	9%	11%	15%	15%	14%	15%	15%	15%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	10%	10%	9%	9%	9%	9%	9%	9%	7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	48%	48%	51%	55%	52%	51%	51%	50%	47%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	7%	6%	10%	11%	12%	12%	12%	12%	12%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	1%	1%	1%	2%	5%	5%	5%	5%	7%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	0%	0%	0%	0%	0%	2%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	1%	2%	2%	2%	5%	6%	7%	10%	11%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	1%	1%	1%	3%	3%	3%	3%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	1%	1%	1%	2%	2%	2%	2%	2%
Improved Auto. Trans. Controls/Externals	IATC	14%	10%	8%	3%	4%	3%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	38%	33%	22%	17%	8%	7%	2%	1%	0%
6-speed DCT	DCT	8%	10%	10%	7%	7%	3%	3%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	27%	28%	32%	27%	16%	14%	15%	10%	7%
High Efficiency Gearbox (Auto or DCT)	HETRANS	5%	13%	24%	38%	54%	60%	66%	75%	79%
Shift Optimizer	SHFTOPT	11%	18%	33%	45%	60%	62%	63%	67%	73%
Electric Power Steering	EPS	69%	73%	74%	76%	79%	79%	80%	82%	84%
Improved Accessories - Level 1	IACC1	48%	50%	55%	57%	57%	58%	58%	59%	59%
Improved Accessories - Level 2	IACC2	4%	5%	6%	5%	8%	11%	11%	17%	19%
12V Micro-Hybrid (Stop-Start)	MHEV	3%	3%	3%	3%	3%	3%	3%	3%	3%
Integrated Starter Generator	ISG	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 1	SHEV1	2%	2%	1%	2%	2%	2%	1%	1%	1%

Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	88%	89%	94%	97%	98%	100%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	35%	44%	56%	67%	76%	81%	84%	84%	85%
Mass Reduction - Level 3	MR3	16%	16%	19%	24%	29%	32%	39%	44%	48%
Mass Reduction - Level 4	MR4	8%	9%	9%	14%	16%	19%	19%	23%	27%
Mass Reduction - Level 5	MR5	0%	0%	0%	3%	3%	3%	3%	5%	9%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	13%	24%	43%	60%	75%	84%	89%	95%	97%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	74%	75%	77%	78%	81%	81%	81%	82%	84%
Secondary Axle Disconnect	SAX	27%	33%	34%	38%	38%	38%	38%	38%	42%
Aero Drag Reduction, Level 1	AERO1	100%	100%	99%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	61%	69%	86%	93%	95%	98%	100%	100 %	100 %

3% Annual Increase - Light Trucks - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Engine Friction Reduction - Level 1	EFR1	71%	72%	72%	74%	74%	74%	74%	74%	74%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	8%	17%	23%	27%	38%	41%	43%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	25%	25%	26%	26%	26%	26%	26%	25%	25%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	22%	23%	23%	23%	23%	23%	24%	24%	23%
Cylinder Deactivation on SOHC	DEACS	8%	8%	5%	5%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	48%	48%	48%	47%	47%	47%	47%	48%	48%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	18%	17%	18%	18%	18%	18%	18%	18%	18%
Continuously Variable Valve Lift (CVVL)	CVVL	10%	11%	11%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on DOHC	DEACD	8%	7%	6%	7%	6%	4%	4%	4%	4%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	54%	56%	62%	62%	67%	69%	70%	71%	71%
Cylinder Deactivation on OHV	DEACO	9%	9%	7%	3%	3%	2%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	16%	16%	16%	16%	16%	16%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	10%	10%	11%	16%	16%	16%	18%	18%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	12%	12%	13%	12%	12%	12%	12%	12%	12%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	36%	38%	41%	42%	42%	43%	43%	43%	42%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	15%	15%	17%	22%	26%	27%	30%	30%	30%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	5%	5%	5%	5%	5%	6%	6%	5%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	1%	1%	1%	2%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	1%	1%	1%	1%	1%	1%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	1%	1%	1%	1%
Improved Auto. Trans. Controls/Externals	IATC	55%	52%	38%	22%	8%	5%	1%	1%	1%
6-Speed Trans with Improved Internals (Auto)	NAUTO	70%	68%	50%	30%	15%	10%	2%	2%	2%
6-speed DCT	DCT	8%	9%	9%	7%	7%	5%	5%	3%	2%
8-Speed Trans (Auto or DCT)	8SPD	5%	8%	19%	27%	23%	23%	23%	16%	9%
High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	2%	14%	19%	42%	44%	50%	59%	66%
Shift Optimizer	SHFTOPT	0%	0%	6%	18%	22%	31%	39%	44%	47%
Electric Power Steering	EPS	72%	75%	81%	84%	85%	85%	85%	85%	85%
Improved Accessories - Level 1	IACC1	66%	70%	74%	77%	78%	78%	78%	80%	80%
Improved Accessories - Level 2	IACC2	8%	9%	10%	10%	10%	12%	12%	13%	14%
12V Micro-Hybrid (Stop-Start)	MHEV	13%	12%	13%	13%	12%	12%	12%	12%	12%
Integrated Starter Generator	ISG	2%	2%	2%	3%	4%	4%	4%	4%	4%

Strong Hybrid - Level 1	SHEV1	1%	1%	1%	1%	1%	1%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	1%	1%	1%	1%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	71%	75%	82%	90%	96%	97%	97%	97%	100%
Mass Reduction - Level 2	MR2	30%	37%	50%	57%	63%	66%	66%	73%	78%
Mass Reduction - Level 3	MR3	15%	15%	16%	17%	25%	27%	32%	37%	42%
Mass Reduction - Level 4	MR4	6%	6%	7%	14%	16%	18%	19%	20%	25%
Mass Reduction - Level 5	MR5	0%	0%	1%	2%	2%	3%	3%	3%	7%
Low Rolling Resistance Tires - Level 1	ROLL1	98%	98%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	18%	33%	47%	55%	71%	82%	84%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	76%	77%	80%	83%	83%	83%	83%	83%	83%
Secondary Axle Disconnect	SAX	29%	31%	35%	37%	37%	38%	38%	38%	38%
Aero Drag Reduction, Level 1	AERO1	100%	100%	100%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	49%	56%	68%	84%	87%	89%	92%	97%	100%

4% Annual Increase - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	78%	78%	78%	77%	77%	76%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	89%	89%	89%	89%	89%	89%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	11%	23%	38%	52%	66%	72%	77%	82%	84%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	14%	13%	13%	13%	13%	13%	13%	13%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	12%	12%	12%	12%	12%	12%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	2%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	58%	58%	58%	59%	60%	61%	62%	62%	62%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	41%	40%	41%	42%	43%	43%	44%	44%	44%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	7%	7%	6%	6%	5%	4%	1%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	68%	69%	70%	70%	74%	76%	79%	81%	81%
Cylinder Deactivation on OHV	DEACO	12%	12%	3%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	19%	17%	17%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	11%	12%	15%	20%	19%	18%	17%	17%	17%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	10%	10%	9%	7%	7%	4%	4%	2%	1%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	50%	50%	50%	45%	39%	35%	32%	26%	22%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	9%	9%	17%	18%	14%	11%	13%	13%	13%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	1%	1%	1%	1%	1%	3%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	2%	9%	9%	10%	12%	13%	16%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	1%	1%	4%	4%	5%	5%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	5%	6%	8%	15%	19%	21%	25%	27%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	0%	0%	3%	3%	3%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	1%	1%	1%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	1%	1%	4%	7%	7%	7%	7%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	1%	1%	1%	2%	2%	2%	2%	2%
Improved Auto. Trans. Controls/Externals	IATC	13%	6%	5%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	32%	24%	12%	6%	3%	3%	1%	1%	1%
6-speed DCT	DCT	5%	5%	4%	2%	1%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	34%	40%	40%	34%	17%	14%	9%	5%	5%
High Efficiency Gearbox (Auto or DCT)	HETRANS	8%	15%	31%	45%	60%	64%	71%	75%	75%
Shift Optimizer	SHFTOPT	11%	19%	34%	49%	66%	74%	81%	93%	94%
Electric Power Steering	EPS	79%	83%	92%	92%	92%	92%	92%	93%	93%
Improved Accessories - Level 1	IACC1	51%	53%	56%	63%	69%	71%	75%	85%	87%
Improved Accessories - Level 2	IACC2	7%	8%	11%	15%	24%	28%	32%	35%	43%
12V Micro-Hybrid (Stop-Start)	MHEV	3%	3%	3%	3%	6%	7%	7%	7%	7%

Integrated Starter Generator	ISG	0%	0%	0%	1%	1%	2%	2%	4%	9%
Strong Hybrid - Level 1	SHEV1	2%	2%	1%	2%	2%	2%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	87%	88%	93%	98%	99%	100%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	30%	39%	54%	64%	77%	82%	84%	87%	88%
Mass Reduction - Level 3	MR3	16%	18%	22%	29%	34%	38%	44%	49%	52%
Mass Reduction - Level 4	MR4	9%	10%	12%	17%	25%	28%	33%	41%	46%
Mass Reduction - Level 5	MR5	0%	0%	2%	5%	8%	9%	11%	17%	21%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	13%	28%	48%	66%	71%	76%	85%	89%	90%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	81%	82%	83%	84%	84%	84%	84%	84%	84%
Secondary Axle Disconnect	SAX	34%	38%	39%	44%	43%	43%	43%	43%	43%
Aero Drag Reduction, Level 1	AERO1	100%	100%	99%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	61%	69%	86%	93%	95%	98%	100%	100 %	100 %

4% Annual Increase - Light Trucks - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100%	100%	100%	100%	100 %	99%
Engine Friction Reduction - Level 1	EFR1	71%	72%	72%	74%	74%	74%	74%	74%	73%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	8%	17%	20%	21%	26%	32%	39%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	25%	25%	26%	26%	26%	26%	26%	25%	24%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	23%	24%	24%	24%	24%	24%	24%	24%	23%
Cylinder Deactivation on SOHC	DEACS	7%	7%	5%	6%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	48%	48%	48%	47%	47%	47%	47%	48%	48%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	19%	18%	18%	18%	19%	19%	19%	19%	19%
Continuously Variable Valve Lift (CVVL)	CVVL	10%	11%	10%	10%	10%	10%	10%	10%	10%
Cylinder Deactivation on DOHC	DEACD	10%	6%	2%	2%	2%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	53%	58%	66%	65%	70%	72%	74%	74%	74%
Cylinder Deactivation on OHV	DEACO	9%	9%	7%	3%	3%	2%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	16%	16%	16%	16%	16%	16%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	10%	10%	11%	16%	16%	16%	18%	18%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	12%	12%	12%	11%	11%	9%	9%	5%	1%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	34%	36%	41%	37%	36%	36%	33%	22%	13%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	16%	19%	21%	24%	29%	29%	30%	29%	27%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	1%	2%	2%	9%	10%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	3%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	1%	1%	3%	3%	6%	10%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	5%	5%	10%	10%	11%	13%	18%	24%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	1%	2%	3%	3%	6%	7%	7%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	1%	1%	1%	1%	1%	1%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	1%	1%	1%	1%
Improved Auto. Trans. Controls/Externals	IATC	50%	44%	30%	14%	5%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	66%	61%	46%	25%	10%	7%	3%	0%	0%
6-speed DCT	DCT	7%	9%	9%	6%	6%	4%	3%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	9%	14%	18%	18%	14%	14%	10%	5%	4%
High Efficiency Gearbox (Auto or DCT)	HETRANS	2%	3%	14%	25%	43%	46%	50%	57%	57%
Shift Optimizer	SHFTOPT	0%	0%	12%	28%	53%	57%	71%	83%	89%
Electric Power Steering	EPS	72%	77%	82%	86%	88%	90%	90%	92%	92%
Improved Accessories - Level 1	IACC1	61%	63%	63%	65%	70%	74%	77%	82%	85%
Improved Accessories - Level 2	IACC2	8%	10%	14%	22%	26%	31%	32%	49%	59%
12V Micro-Hybrid (Stop-Start)	MHEV	12%	13%	13%	14%	12%	12%	13%	13%	10%
Integrated Starter Generator	ISG	3%	3%	3%	3%	5%	5%	5%	5%	6%

Strong Hybrid - Level 1	SHEV1	1%	1%	1%	1%	1%	1%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	73%	80%	87%	92%	96%	97%	98%	100%	100%
Mass Reduction - Level 2	MR2	31%	37%	57%	64%	74%	76%	78%	81%	87%
Mass Reduction - Level 3	MR3	16%	17%	22%	27%	34%	35%	42%	47%	59%
Mass Reduction - Level 4	MR4	7%	7%	11%	21%	22%	25%	29%	31%	31%
Mass Reduction - Level 5	MR5	0%	1%	1%	4%	5%	8%	8%	10%	11%
Low Rolling Resistance Tires - Level 1	ROLL1	98%	98%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	17%	31%	48%	55%	66%	79%	87%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	76%	76%	81%	82%	83%	83%	83%	83%	83%
Secondary Axle Disconnect	SAX	29%	31%	34%	35%	36%	36%	36%	37%	37%
Aero Drag Reduction, Level 1	AERO1	100%	100%	100%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	49%	56%	70%	85%	88%	90%	93%	96%	100%

5% Annual Increase - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	78%	78%	77%	77%	77%	74%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	89%	89%	89%	89%	89%	89%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	11%	23%	37%	53%	59%	65%	70%	76%	76%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	14%	13%	13%	13%	13%	13%	12%	12%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	12%	12%	12%	12%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	2%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	58%	58%	58%	59%	60%	58%	59%	59%	57%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	41%	40%	41%	40%	41%	39%	40%	39%	38%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	5%	4%	3%	3%	3%	3%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	70%	71%	72%	72%	74%	73%	76%	76%	74%
Cylinder Deactivation on OHV	DEACO	12%	12%	3%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	19%	17%	17%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	12%	14%	17%	20%	19%	18%	17%	17%	17%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	10%	10%	8%	6%	6%	3%	3%	0%	0%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	53%	55%	53%	43%	33%	28%	25%	12%	12%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	9%	9%	9%	9%	7%	5%	3%	3%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	2%	2%	2%	2%	4%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	2%	3%	3%	3%	3%	5%	5%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	4%	9%	19%	26%	29%	33%	41%	42%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	4%	4%	4%	3%	3%	3%	3%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	1%	4%	5%	6%	8%	8%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	5%	7%	10%	11%	15%	15%	15%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	1%	1%	4%	4%	4%	4%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	1%	1%	1%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	1%	1%	1%	2%	2%	2%	2%	2%
Improved Auto. Trans. Controls/Externals	IATC	16%	9%	7%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	33%	25%	14%	5%	1%	0%	0%	0%	0%
6-speed DCT	DCT	3%	3%	3%	2%	1%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	33%	33%	31%	26%	8%	6%	5%	5%	5%
High Efficiency Gearbox (Auto or DCT)	HETRANS	10%	23%	38%	50%	65%	70%	71%	69%	67%
Shift Optimizer	SHFTOPT	11%	24%	45%	67%	83%	89%	93%	92%	90%
Electric Power Steering	EPS	80%	84%	94%	96%	97%	97%	98%	98%	98%
Improved Accessories - Level 1	IACC1	61%	66%	68%	76%	82%	86%	87%	97%	98%
Improved Accessories - Level 2	IACC2	18%	26%	41%	58%	68%	72%	82%	89%	96%
12V Micro-Hybrid (Stop-Start)	MHEV	3%	4%	5%	13%	23%	27%	30%	27%	26%

Integrated Starter Generator	ISG	0%	2%	2%	6%	11%	15%	17%	27%	28%
Strong Hybrid - Level 1	SHEV1	2%	1%	1%	1%	1%	1%	1%	1%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	1%	1%	3%	3%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	2%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	87%	89%	95%	99%	99%	99%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	35%	44%	61%	72%	81%	86%	88%	88%	89%
Mass Reduction - Level 3	MR3	16%	19%	23%	32%	37%	40%	46%	51%	51%
Mass Reduction - Level 4	MR4	12%	14%	17%	29%	31%	34%	37%	41%	42%
Mass Reduction - Level 5	MR5	1%	3%	4%	16%	20%	23%	25%	30%	31%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	12%	28%	50%	66%	75%	80%	85%	89%	90%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	82%	82%	83%	84%	84%	84%	84%	84%	84%
Secondary Axle Disconnect	SAX	34%	38%	39%	44%	44%	43%	44%	44%	43%
Aero Drag Reduction, Level 1	AERO1	100%	100%	99%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	61%	69%	86%	93%	95%	98%	100%	100 %	100 %

5% Annual Increase - Light Trucks - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Engine Friction Reduction - Level 1	EFR1	71%	72%	72%	74%	74%	74%	74%	74%	74%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	7%	14%	19%	23%	26%	32%	40%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	25%	25%	25%	25%	25%	25%	25%	25%	25%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	23%	24%	23%	23%	22%	22%	22%	21%	21%
Cylinder Deactivation on SOHC	DEACS	8%	8%	5%	6%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	48%	48%	48%	43%	43%	41%	41%	41%	41%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	20%	18%	18%	18%	19%	17%	17%	17%	17%
Continuously Variable Valve Lift (CVVL)	CVVL	10%	11%	10%	10%	10%	10%	10%	10%	10%
Cylinder Deactivation on DOHC	DEACD	8%	5%	2%	1%	1%	1%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	56%	59%	66%	63%	66%	64%	66%	66%	66%
Cylinder Deactivation on OHV	DEACO	9%	9%	7%	3%	3%	2%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	16%	16%	16%	16%	16%	16%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	10%	10%	11%	16%	16%	16%	18%	18%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	12%	12%	12%	11%	11%	9%	9%	5%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	37%	38%	41%	37%	35%	32%	29%	18%	14%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	15%	18%	20%	24%	18%	16%	15%	14%	12%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	2%	2%	2%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	0%	0%	0%	0%	4%	6%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	5%	7%	9%	9%	10%	13%	22%	26%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	7%	7%	7%	7%	9%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	1%	1%	1%	3%	3%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	1%	3%	6%	7%	10%	10%	11%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	1%	1%	3%	3%	3%	3%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	1%	4%	4%	4%	4%	4%	5%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	2%	2%	2%	2%	2%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	1%	1%	1%	1%
Improved Auto. Trans. Controls/Externals	IATC	48%	43%	29%	13%	3%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	68%	63%	45%	25%	8%	4%	0%	0%	0%
6-speed DCT	DCT	8%	10%	8%	4%	4%	2%	2%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	11%	15%	16%	16%	11%	8%	4%	2%	2%
High Efficiency Gearbox (Auto or DCT)	HETRANS	2%	5%	20%	32%	50%	52%	51%	53%	51%
Shift Optimizer	SHFTOPT	0%	0%	21%	37%	57%	72%	86%	90%	89%
Electric Power Steering	EPS	77%	82%	90%	91%	92%	92%	92%	93%	93%
Improved Accessories - Level 1	IACC1	70%	75%	87%	90%	91%	93%	93%	96%	97%
Improved Accessories - Level 2	IACC2	9%	12%	25%	32%	39%	45%	55%	80%	83%

12V Micro-Hybrid (Stop-Start)	MHEV	12%	13%	21%	30%	45%	47%	45%	51%	49%
Integrated Starter Generator	ISG	3%	5%	9%	16%	18%	20%	21%	28%	30%
Strong Hybrid - Level 1	SHEV1	1%	1%	1%	0%	0%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	3%	4%	6%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	73%	80%	87%	95%	100%	100%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	31%	38%	58%	67%	77%	81%	82%	84%	84%
Mass Reduction - Level 3	MR3	16%	17%	22%	31%	43%	45%	54%	58%	66%
Mass Reduction - Level 4	MR4	7%	8%	10%	20%	21%	24%	28%	33%	46%
Mass Reduction - Level 5	MR5	0%	1%	1%	5%	6%	11%	15%	21%	34%
Low Rolling Resistance Tires - Level 1	ROLL1	98%	98%	99%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	18%	34%	50%	56%	73%	84%	89%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	76%	77%	82%	82%	83%	83%	83%	83%	83%
Secondary Axle Disconnect	SAX	29%	32%	34%	35%	36%	36%	36%	37%	38%
Aero Drag Reduction, Level 1	AERO1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	49%	56%	70%	85%	88%	90%	93%	96%	97%

6% Annual Increase - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	76%	76%	76%	75%	74%	73%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	89%	89%	89%	89%	88%	88%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR 2	11%	23%	37%	46%	59%	67%	67%	75%	75%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	14%	13%	13%	13%	13%	13%	12%	12%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	12%	12%	12%	12%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	2%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	58%	58%	58%	55%	57%	54%	54%	52%	52%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	41%	40%	40%	38%	39%	37%	37%	35%	35%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	15%	15%	15%
Cylinder Deactivation on DOHC	DEACD	2%	1%	1%	1%	1%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	73%	74%	75%	70%	73%	72%	72%	69%	69%
Cylinder Deactivation on OHV	DEACO	9%	10%	2%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	18%	17%	16%	15%	15%	15%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	15%	16%	18%	20%	18%	18%	17%	17%	17%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_S D	10%	10%	8%	6%	6%	3%	3%	1%	1%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_ MD	56%	56%	53%	41%	29%	24%	22%	7%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_L D	11%	11%	12%	12%	13%	12%	7%	7%	5%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_S D	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_ MD	0%	0%	1%	1%	2%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_L D	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_S D	0%	0%	2%	2%	2%	2%	2%	1%	1%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_M D	4%	5%	9%	18%	26%	29%	29%	32%	32%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_L D	1%	1%	1%	1%	1%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_S D	0%	0%	0%	0%	0%	0%	0%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_M D	0%	0%	0%	0%	4%	5%	6%	14%	16%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_L D	1%	1%	8%	10%	10%	10%	13%	13%	8%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	2%	2%	4%	4%	4%	4%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	2%	2%	3%	4%	5%	5%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANS M	0%	1%	1%	1%	2%	2%	2%	2%	2%
Improved Auto. Trans. Controls/Externals	IATC	14%	7%	6%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	33%	24%	11%	4%	1%	0%	0%	0%	0%
6-speed DCT	DCT	4%	5%	4%	1%	1%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	34%	34%	32%	25%	7%	5%	5%	3%	0%
High Efficiency Gearbox (Auto or DCT)	HETRANS	11%	24%	39%	52%	65%	68%	69%	66%	60%
Shift Optimizer	SHFTOPT	11%	24%	45%	65%	87%	91%	89%	85%	76%
Electric Power Steering	EPS	80%	85%	94%	97%	97%	97%	98%	98%	98%

Improved Accessories - Level 1	IACC1	61%	66%	76%	86%	90%	96%	96%	98%	98%
Improved Accessories - Level 2	IACC2	19%	31%	51%	69%	78%	87%	93%	95%	95%
12V Micro-Hybrid (Stop-Start)	MHEV	13%	14%	15%	25%	33%	36%	38%	36%	35%
Integrated Starter Generator	ISG	2%	5%	11%	18%	23%	25%	27%	33%	34%
Strong Hybrid - Level 1	SHEV1	2%	1%	1%	0%	0%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	1%	1%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	2%	4%	8%	17%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	2%	2%	2%	2%	3%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	1%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	87%	90%	95%	100%	100%	100%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	35%	44%	61%	72%	81%	86%	88%	88%	89%
Mass Reduction - Level 3	MR3	17%	19%	23%	34%	39%	45%	50%	55%	62%
Mass Reduction - Level 4	MR4	12%	14%	17%	27%	29%	35%	38%	43%	52%
Mass Reduction - Level 5	MR5	1%	3%	4%	15%	17%	24%	26%	31%	44%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	12%	27%	45%	66%	83%	91%	93%	96%	99%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	82%	82%	84%	84%	84%	84%	84%	84%	84%
Secondary Axle Disconnect	SAX	34%	39%	40%	44%	44%	44%	44%	44%	43%
Aero Drag Reduction, Level 1	AERO1	100%	100%	99%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	61%	69%	86%	93%	95%	98%	100%	100 %	100 %

6% Annual Increase - Light Trucks - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100%	100%	100%	100%	98%	96%
Engine Friction Reduction - Level 1	EFR1	71%	72%	72%	74%	74%	74%	74%	74%	74%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	8%	17%	19%	25%	28%	33%	39%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	25%	25%	25%	25%	24%	24%	24%	24%	24%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	23%	24%	23%	23%	21%	21%	21%	20%	20%
Cylinder Deactivation on SOHC	DEACS	5%	5%	5%	6%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	48%	48%	48%	43%	43%	43%	42%	41%	38%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	19%	18%	18%	18%	18%	18%	17%	15%	15%
Continuously Variable Valve Lift (CVVL)	CVVL	11%	11%	11%	11%	10%	10%	10%	10%	9%
Cylinder Deactivation on DOHC	DEACD	6%	3%	3%	2%	2%	1%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	59%	64%	66%	62%	64%	65%	66%	62%	59%
Cylinder Deactivation on OHV	DEACO	9%	9%	7%	3%	3%	2%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	16%	16%	16%	16%	16%	16%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	10%	10%	11%	16%	16%	16%	18%	18%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	12%	12%	12%	9%	9%	8%	8%	3%	2%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	41%	42%	41%	37%	33%	29%	26%	13%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	16%	18%	20%	23%	17%	16%	16%	15%	8%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	1%	2%	2%	4%	4%	7%	7%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	5%	5%	7%	10%	14%	16%	21%	22%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	7%	7%	7%	7%	9%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	1%	3%	3%	4%	6%	6%	5%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	1%	1%	1%	2%	2%	2%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	1%	4%	5%	5%	6%	8%	9%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	2%	2%	2%	2%	2%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	1%	1%	1%	1%
Improved Auto. Trans. Controls/Externals	IATC	45%	40%	28%	12%	3%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	62%	57%	41%	22%	6%	5%	0%	0%	0%
6-speed DCT	DCT	8%	9%	6%	2%	2%	2%	2%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	14%	18%	18%	16%	8%	5%	1%	0%	0%
High Efficiency Gearbox (Auto or DCT)	HETRANS	5%	7%	21%	32%	44%	47%	45%	43%	40%
Shift Optimizer	SHFTOPT	0%	0%	20%	39%	58%	69%	83%	81%	74%
Electric Power Steering	EPS	78%	83%	90%	93%	93%	93%	93%	93%	93%
Improved Accessories - Level 1	IACC1	72%	77%	89%	91%	93%	95%	97%	97%	97%
Improved Accessories - Level 2	IACC2	11%	19%	34%	43%	53%	60%	62%	62%	63%
12V Micro-Hybrid (Stop-Start)	MHEV	15%	18%	35%	45%	56%	59%	59%	50%	44%

Integrated Starter Generator	ISG	3%	5%	12%	19%	21%	25%	25%	26%	25%
Strong Hybrid - Level 1	SHEV1	1%	1%	0%	0%	0%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	3%	4%	7%	13%	21%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	2%	2%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	1%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	74%	82%	91%	95%	100%	100%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	31%	38%	58%	67%	76%	80%	81%	84%	87%
Mass Reduction - Level 3	MR3	16%	17%	23%	28%	42%	44%	52%	56%	72%
Mass Reduction - Level 4	MR4	7%	8%	12%	22%	30%	32%	37%	44%	61%
Mass Reduction - Level 5	MR5	0%	1%	3%	7%	11%	16%	21%	28%	45%
Low Rolling Resistance Tires - Level 1	ROLL1	98%	98%	99%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	18%	32%	49%	60%	73%	86%	96%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	77%	77%	83%	83%	83%	83%	83%	83%	83%
Secondary Axle Disconnect	SAX	29%	31%	36%	37%	37%	38%	38%	38%	38%
Aero Drag Reduction, Level 1	AERO1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	49%	56%	70%	86%	89%	91%	94%	97%	100 %

7% Annual Increase - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	78%	77%	77%	76%	75%	73%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	89%	89%	88%	88%	88%	88%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	11%	23%	39%	49%	54%	61%	62%	69%	69%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	14%	13%	13%	13%	13%	13%	12%	12%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	12%	12%	12%	12%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	2%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	58%	58%	58%	54%	55%	52%	51%	50%	48%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	41%	40%	40%	36%	36%	33%	32%	31%	29%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	6%	2%	1%	1%	1%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	69%	74%	74%	69%	72%	69%	68%	67%	64%
Cylinder Deactivation on OHV	DEACO	8%	8%	1%	1%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	18%	17%	16%	15%	15%	15%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	16%	17%	19%	20%	18%	18%	17%	17%	17%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	10%	10%	8%	5%	5%	2%	2%	0%	0%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	56%	56%	46%	30%	20%	16%	14%	6%	5%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	8%	11%	18%	17%	15%	13%	9%	9%	7%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	1%	1%	1%	2%	2%	2%	2%	1%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	2%	3%	2%	2%	2%	1%	1%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	6%	14%	23%	24%	27%	26%	27%	25%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	2%	4%	12%	13%	13%	13%	12%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	2%	3%	3%	4%	4%	4%	4%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	1%	1%	4%	4%	6%	6%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	1%	5%	5%	7%	7%	7%	7%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	1%	1%	1%	2%	2%	2%	2%	2%
Improved Auto. Trans. Controls/Externals	IATC	16%	7%	5%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	37%	27%	9%	3%	1%	0%	0%	0%	0%
6-speed DCT	DCT	4%	5%	4%	1%	1%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	39%	39%	34%	24%	6%	6%	6%	4%	2%
High Efficiency Gearbox (Auto or DCT)	HETRANS	9%	23%	38%	54%	60%	65%	61%	58%	54%
Shift Optimizer	SHFTOPT	16%	34%	52%	74%	88%	88%	81%	75%	69%
Electric Power Steering	EPS	81%	86%	95%	98%	98%	98%	98%	98%	98%

Improved Accessories - Level 1	IACC1	68%	75%	81%	93%	93%	97%	98%	98%	98%
Improved Accessories - Level 2	IACC2	21%	35%	56%	69%	78%	85%	86%	86%	86%
12V Micro-Hybrid (Stop-Start)	MHEV	15%	19%	34%	46%	48%	50%	47%	38%	32%
Integrated Starter Generator	ISG	3%	6%	13%	20%	25%	28%	29%	31%	31%
Strong Hybrid - Level 1	SHEV1	2%	1%	1%	0%	0%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	1%	1%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	1%	5%	6%	12%	19%	23%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	1%	1%	1%	4%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	87%	90%	95%	99%	100%	100%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	35%	44%	61%	72%	81%	86%	88%	88%	89%
Mass Reduction - Level 3	MR3	17%	19%	23%	34%	43%	49%	55%	59%	67%
Mass Reduction - Level 4	MR4	12%	14%	17%	30%	40%	47%	53%	59%	67%
Mass Reduction - Level 5	MR5	2%	4%	5%	22%	30%	36%	42%	48%	57%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	12%	28%	47%	68%	86%	90%	94%	96%	99%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	83%	83%	84%	84%	84%	84%	84%	84%	84%
Secondary Axle Disconnect	SAX	45%	45%	44%	44%	44%	43%	44%	44%	43%
Aero Drag Reduction, Level 1	AERO1	100%	100%	99%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	61%	69%	86%	93%	95%	98%	100%	100 %	100 %

7% Annual Increase - Light Trucks - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	99%	99%	99%	98%	97%	97%
Engine Friction Reduction - Level 1	EFR1	71%	72%	72%	74%	74%	74%	74%	73%	73%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	8%	14%	17%	20%	23%	25%	26%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	25%	25%	25%	25%	22%	22%	22%	22%	22%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	23%	23%	23%	23%	20%	20%	20%	20%	20%
Cylinder Deactivation on SOHC	DEACS	5%	5%	5%	6%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	48%	48%	48%	40%	40%	40%	40%	37%	37%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	19%	18%	18%	18%	18%	18%	17%	16%	16%
Continuously Variable Valve Lift (CVVL)	CVVL	11%	11%	11%	11%	10%	10%	10%	10%	10%
Cylinder Deactivation on DOHC	DEACD	6%	3%	2%	1%	1%	1%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	59%	64%	66%	59%	61%	61%	63%	60%	60%
Cylinder Deactivation on OHV	DEACO	9%	9%	7%	3%	3%	2%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	16%	16%	16%	16%	16%	16%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	10%	10%	11%	16%	16%	16%	18%	18%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	12%	12%	12%	7%	7%	5%	5%	1%	1%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	41%	42%	39%	32%	26%	23%	20%	16%	10%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	16%	18%	14%	17%	13%	12%	12%	12%	10%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	2%	2%	2%	2%	2%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	1%	2%	2%	4%	4%	6%	5%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	5%	7%	9%	12%	14%	15%	16%	20%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	2%	2%	1%	1%	1%	2%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	4%	4%	4%	4%	4%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	6%	8%	15%	16%	18%	18%	12%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	3%	3%	3%	3%	4%	4%
Advanced Diesel - Medium Displacement	ADSL_MD	1%	1%	1%	5%	5%	5%	5%	5%	5%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	3%	3%	3%	3%	3%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	1%	1%	1%	1%
Improved Auto. Trans. Controls/Externals	IATC	45%	40%	26%	11%	1%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	64%	58%	39%	20%	5%	4%	0%	0%	0%
6-speed DCT	DCT	7%	8%	7%	3%	3%	3%	3%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	15%	16%	15%	14%	6%	3%	2%	2%	0%
High Efficiency Gearbox (Auto or DCT)	HETRANS	5%	11%	27%	36%	41%	41%	39%	35%	34%
Shift Optimizer	SHFTOPT	0%	0%	20%	37%	65%	71%	87%	85%	79%
Electric Power Steering	EPS	77%	84%	90%	93%	93%	93%	93%	93%	93%
Improved Accessories - Level 1	IACC1	72%	78%	91%	96%	96%	96%	97%	97%	97%
Improved Accessories - Level 2	IACC2	20%	26%	35%	43%	49%	50%	50%	52%	53%
12V Micro-Hybrid (Stop-Start)	MHEV	31%	34%	49%	58%	63%	62%	62%	54%	47%

Integrated Starter Generator	ISG	5%	7%	14%	19%	21%	24%	23%	26%	26%
Strong Hybrid - Level 1	SHEV1	1%	1%	0%	0%	0%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	3%	5%	9%	17%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	1%	1%	1%	1%	2%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	1%	2%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	77%	86%	91%	95%	100%	100%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	32%	39%	59%	70%	84%	86%	87%	90%	91%
Mass Reduction - Level 3	MR3	17%	18%	24%	32%	43%	44%	52%	56%	69%
Mass Reduction - Level 4	MR4	8%	9%	12%	25%	31%	33%	38%	45%	59%
Mass Reduction - Level 5	MR5	0%	1%	3%	10%	14%	20%	25%	32%	47%
Low Rolling Resistance Tires - Level 1	ROLL1	98%	98%	99%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	19%	36%	47%	60%	75%	87%	94%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	79%	80%	83%	83%	83%	83%	83%	83%	83%
Secondary Axle Disconnect	SAX	29%	31%	36%	37%	37%	38%	38%	38%	38%
Aero Drag Reduction, Level 1	AERO1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	49%	56%	70%	82%	85%	87%	90%	93%	100 %

Max Net Benefits - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	75%	74%	74%	74%	74%	73%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	88%	88%	88%	88%	88%	88%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	14%	20%	33%	45%	59%	65%	66%	73%	77%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	13%	13%	12%	12%	12%	12%	12%	12%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	2%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	57%	57%	57%	55%	57%	58%	58%	58%	58%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	40%	40%	40%	38%	39%	39%	40%	39%	39%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	1%	1%	1%	1%	1%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	74%	73%	73%	70%	73%	74%	75%	74%	74%
Cylinder Deactivation on OHV	DEACO	2%	2%	1%	1%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	18%	17%	16%	15%	14%	14%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	17%	18%	20%	20%	18%	18%	17%	16%	16%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	10%	10%	8%	5%	5%	3%	3%	1%	1%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	53%	53%	49%	39%	29%	27%	24%	14%	12%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	18%	18%	19%	17%	18%	16%	12%	11%	11%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	2%	3%	3%	3%	3%	5%	5%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	7%	9%	13%	17%	27%	28%	30%	38%	40%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	2%	2%	2%	3%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	5%	5%	5%	7%	6%	6%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	3%	3%	5%	8%	8%	8%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	1%	1%	1%	1%	1%	1%	2%	3%	3%
Advanced Diesel - Large Displacement	ADSL_LD	1%	1%	1%	1%	1%	1%	1%	1%	1%
6-Speed Manual/Improved Internals	6MAN	1%	1%	0%	0%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	1%	2%	2%	2%	2%	2%	2%	2%
Improved Auto. Trans. Controls/Externals	IATC	14%	7%	5%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	33%	23%	10%	4%	1%	1%	0%	0%	0%
6-speed DCT	DCT	6%	3%	3%	0%	0%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	42%	41%	33%	24%	5%	5%	4%	3%	1%
High Efficiency Gearbox (Auto or DCT)	HETRANS	10%	23%	44%	57%	68%	69%	71%	69%	72%
Shift Optimizer	SHFTOPT	16%	27%	50%	66%	88%	90%	91%	88%	88%
Electric Power Steering	EPS	82%	86%	94%	97%	98%	98%	98%	98%	98%
Improved Accessories - Level 1	IACC1	94%	94%	94%	97%	97%	97%	97%	98%	98%
Improved Accessories - Level 2	IACC2	42%	49%	62%	70%	72%	78%	81%	85%	86%

12V Micro-Hybrid (Stop-Start)	MHEV	38%	38%	42%	37%	36%	36%	35%	31%	32%
Integrated Starter Generator	ISG	11%	13%	14%	16%	16%	19%	20%	23%	25%
Strong Hybrid - Level 1	SHEV1	2%	1%	1%	1%	1%	1%	1%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	1%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	1%	1%	1%	1%	1%	1%	2%	5%	5%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	3%	3%	3%	3%	3%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	90%	90%	95%	98%	100%	100%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	40%	48%	60%	71%	80%	81%	83%	85%	89%
Mass Reduction - Level 3	MR3	22%	23%	28%	32%	40%	41%	48%	51%	63%
Mass Reduction - Level 4	MR4	16%	17%	21%	26%	31%	36%	39%	43%	56%
Mass Reduction - Level 5	MR5	3%	3%	6%	16%	21%	22%	25%	29%	39%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	16%	24%	46%	58%	78%	87%	89%	96%	97%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	83%	83%	84%	84%	84%	84%	84%	84%	84%
Secondary Axle Disconnect	SAX	46%	45%	45%	44%	44%	44%	44%	44%	43%
Aero Drag Reduction, Level 1	AERO1	100%	100%	99%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	61%	69%	85%	93%	94%	98%	99%	99%	99%

Max Net Benefits - Light Trucks - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Engine Friction Reduction - Level 1	EFR1	71%	72%	72%	74%	74%	74%	74%	74%	74%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	10%	22%	30%	32%	35%	38%	47%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	25%	25%	25%	25%	25%	25%	25%	25%	25%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	23%	24%	23%	23%	23%	23%	23%	23%	23%
Cylinder Deactivation on SOHC	DEACS	8%	8%	5%	6%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	48%	48%	47%	43%	43%	43%	43%	43%	43%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	18%	18%	18%	18%	18%	18%	18%	18%	18%
Continuously Variable Valve Lift (CVVL)	CVVL	11%	11%	11%	10%	10%	10%	10%	10%	10%
Cylinder Deactivation on DOHC	DEACD	6%	3%	3%	2%	2%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	57%	62%	65%	62%	67%	68%	70%	70%	70%
Cylinder Deactivation on OHV	DEACO	9%	9%	7%	3%	3%	2%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	16%	16%	16%	16%	16%	16%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	10%	10%	11%	16%	16%	16%	18%	18%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	12%	12%	13%	10%	10%	8%	8%	4%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	38%	39%	38%	34%	30%	28%	25%	20%	15%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	16%	18%	20%	24%	22%	21%	19%	19%	11%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	1%	1%	1%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	2%	2%	3%	3%	4%	5%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	5%	8%	9%	13%	16%	19%	21%	24%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	7%	7%	8%	7%	14%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	2%	2%	4%	4%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	1%	2%	3%	4%	7%	7%	7%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	1%	1%	1%	1%	1%	1%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	2%	5%	5%	5%	5%	5%	5%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	1%	1%	1%	1%
Improved Auto. Trans. Controls/Externals	IATC	48%	43%	27%	12%	2%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	69%	61%	40%	21%	5%	4%	0%	0%	0%
6-speed DCT	DCT	6%	8%	7%	3%	2%	2%	2%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	15%	17%	14%	13%	7%	5%	4%	2%	1%
High Efficiency Gearbox (Auto or DCT)	HETRANS	4%	9%	23%	31%	43%	44%	43%	42%	42%
Shift Optimizer	SHFTOPT	0%	0%	20%	41%	67%	71%	79%	88%	90%
Electric Power Steering	EPS	85%	89%	92%	93%	93%	93%	93%	93%	93%
Improved Accessories - Level 1	IACC1	70%	73%	85%	91%	91%	91%	91%	92%	92%

Improved Accessories - Level 2	IACC2	18%	22%	27%	31%	34%	36%	36%	42%	53%
12V Micro-Hybrid (Stop-Start)	MHEV	39%	38%	43%	48%	50%	52%	49%	49%	46%
Integrated Starter Generator	ISG	7%	9%	13%	13%	16%	17%	18%	19%	20%
Strong Hybrid - Level 1	SHEV1	1%	1%	1%	0%	0%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	1%	1%	1%	1%	4%	5%	7%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	77%	79%	85%	94%	98%	99%	100%	100%	100%
Mass Reduction - Level 2	MR2	32%	39%	57%	65%	77%	78%	81%	85%	88%
Mass Reduction - Level 3	MR3	17%	18%	22%	26%	39%	39%	48%	52%	65%
Mass Reduction - Level 4	MR4	8%	9%	12%	23%	27%	29%	34%	36%	49%
Mass Reduction - Level 5	MR5	0%	1%	3%	7%	10%	15%	19%	20%	21%
Low Rolling Resistance Tires - Level 1	ROLL1	98%	98%	98%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	17%	35%	52%	57%	72%	85%	92%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	83%	83%	82%	83%	83%	83%	83%	83%	83%
Secondary Axle Disconnect	SAX	31%	33%	36%	37%	37%	37%	37%	38%	38%
Aero Drag Reduction, Level 1	AERO1	100%	100%	100%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	49%	56%	72%	87%	90%	92%	95%	96%	100%

Total Cost = Total Benefits - Light Trucks - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	82%	80%	79%	75%	74%	74%	74%	74%	73%
Engine Friction Reduction - Level 1	EFR1	89%	89%	89%	88%	88%	88%	88%	88%	88%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	15%	19%	34%	42%	60%	62%	62%	69%	69%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	14%	13%	13%	13%	13%	13%	13%	13%	13%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	13%	12%	12%	12%	12%	12%	12%	12%	12%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	2%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	57%	57%	57%	51%	52%	53%	53%	53%	53%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	40%	40%	40%	34%	34%	35%	35%	34%	35%
Continuously Variable Valve Lift (CVVL)	CVVL	15%	15%	15%	15%	15%	15%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	1%	1%	1%	1%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	74%	74%	74%	67%	69%	70%	71%	70%	70%
Cylinder Deactivation on OHV	DEACO	2%	2%	1%	1%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	17%	18%	18%	17%	16%	16%	15%	15%	15%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	17%	18%	20%	19%	18%	17%	17%	17%	17%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	9%	9%	7%	5%	5%	2%	2%	0%	0%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	53%	53%	48%	38%	28%	24%	21%	10%	9%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	18%	18%	19%	17%	18%	17%	12%	12%	11%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	0%	0%	0%	1%	1%	1%	2%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	1%	1%	2%	3%	3%	5%	5%	8%	7%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	8%	9%	15%	18%	28%	28%	29%	36%	36%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	0%	0%	0%	0%	0%	0%	0%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	1%	1%	1%	4%	4%	5%	5%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	3%	3%	4%	8%	7%	8%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	1%	1%	1%	5%	6%	6%	7%	7%	7%
Advanced Diesel - Large Displacement	ADSL_LD	1%	1%	1%	1%	1%	1%	1%	1%	1%
6-Speed Manual/Improved Internals	6MAN	1%	1%	0%	0%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	1%	2%	2%	2%	2%	2%	2%	2%
Improved Auto. Trans. Controls/Externals	IATC	12%	6%	5%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	31%	21%	9%	3%	0%	0%	0%	0%	0%
6-speed DCT	DCT	8%	5%	3%	0%	0%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	43%	43%	34%	24%	9%	8%	8%	7%	5%

High Efficiency Gearbox (Auto or DCT)	HETRANS	8%	25%	41%	54%	66%	67%	68%	67%	68%
Shift Optimizer	SHFTOPT	18%	29%	54%	69%	87%	91%	88%	86%	85%
Electric Power Steering	EPS	82%	83%	91%	94%	98%	98%	98%	98%	98%
Improved Accessories - Level 1	IACC1	96%	96%	96%	98%	98%	98%	98%	98%	98%
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	42%	47%	58%	67%	70%	70%	75%	79%	81%
12V Micro-Hybrid (Stop-Start)	MHEV	39%	40%	46%	41%	43%	44%	42%	37%	35%
Integrated Starter Generator	ISG	13%	14%	16%	17%	18%	22%	22%	22%	23%
Strong Hybrid - Level 1	SHEV1	2%	1%	1%	1%	1%	1%	1%	1%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	1%	1%	1%	1%	1%	1%	4%	7%	8%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	3%	3%	3%	3%	3%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	90%	90%	95%	98%	100%	100%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	40%	48%	60%	71%	80%	81%	83%	85%	89%
Mass Reduction - Level 3	MR3	22%	23%	28%	32%	40%	41%	48%	51%	63%
Mass Reduction - Level 4	MR4	20%	20%	24%	28%	30%	32%	38%	43%	55%
Mass Reduction - Level 5	MR5	6%	6%	7%	18%	21%	24%	26%	30%	41%
Low Rolling Resistance Tires - Level 1	ROLL1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	16%	25%	47%	61%	80%	87%	90%	93%	96%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	83%	83%	84%	84%	84%	84%	84%	84%	84%
Secondary Axle Disconnect	SAX	46%	45%	45%	44%	44%	44%	44%	44%	43%
Aero Drag Reduction, Level 1	AERO1	100%	100%	99%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	61%	69%	85%	93%	94%	98%	99%	99%	99%

Total Cost = Total Benefits - Light Trucks - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100%	100%	99%	99%	99%	99%
Engine Friction Reduction - Level 1	EFR1	71%	72%	72%	74%	74%	74%	74%	74%	74%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	10%	22%	26%	26%	29%	33%	42%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	25%	25%	25%	25%	25%	25%	25%	25%	25%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	23%	24%	23%	23%	23%	23%	23%	23%	23%
Cylinder Deactivation on SOHC	DEACS	6%	6%	5%	6%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	0%	0%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	48%	48%	47%	41%	41%	41%	41%	42%	41%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	18%	18%	18%	18%	18%	18%	18%	18%	19%
Continuously Variable Valve Lift (CVVL)	CVVL	11%	11%	11%	10%	10%	10%	10%	10%	10%
Cylinder Deactivation on DOHC	DEACD	6%	3%	3%	2%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	58%	62%	63%	58%	65%	65%	66%	67%	66%
Cylinder Deactivation on OHV	DEACO	9%	9%	7%	3%	3%	2%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	16%	16%	16%	16%	16%	16%	16%	16%	16%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	10%	10%	11%	16%	16%	16%	18%	18%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	TRBDS1_SD	11%	10%	11%	6%	6%	6%	6%	2%	2%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	TRBDS1_MD	40%	41%	40%	33%	28%	25%	23%	12%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	TRBDS1_LD	16%	18%	20%	24%	26%	26%	27%	26%	23%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	TRBDS2_MD	0%	0%	0%	0%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	TRBDS2_LD	0%	0%	1%	1%	1%	1%	1%	1%	1%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	2%	2%	2%	5%	5%	5%	5%	9%	9%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	5%	5%	9%	15%	18%	20%	30%	30%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	1%	1%	1%	2%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	1%	3%	3%	4%	4%	4%	5%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	2%	2%	2%	2%	2%	2%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	2%	5%	5%	5%	5%	5%	5%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	1%	1%	1%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	1%	1%	1%	1%	1%	1%
Improved Auto. Trans. Controls/Externals	IATC	51%	46%	30%	15%	2%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	67%	60%	42%	23%	5%	4%	0%	0%	0%
6-speed DCT	DCT	8%	9%	7%	3%	2%	2%	2%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	12%	14%	14%	12%	8%	4%	3%	2%	2%

High Efficiency Gearbox (Auto or DCT)	HETRANS	3%	8%	22%	32%	36%	40%	38%	37%	33%
Shift Optimizer	SHFTOPT	0%	0%	21%	41%	67%	71%	79%	86%	85%
Electric Power Steering	EPS	86%	90%	90%	93%	93%	93%	93%	93%	93%
Improved Accessories - Level 1	IACC1	83%	84%	89%	93%	94%	94%	95%	95%	95%
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	21%	25%	34%	42%	47%	49%	54%	54%	61%
12V Micro-Hybrid (Stop-Start)	MHEV	39%	38%	47%	51%	48%	50%	47%	46%	44%
Integrated Starter Generator	ISG	7%	9%	12%	17%	19%	20%	21%	21%	18%
Strong Hybrid - Level 1	SHEV1	1%	1%	0%	0%	0%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	3%	3%	5%	7%	11%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	79%	81%	85%	94%	98%	98%	100%	100 %	100 %
Mass Reduction - Level 2	MR2	32%	39%	57%	68%	77%	78%	81%	85%	87%
Mass Reduction - Level 3	MR3	17%	18%	22%	29%	37%	37%	45%	50%	63%
Mass Reduction - Level 4	MR4	8%	9%	10%	23%	25%	27%	35%	38%	52%
Mass Reduction - Level 5	MR5	0%	1%	1%	8%	8%	12%	18%	19%	21%
Low Rolling Resistance Tires - Level 1	ROLL1	98%	98%	98%	100%	100%	100%	100%	100 %	100 %
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	17%	37%	47%	49%	64%	76%	85%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	83%	83%	82%	83%	83%	83%	83%	83%	83%
Secondary Axle Disconnect	SAX	36%	36%	36%	37%	37%	38%	38%	38%	38%
Aero Drag Reduction, Level 1	AERO1	100%	100%	100%	100%	100%	100%	100%	100 %	100 %
Aero Drag Reduction, Level 2	AERO2	49%	56%	72%	87%	90%	92%	95%	96%	100 %

Table V-152 Penetration Rate of New Technologies to Combined Fleet, by Baseline Model Year and Alternative

Preferred Alternative - Combined - 2008 Baseline										
Technology	Abbr.	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Low Friction Lubricants - Level 1	LUB1	86%	86%	85%	85%	85%	85%	85%	85%	84%
Engine Friction Reduction - Level 1	EFR1	81%	83%	88%	88%	88%	88%	88%	88%	87%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	14%	23%	40%	46%	55%	59%	63%	67%	70%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	8%	8%	12%	11%	11%	11%	11%	11%	11%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	12%	12%	12%	12%	12%	12%	12%	12%	11%
Cylinder Deactivation on SOHC	DEACS	3%	3%	3%	2%	1%	1%	1%	1%	1%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	3%	3%	3%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	67%	67%	68%	69%	70%	70%	70%	70%	70%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	47%	49%	49%	51%	52%	52%	52%	52%	52%
Continuously Variable Valve Lift (CVVL)	CVVL	12%	13%	15%	16%	16%	16%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	13%	12%	11%	10%	9%	9%	8%	6%	5%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	43%	49%	54%	59%	67%	71%	72%	80%	80%
Cylinder Deactivation on OHV	DEACO	7%	6%	5%	4%	4%	3%	2%	2%	2%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	8%	9%	9%	10%	9%	9%	9%	8%	8%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	3%	4%	5%	7%	7%	7%	7%	7%	7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	18%	20%	21%	19%	25%	23%	21%	24%	22%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	17%	21%	22%	26%	25%	24%	21%	21%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	4%	4%	4%	4%	5%	4%	4%	3%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	1%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	1%	1%	1%	2%	2%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	2%	6%	6%	11%	13%	15%	18%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	2%	2%	4%	5%	6%	7%	11%	12%	14%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	1%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	2%	2%	2%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	1%	1%	2%	3%	3%	3%	3%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	2%	2%	1%	1%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	2%	3%	4%	6%	6%	6%	6%	6%

Improved Auto. Trans. Controls/Externals	IATC	17%	13%	10%	6%	1%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	21%	15%	9%	5%	4%	2%	1%	0%	0%
6-speed DCT	DCT	20%	16%	13%	8%	4%	2%	1%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	22%	25%	25%	20%	13%	10%	7%	5%	2%
High Efficiency Gearbox (Auto or DCT)	HETRANS	5%	15%	29%	42%	59%	69%	74%	78%	79%
Shift Optimizer	SHFTOPT	8%	18%	32%	43%	55%	67%	76%	85%	85%
Electric Power Steering	EPS	78%	82%	88%	90%	92%	92%	92%	93%	95%
Improved Accessories - Level 1	IACC1	56%	58%	62%	68%	73%	75%	78%	87%	89%
Improved Accessories - Level 2	IACC2	15%	19%	28%	36%	44%	51%	55%	68%	76%
12V Micro-Hybrid (Stop-Start)	MHEV	5%	5%	7%	9%	10%	10%	11%	10%	8%
Integrated Starter Generator	ISG	1%	1%	1%	4%	5%	7%	7%	11%	17%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	59%	62%	66%	68%	69%	69%	69%	68%	68%
Mass Reduction - Level 2	MR2	29%	36%	48%	54%	57%	59%	60%	61%	62%
Mass Reduction - Level 3	MR3	11%	13%	14%	18%	23%	24%	26%	28%	32%
Mass Reduction - Level 4	MR4	5%	5%	6%	7%	11%	12%	12%	14%	20%
Mass Reduction - Level 5	MR5	1%	1%	1%	2%	2%	3%	4%	5%	11%
Low Rolling Resistance Tires - Level 1	ROLL1	96%	98%	99%	100%	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	17%	30%	51%	65%	77%	84%	88%	89%	91%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	86%	86%	88%	88%	89%	89%	89%	89%	89%
Secondary Axle Disconnect	SAX	11%	13%	13%	14%	14%	14%	14%	13%	13%
Aero Drag Reduction, Level 1	AERO1	94%	98%	99%	100%	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	52%	62%	76%	86%	91%	92%	93%	92%	92%

Preferred Alternative - Combined - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100 %	100 %	100%	100 %	100 %	100 %	100%	100%
Engine Friction Reduction - Level 1	EFR1	74%	77%	77%	78%	78%	78%	79%	79%	79%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	8%	12%	18%	21%	28%	35%	39%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	19%	19%	19%	19%	18%	18%	18%	18%	18%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	17%	17%	17%	18%	18%	18%	18%	18%	18%
Cylinder Deactivation on SOHC	DEACS	10%	10%	8%	7%	3%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	4%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	59%	60%	61%	61%	61%	61%	61%	61%	61%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	29%	30%	31%	32%	32%	33%	33%	33%	33%
Continuously Variable Valve Lift (CVVL)	CVVL	20%	20%	21%	21%	21%	21%	22%	22%	22%
Cylinder Deactivation on DOHC	DEACD	10%	12%	8%	8%	6%	6%	6%	5%	4%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	39%	47%	59%	62%	72%	76%	77%	80%	80%
Cylinder Deactivation on OHV	DEACO	5%	4%	4%	1%	1%	1%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	7%	7%	7%	7%	7%	7%	7%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	2%	3%	5%	7%	8%	8%	8%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	22%	27%	31%	32%	35%	34%	31%	30%	26%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	14%	17%	22%	23%	23%	24%	24%	23%	20%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	2%	2%	5%	7%	11%	11%	11%	11%	10%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	1%	1%	1%	2%	2%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	2%	2%	2%	2%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	2%	3%	5%	7%	10%	14%	17%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	2%	3%	3%	4%	3%	3%	4%	5%	7%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	2%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	1%	2%	2%	3%	3%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	1%	1%	1%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	2%	2%	2%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	2%	2%	3%	3%	3%	3%
Improved Auto. Trans. Controls/Externals	IATC	34%	32%	20%	10%	4%	2%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	41%	39%	28%	17%	11%	9%	2%	0%	0%
6-speed DCT	DCT	24%	25%	21%	14%	15%	11%	8%	5%	5%
8-Speed Trans (Auto or DCT)	8SPD	9%	13%	20%	22%	19%	18%	15%	6%	6%
High Efficiency Gearbox (Auto or DCT)	HETRANS	0%	2%	12%	24%	36%	45%	54%	63%	65%
Shift Optimizer	SHFTOPT	0%	0%	10%	21%	31%	37%	52%	62%	66%
Electric Power Steering	EPS	73%	79%	87%	90%	91%	92%	93%	95%	95%
Improved Accessories - Level 1	IACC1	54%	62%	71%	76%	80%	83%	85%	89%	92%
Improved Accessories - Level 2	IACC2	6%	12%	18%	24%	36%	41%	48%	59%	62%

12V Micro-Hybrid (Stop-Start)	MHEV	6%	7%	7%	8%	8%	8%	9%	9%	9%
Integrated Starter Generator	ISG	2%	2%	3%	4%	5%	5%	6%	8%	10%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	54%	59%	68%	70%	72%	72%	72%	73%	73%
Mass Reduction - Level 2	MR2	21%	30%	40%	43%	51%	53%	56%	61%	62%
Mass Reduction - Level 3	MR3	10%	10%	11%	12%	15%	16%	19%	22%	23%
Mass Reduction - Level 4	MR4	3%	4%	4%	5%	6%	6%	6%	8%	8%
Mass Reduction - Level 5	MR5	0%	0%	1%	1%	2%	3%	3%	5%	5%
Low Rolling Resistance Tires - Level 1	ROLL1	93%	97%	98%	99%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	20%	28%	49%	58%	67%	78%	81%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	85%	86%	88%	89%	89%	89%	90%	90%	90%
Secondary Axle Disconnect	SAX	10%	11%	12%	12%	12%	13%	13%	13%	13%
Aero Drag Reduction, Level 1	AERO1	94%	98%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	45%	56%	70%	81%	87%	88%	89%	91%	92%

2% Annual Increase - Combined - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	86%	86%	85%	85%	85%	85%	85%	85%	85%
Engine Friction Reduction - Level 1	EFR1	85%	88%	88%	88%	88%	88%	88%	88%	88%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	12%	24%	37%	47%	55%	59%	63%	65%	69%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	8%	7%	7%	7%	7%	7%	7%	7%	7%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	12%	12%	12%	12%	12%	12%	12%	12%	12%
Cylinder Deactivation on SOHC	DEACS	3%	3%	3%	2%	1%	1%	1%	1%	1%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	9%	6%	4%	3%	3%	3%	3%	3%	3%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	61%	65%	66%	68%	68%	69%	69%	69%	69%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	44%	46%	46%	48%	49%	49%	50%	50%	50%
Continuously Variable Valve Lift (CVVL)	CVVL	12%	13%	16%	18%	18%	19%	19%	19%	19%
Cylinder Deactivation on DOHC	DEACD	6%	7%	6%	7%	7%	7%	6%	6%	6%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	48%	49%	51%	52%	53%	54%	56%	58%	59%
Cylinder Deactivation on OHV	DEACO	6%	6%	6%	6%	6%	5%	4%	4%	4%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	8%	9%	9%	9%	8%	8%	7%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	3%	3%	3%	4%	3%	3%	4%	3%	3%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	16%	16%	17%	17%	18%	17%	18%	21%	20%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	25%	25%	26%	26%	26%	26%	27%	27%	27%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	4%	4%	4%	4%	4%	4%	4%	4%	4%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	1%	0%	0%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	1%	1%	1%	2%	2%	2%	3%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	2%	2%	2%	3%	3%	4%	4%	5%	5%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	1%	1%	2%	1%	1%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	2%	2%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	2%	3%	4%	5%	6%	6%	6%	6%
Improved Auto. Trans. Controls/Externals	IATC	15%	10%	7%	3%	3%	2%	3%	2%	2%
6-Speed Trans with Improved Internals (Auto)	NAUTO	24%	22%	18%	15%	13%	10%	9%	6%	6%
6-speed DCT	DCT	24%	22%	20%	15%	11%	9%	7%	13%	12%
8-Speed Trans (Auto or DCT)	8SPD	16%	17%	21%	18%	16%	19%	17%	13%	12%
High Efficiency Gearbox (Auto or DCT)	HETRANS	3%	11%	18%	27%	37%	42%	48%	54%	56%
Shift Optimizer	SHFTOPT	6%	10%	19%	24%	27%	30%	34%	34%	34%
Electric Power Steering	EPS	76%	81%	84%	86%	86%	86%	87%	89%	91%
Improved Accessories - Level 1	IACC1	52%	54%	54%	58%	61%	64%	67%	75%	77%
Improved Accessories - Level 2	IACC2	8%	11%	13%	17%	21%	25%	29%	41%	44%
12V Micro-Hybrid (Stop-Start)	MHEV	5%	5%	5%	5%	5%	5%	5%	5%	5%

Integrated Starter Generator	ISG	1%	1%	1%	2%	2%	2%	2%	3%	4%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	3%	3%	3%	3%	3%	3%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	57%	60%	64%	65%	65%	65%	66%	65%	65%
Mass Reduction - Level 2	MR2	28%	34%	45%	50%	52%	53%	58%	59%	60%
Mass Reduction - Level 3	MR3	12%	13%	14%	16%	17%	18%	21%	23%	23%
Mass Reduction - Level 4	MR4	5%	5%	6%	6%	6%	8%	7%	9%	9%
Mass Reduction - Level 5	MR5	0%	0%	1%	1%	1%	1%	1%	2%	3%
Low Rolling Resistance Tires - Level 1	ROLL1	96%	97%	99%	99%	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	17%	29%	46%	60%	74%	81%	84%	87%	88%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	85%	86%	87%	87%	87%	87%	87%	87%	87%
Secondary Axle Disconnect	SAX	10%	11%	12%	12%	12%	13%	13%	13%	13%
Aero Drag Reduction, Level 1	AERO1	94%	98%	99%	100%	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	52%	62%	76%	85%	91%	92%	93%	92%	92%

2% Annual Increase - Combined - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100 %	100 %	100 %	100 %	100%	100%
Engine Friction Reduction - Level 1	EFR1	74%	77%	77%	78%	78%	78%	78%	78%	78%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	8%	17%	21%	23%	28%	36%	38%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	18%	18%	18%	18%	18%	18%	18%	18%	18%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	17%	17%	17%	18%	18%	18%	18%	18%	18%
Cylinder Deactivation on SOHC	DEACS	6%	6%	6%	6%	6%	6%	6%	5%	5%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	5%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	59%	61%	62%	62%	62%	62%	62%	62%	62%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	27%	28%	29%	30%	32%	33%	33%	33%	33%
Continuously Variable Valve Lift (CVVL)	CVVL	16%	17%	20%	21%	22%	22%	23%	22%	23%
Cylinder Deactivation on DOHC	DEACD	9%	10%	9%	10%	10%	10%	10%	10%	10%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	38%	44%	46%	48%	52%	53%	54%	57%	58%
Cylinder Deactivation on OHV	DEACO	5%	5%	5%	5%	5%	5%	5%	5%	5%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	7%	7%	7%	7%	7%	7%	7%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	4%	4%	4%	4%	4%	4%	4%	4%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	13%	18%	19%	20%	24%	25%	25%	27%	28%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	16%	17%	18%	19%	19%	19%	19%	19%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	6%	6%	7%	7%	7%	7%	6%	6%	6%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	1%	1%	1%	0%	0%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	1%	1%	1%	1%	1%	1%	1%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	2%	3%	3%	3%	3%	3%	3%	4%	5%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	0%	1%	1%	1%	1%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	2%	2%	2%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANS M	0%	0%	1%	1%	2%	3%	3%	3%	3%
Improved Auto. Trans. Controls/Externals	IATC	36%	33%	27%	18%	15%	15%	15%	19%	19%
6-Speed Trans with Improved Internals (Auto)	NAUTO	40%	35%	30%	20%	21%	21%	21%	23%	23%
6-speed DCT	DCT	22%	23%	18%	11%	10%	8%	5%	5%	5%
8-Speed Trans (Auto or DCT)	8SPD	8%	11%	12%	17%	16%	15%	19%	19%	19%
High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	3%	10%	19%	24%	26%	30%	29%	30%
Shift Optimizer	SHFTOPT	0%	0%	11%	17%	20%	23%	26%	27%	27%
Electric Power Steering	EPS	70%	75%	81%	82%	88%	90%	91%	91%	91%
Improved Accessories - Level 1	IACC1	44%	45%	48%	50%	57%	61%	67%	77%	77%
Improved Accessories - Level 2	IACC2	4%	5%	9%	10%	15%	16%	22%	30%	33%
12V Micro-Hybrid (Stop-Start)	MHEV	7%	7%	7%	8%	7%	7%	7%	7%	7%
Integrated Starter Generator	ISG	2%	2%	2%	2%	2%	3%	3%	4%	4%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	50%	55%	63%	65%	67%	68%	69%	68%	68%
Mass Reduction - Level 2	MR2	21%	27%	34%	37%	44%	46%	51%	58%	59%
Mass Reduction - Level 3	MR3	10%	10%	10%	10%	12%	13%	15%	18%	19%
Mass Reduction - Level 4	MR4	3%	3%	3%	3%	3%	3%	4%	6%	7%
Mass Reduction - Level 5	MR5	0%	0%	0%	1%	1%	1%	1%	4%	4%
Low Rolling Resistance Tires - Level 1	ROLL1	93%	97%	98%	99%	99%	99%	99%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	18%	34%	43%	55%	67%	79%	80%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	84%	84%	86%	86%	89%	89%	89%	89%	89%
Secondary Axle Disconnect	SAX	10%	11%	12%	12%	12%	13%	13%	13%	13%
Aero Drag Reduction, Level 1	AERO1	91%	95%	97%	100 %	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	45%	56%	70%	80%	86%	87%	88%	90%	90%

3% Annual Increase - Combined - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	86%	86%	85%	85%	85%	85%	85%	85%	84%
Engine Friction Reduction - Level 1	EFR1	85%	88%	88%	88%	88%	88%	88%	88%	88%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	13%	25%	37%	47%	56%	62%	66%	69%	73%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	8%	7%	7%	7%	9%	9%	9%	11%	11%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	12%	12%	12%	12%	12%	12%	12%	12%	12%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	2%	1%	1%	1%	1%	1%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	5%	4%	4%	3%	3%	3%	3%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	65%	67%	67%	68%	69%	69%	70%	70%	70%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	46%	48%	48%	50%	51%	52%	52%	52%	52%
Continuously Variable Valve Lift (CVVL)	CVVL	12%	13%	15%	16%	16%	17%	17%	17%	17%
Cylinder Deactivation on DOHC	DEACD	6%	6%	5%	6%	5%	5%	4%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	50%	52%	56%	60%	62%	66%	67%	69%	69%
Cylinder Deactivation on OHV	DEACO	6%	6%	4%	3%	2%	2%	2%	1%	1%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	8%	9%	9%	9%	9%	8%	8%	8%	8%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	3%	4%	4%	8%	7%	7%	8%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	17%	18%	21%	21%	22%	22%	21%	20%	18%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	25%	27%	28%	31%	28%	27%	28%	27%	26%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	4%	4%	5%	6%	6%	6%	5%	5%	5%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	1%	1%	2%	2%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	1%	1%	1%	2%	2%	3%	3%	2%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	1%	2%	2%	4%	4%	6%	7%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	2%	3%	3%	3%	6%	7%	8%	11%	11%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	1%	2%	2%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	2%	2%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	2%	3%	5%	6%	6%	6%	6%	6%
Improved Auto. Trans. Controls/Externals	IATC	11%	8%	6%	2%	2%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	23%	17%	12%	8%	3%	3%	1%	0%	0%
6-speed DCT	DCT	22%	19%	16%	11%	9%	5%	5%	4%	4%
8-Speed Trans (Auto or DCT)	8SPD	25%	26%	27%	21%	11%	10%	9%	7%	6%
High Efficiency Gearbox (Auto or DCT)	HETRANS	4%	17%	28%	42%	55%	60%	64%	67%	68%
Shift Optimizer	SHFTOPT	8%	20%	35%	47%	56%	61%	68%	72%	74%
Electric Power Steering	EPS	76%	81%	85%	86%	89%	89%	90%	90%	91%
Improved Accessories - Level 1	IACC1	52%	54%	58%	61%	66%	68%	70%	70%	71%
Improved Accessories - Level 2	IACC2	10%	17%	20%	23%	25%	30%	34%	39%	42%
12V Micro-Hybrid (Stop-Start)	MHEV	5%	5%	5%	5%	5%	5%	5%	5%	5%
Integrated Starter Generator	ISG	1%	1%	1%	3%	3%	3%	3%	4%	7%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	61%	64%	67%	68%	68%	69%	69%	68%	68%
Mass Reduction - Level 2	MR2	29%	37%	48%	54%	57%	59%	61%	62%	62%
Mass Reduction - Level 3	MR3	12%	14%	15%	18%	20%	21%	23%	25%	27%
Mass Reduction - Level 4	MR4	5%	6%	6%	8%	9%	10%	10%	11%	14%
Mass Reduction - Level 5	MR5	0%	1%	1%	3%	3%	4%	3%	4%	7%
Low Rolling Resistance Tires - Level 1	ROLL1	96%	98%	99%	99%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	17%	31%	49%	63%	74%	82%	86%	89%	90%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	85%	86%	86%	87%	88%	88%	89%	89%	90%
Secondary Axle Disconnect	SAX	11%	13%	13%	14%	14%	14%	14%	13%	15%
Aero Drag Reduction, Level 1	AERO1	95%	98%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	52%	62%	76%	86%	91%	92%	93%	92%	92%

3% Annual Increase - Combined - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100 %	100 %	100 %	100 %	100%	100%
Engine Friction Reduction - Level 1	EFR1	74%	77%	77%	78%	78%	78%	78%	78%	78%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	6%	12%	15%	17%	22%	27%	29%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	19%	19%	19%	19%	19%	19%	19%	19%	19%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	17%	17%	17%	18%	18%	18%	19%	18%	18%
Cylinder Deactivation on SOHC	DEACS	6%	6%	4%	3%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	3%	2%	2%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	59%	61%	61%	61%	61%	61%	61%	61%	61%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	29%	30%	30%	31%	31%	31%	32%	32%	32%
Continuously Variable Valve Lift (CVVL)	CVVL	19%	20%	21%	22%	22%	23%	23%	23%	23%
Cylinder Deactivation on DOHC	DEACD	8%	9%	8%	6%	5%	5%	4%	3%	3%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	44%	51%	63%	65%	69%	74%	75%	78%	78%
Cylinder Deactivation on OHV	DEACO	5%	5%	4%	3%	2%	2%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	7%	7%	7%	7%	7%	7%	7%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	4%	4%	4%	6%	6%	6%	8%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	17%	18%	22%	23%	25%	28%	31%	33%	31%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	19%	20%	23%	26%	25%	25%	27%	27%	23%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	7%	7%	8%	9%	11%	11%	12%	12%	12%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	1%	1%	1%	1%	4%	4%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	1%	1%	1%	1%	4%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	3%	3%	3%	3%	3%	3%	4%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	2%	3%	3%	3%	3%	3%	4%	5%	5%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	1%	1%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	2%	2%	2%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANS M	0%	0%	1%	2%	2%	3%	3%	3%	3%
Improved Auto. Trans. Controls/Externals	IATC	35%	33%	22%	15%	7%	4%	2%	1%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	42%	38%	26%	14%	8%	7%	3%	2%	3%
6-speed DCT	DCT	26%	27%	25%	18%	21%	19%	17%	13%	12%
8-Speed Trans (Auto or DCT)	8SPD	9%	15%	24%	30%	27%	27%	23%	16%	10%
High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	2%	10%	17%	30%	32%	39%	53%	59%
Shift Optimizer	SHFTOPT	0%	0%	4%	15%	21%	26%	34%	44%	50%
Electric Power Steering	EPS	72%	78%	86%	89%	90%	90%	90%	90%	90%
Improved Accessories - Level 1	IACC1	56%	61%	69%	75%	75%	76%	76%	77%	78%
Improved Accessories - Level 2	IACC2	5%	6%	9%	11%	14%	19%	20%	23%	24%
12V Micro-Hybrid (Stop-Start)	MHEV	7%	7%	7%	8%	8%	8%	7%	7%	7%
Integrated Starter Generator	ISG	2%	2%	2%	2%	3%	3%	3%	4%	5%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	55%	59%	67%	71%	73%	73%	73%	73%	74%
Mass Reduction - Level 2	MR2	21%	31%	43%	47%	53%	55%	55%	62%	65%
Mass Reduction - Level 3	MR3	10%	10%	11%	12%	16%	17%	19%	22%	25%
Mass Reduction - Level 4	MR4	3%	3%	4%	6%	7%	8%	8%	9%	13%
Mass Reduction - Level 5	MR5	0%	0%	0%	1%	1%	1%	1%	2%	5%
Low Rolling Resistance Tires - Level 1	ROLL1	93%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	19%	35%	45%	55%	73%	82%	85%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	86%	86%	88%	89%	89%	89%	89%	89%	89%
Secondary Axle Disconnect	SAX	11%	12%	13%	14%	14%	14%	14%	13%	13%
Aero Drag Reduction, Level 1	AERO1	94%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	45%	56%	70%	82%	87%	88%	89%	92%	94%

4% Annual Increase - Combined - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	86%	86%	85%	85%	85%	85%	85%	85%	84%
Engine Friction Reduction - Level 1	EFR1	85%	88%	88%	88%	88%	88%	88%	88%	87%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	15%	27%	38%	46%	55%	60%	64%	68%	70%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	11%	11%	12%	11%	11%	11%	11%	11%	11%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	12%	12%	12%	12%	12%	12%	12%	12%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	1%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	4%	4%	3%	3%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	67%	67%	67%	68%	69%	70%	70%	70%	70%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	48%	50%	50%	51%	52%	52%	52%	52%	52%
Continuously Variable Valve Lift (CVVL)	CVVL	13%	15%	15%	16%	16%	16%	16%	16%	16%
Cylinder Deactivation on DOHC	DEACD	5%	4%	4%	5%	4%	4%	2%	1%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	56%	61%	66%	68%	75%	77%	80%	85%	86%
Cylinder Deactivation on OHV	DEACO	6%	5%	2%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	8%	9%	9%	10%	9%	9%	9%	8%	8%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	4%	5%	7%	10%	10%	9%	9%	9%	9%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	20%	23%	25%	24%	28%	23%	20%	18%	16%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	26%	29%	29%	28%	24%	22%	19%	15%	13%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	5%	5%	8%	8%	6%	5%	5%	5%	5%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	1%	2%	2%	2%	4%	5%	5%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	1%	4%	4%	4%	5%	6%	7%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	1%	5%	5%	10%	12%	16%	19%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	4%	5%	7%	12%	14%	17%	21%	22%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	1%	1%	1%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	2%	3%	4%	5%	4%	4%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	2%	2%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	2%	3%	5%	6%	6%	6%	6%	6%
Improved Auto. Trans. Controls/Externals	IATC	8%	4%	4%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	18%	12%	7%	2%	1%	1%	0%	0%	0%
6-speed DCT	DCT	26%	21%	16%	10%	4%	2%	1%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	25%	28%	28%	21%	12%	8%	5%	3%	2%
High Efficiency Gearbox (Auto or DCT)	HETRANS	8%	20%	32%	47%	59%	63%	67%	71%	70%
Shift Optimizer	SHFTOPT	11%	23%	39%	52%	69%	77%	81%	86%	87%
Electric Power Steering	EPS	81%	85%	91%	92%	94%	94%	94%	94%	94%
Improved Accessories - Level 1	IACC1	53%	55%	60%	67%	75%	79%	82%	89%	91%
Improved Accessories - Level 2	IACC2	13%	20%	23%	29%	33%	37%	42%	48%	57%
12V Micro-Hybrid (Stop-Start)	MHEV	5%	5%	6%	10%	12%	13%	13%	13%	12%
Integrated Starter Generator	ISG	1%	1%	2%	4%	5%	8%	10%	13%	16%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	62%	65%	67%	69%	69%	69%	69%	68%	68%
Mass Reduction - Level 2	MR2	27%	35%	48%	54%	58%	60%	63%	63%	64%
Mass Reduction - Level 3	MR3	12%	14%	16%	21%	23%	24%	26%	29%	30%
Mass Reduction - Level 4	MR4	6%	7%	7%	9%	12%	13%	15%	19%	22%
Mass Reduction - Level 5	MR5	1%	1%	2%	4%	6%	7%	7%	11%	13%
Low Rolling Resistance Tires - Level 1	ROLL1	96%	98%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	16%	32%	49%	66%	75%	82%	86%	88%	89%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	88%	88%	89%	89%	89%	89%	90%	90%	90%
Secondary Axle Disconnect	SAX	13%	14%	15%	16%	16%	16%	15%	15%	15%
Aero Drag Reduction, Level 1	AERO1	95%	98%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	52%	62%	76%	86%	91%	92%	93%	92%	92%

4% Annual Increase - Combined - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100 %	100 %	100 %	100 %	100%	99%
Engine Friction Reduction - Level 1	EFR1	74%	77%	77%	78%	78%	78%	78%	78%	78%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	6%	13%	14%	16%	21%	30%	33%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	19%	19%	18%	18%	18%	18%	18%	18%	18%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	17%	18%	17%	18%	18%	18%	18%	18%	18%
Cylinder Deactivation on SOHC	DEACS	6%	6%	5%	4%	2%	2%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	3%	2%	2%	2%	2%	2%	2%	2%	1%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	59%	61%	61%	61%	61%	61%	61%	61%	61%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	29%	30%	31%	32%	32%	32%	32%	32%	32%
Continuously Variable Valve Lift (CVVL)	CVVL	20%	21%	21%	22%	22%	22%	22%	22%	22%
Cylinder Deactivation on DOHC	DEACD	9%	8%	5%	3%	2%	1%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	52%	59%	70%	73%	80%	82%	85%	86%	86%
Cylinder Deactivation on OHV	DEACO	5%	4%	3%	1%	1%	1%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	7%	7%	7%	7%	7%	7%	7%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	4%	5%	5%	7%	8%	8%	8%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	26%	29%	34%	34%	37%	34%	32%	26%	22%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	17%	19%	24%	26%	25%	25%	25%	21%	15%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	7%	8%	9%	11%	12%	12%	12%	11%	10%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	1%	1%	4%	6%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	1%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	1%	3%	5%	8%	10%	17%	22%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	4%	4%	6%	7%	8%	9%	11%	15%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	2%	2%	2%	4%	4%	4%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	1%	1%	1%	1%	1%	1%	1%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	2%	2%	2%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANS M	0%	0%	1%	2%	2%	3%	3%	3%	3%
Improved Auto. Trans. Controls/Externals	IATC	35%	30%	18%	10%	3%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	42%	38%	26%	14%	6%	3%	1%	0%	0%
6-speed DCT	DCT	24%	26%	22%	15%	15%	11%	5%	2%	1%
8-Speed Trans (Auto or DCT)	8SPD	10%	15%	21%	22%	20%	20%	20%	14%	12%
High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	4%	15%	25%	35%	38%	41%	50%	50%
Shift Optimizer	SHFTOPT	0%	0%	9%	25%	44%	50%	59%	64%	70%
Electric Power Steering	EPS	75%	82%	88%	91%	93%	94%	94%	95%	95%
Improved Accessories - Level 1	IACC1	56%	64%	71%	76%	81%	85%	86%	88%	91%
Improved Accessories - Level 2	IACC2	6%	12%	19%	27%	34%	39%	47%	57%	63%
12V Micro-Hybrid (Stop-Start)	MHEV	8%	8%	9%	10%	9%	11%	12%	12%	10%
Integrated Starter Generator	ISG	2%	2%	3%	5%	6%	7%	8%	9%	14%
Strong Hybrid - Level 1	SHEV1	2%	2%	2%	1%	1%	1%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	0%	0%	1%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	56%	61%	69%	72%	73%	73%	74%	74%	74%
Mass Reduction - Level 2	MR2	21%	30%	43%	49%	55%	57%	60%	62%	65%
Mass Reduction - Level 3	MR3	10%	11%	14%	18%	21%	22%	26%	28%	33%
Mass Reduction - Level 4	MR4	4%	4%	6%	10%	10%	11%	13%	14%	16%
Mass Reduction - Level 5	MR5	0%	0%	1%	2%	3%	4%	5%	5%	8%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	20%	35%	52%	59%	69%	78%	85%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	86%	86%	88%	89%	90%	90%	90%	90%	90%
Secondary Axle Disconnect	SAX	11%	12%	13%	13%	13%	13%	13%	13%	13%
Aero Drag Reduction, Level 1	AERO1	94%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	45%	56%	70%	81%	86%	88%	89%	91%	94%

5% Annual Increase - Combined - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	86%	86%	85%	85%	84%	84%	84%	84%	82%
Engine Friction Reduction - Level 1	EFR1	85%	88%	88%	88%	88%	88%	88%	87%	86%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	14%	25%	36%	44%	48%	53%	56%	59%	59%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	9%	9%	12%	11%	11%	11%	11%	11%	11%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	12%	12%	12%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	2%	2%	2%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	4%	4%	3%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	67%	67%	67%	69%	70%	67%	67%	65%	63%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	48%	50%	50%	51%	52%	51%	50%	49%	47%
Continuously Variable Valve Lift (CVVL)	CVVL	14%	14%	15%	15%	15%	15%	15%	16%	15%
Cylinder Deactivation on DOHC	DEACD	5%	4%	3%	2%	2%	2%	1%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	58%	66%	71%	74%	81%	79%	80%	80%	78%
Cylinder Deactivation on OHV	DEACO	6%	5%	1%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	8%	9%	9%	10%	9%	9%	9%	8%	8%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	5%	7%	8%	10%	10%	9%	9%	9%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	22%	26%	27%	25%	25%	18%	15%	6%	5%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	28%	31%	32%	27%	22%	19%	15%	8%	7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	5%	5%	5%	5%	4%	4%	2%	2%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	2%	2%	3%	3%	3%	2%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	2%	2%	2%	2%	2%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	2%	6%	8%	13%	16%	24%	25%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	4%	6%	11%	14%	17%	20%	25%	26%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	2%	1%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	3%	3%	3%	3%	3%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	1%	4%	5%	7%	9%	8%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	3%	4%	5%	5%	7%	7%	6%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	1%	1%	3%	4%	5%	6%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	0%	0%	0%	0%	1%	1%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	2%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	2%	3%	5%	6%	6%	6%	6%	6%
Improved Auto. Trans. Controls/Externals	IATC	9%	5%	4%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	17%	13%	7%	3%	0%	0%	0%	0%	0%
6-speed DCT	DCT	27%	21%	15%	9%	2%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	25%	25%	23%	16%	8%	6%	5%	5%	4%
High Efficiency Gearbox (Auto or DCT)	HETRANS	9%	24%	38%	50%	61%	64%	65%	64%	62%
Shift Optimizer	SHFTOPT	11%	28%	46%	62%	80%	87%	89%	86%	83%
Electric Power Steering	EPS	84%	87%	93%	95%	95%	95%	96%	96%	96%
Improved Accessories - Level 1	IACC1	60%	63%	67%	76%	86%	88%	92%	96%	96%
Improved Accessories - Level 2	IACC2	16%	27%	36%	48%	58%	66%	74%	82%	86%
12V Micro-Hybrid (Stop-Start)	MHEV	6%	6%	9%	16%	23%	28%	32%	30%	27%
Integrated Starter Generator	ISG	1%	2%	4%	9%	13%	17%	22%	30%	36%
Strong Hybrid - Level 1	SHEV1	3%	3%	3%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	1%	4%	4%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	1%	1%	1%	1%	1%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	62%	65%	67%	69%	69%	69%	69%	68%	68%
Mass Reduction - Level 2	MR2	29%	36%	50%	56%	59%	61%	64%	64%	64%
Mass Reduction - Level 3	MR3	12%	15%	17%	23%	25%	26%	27%	29%	29%
Mass Reduction - Level 4	MR4	7%	8%	10%	16%	16%	17%	18%	20%	20%
Mass Reduction - Level 5	MR5	1%	2%	4%	11%	12%	13%	14%	16%	16%
Low Rolling Resistance Tires - Level 1	ROLL1	96%	98%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	16%	31%	52%	66%	74%	82%	87%	89%	89%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	88%	88%	89%	89%	89%	89%	90%	90%	90%
Secondary Axle Disconnect	SAX	13%	15%	15%	16%	16%	16%	16%	15%	15%
Aero Drag Reduction, Level 1	AERO1	95%	98%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	52%	62%	76%	86%	91%	92%	93%	92%	92%

5% Annual Increase - Combined - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	100%	100 %	99%	99%	99%	99%	97%
Engine Friction Reduction - Level 1	EFR1	74%	77%	77%	78%	78%	78%	78%	78%	76%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	4%	9%	10%	12%	14%	20%	26%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	19%	19%	18%	18%	18%	18%	18%	18%	18%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	17%	18%	17%	17%	17%	17%	17%	17%	16%
Cylinder Deactivation on SOHC	DEACS	6%	5%	4%	4%	2%	2%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	3%	2%	1%	1%	1%	1%	1%	1%	1%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	59%	61%	61%	59%	59%	57%	56%	56%	55%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	29%	31%	31%	31%	32%	30%	30%	30%	29%
Continuously Variable Valve Lift (CVVL)	CVVL	20%	20%	21%	21%	22%	22%	22%	21%	21%
Cylinder Deactivation on DOHC	DEACD	6%	5%	3%	2%	1%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	57%	64%	74%	75%	79%	78%	79%	80%	78%
Cylinder Deactivation on OHV	DEACO	5%	3%	3%	1%	1%	1%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	7%	7%	7%	7%	7%	7%	7%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	4%	5%	6%	7%	7%	7%	8%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	29%	32%	37%	35%	35%	30%	24%	15%	12%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	21%	24%	26%	25%	23%	22%	20%	16%	10%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	7%	8%	9%	11%	8%	7%	7%	6%	4%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	1%	1%	1%	1%	1%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	1%	1%	1%	1%	1%	2%	2%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	1%	2%	4%	6%	9%	12%	23%	25%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	2%	3%	4%	6%	7%	8%	10%	14%	18%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	3%	3%	3%	3%	3%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	1%	2%	2%	2%	2%	3%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	2%	3%	4%	5%	5%	5%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	1%	1%	1%	3%	4%	4%	4%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	2%	2%	2%	2%	2%	2%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	1%	1%	1%	1%	1%
6-Speed Manual/Improved Internals	6MAN	2%	2%	2%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANS M	0%	0%	1%	2%	2%	3%	3%	3%	3%
Improved Auto. Trans. Controls/Externals	IATC	33%	27%	16%	6%	2%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	41%	37%	24%	13%	4%	2%	0%	0%	0%
6-speed DCT	DCT	27%	25%	19%	10%	7%	4%	2%	1%	0%
8-Speed Trans (Auto or DCT)	8SPD	12%	19%	20%	20%	15%	12%	5%	4%	3%
High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	6%	22%	34%	45%	49%	51%	54%	52%
Shift Optimizer	SHFTOPT	0%	0%	23%	39%	61%	74%	84%	88%	85%
Electric Power Steering	EPS	77%	84%	92%	93%	95%	95%	95%	96%	96%
Improved Accessories - Level 1	IACC1	61%	69%	82%	86%	91%	94%	94%	97%	97%
Improved Accessories - Level 2	IACC2	7%	15%	23%	31%	41%	49%	57%	78%	81%
12V Micro-Hybrid (Stop-Start)	MHEV	11%	12%	16%	21%	28%	29%	31%	33%	32%
Integrated Starter Generator	ISG	2%	4%	6%	13%	14%	16%	19%	28%	30%
Strong Hybrid - Level 1	SHEV1	2%	2%	1%	1%	1%	1%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	0%	3%	3%	5%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	2%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	1%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	56%	60%	69%	73%	74%	74%	74%	74%	74%
Mass Reduction - Level 2	MR2	22%	32%	49%	56%	62%	64%	67%	68%	68%
Mass Reduction - Level 3	MR3	10%	11%	13%	19%	25%	26%	30%	33%	37%
Mass Reduction - Level 4	MR4	4%	4%	6%	9%	10%	11%	13%	15%	22%
Mass Reduction - Level 5	MR5	0%	0%	1%	3%	4%	6%	8%	11%	18%
Low Rolling Resistance Tires - Level 1	ROLL1	94%	98%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	21%	38%	51%	60%	70%	81%	87%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	86%	87%	89%	89%	90%	90%	90%	90%	90%
Secondary Axle Disconnect	SAX	11%	12%	13%	13%	13%	13%	13%	13%	13%
Aero Drag Reduction, Level 1	AERO1	94%	98%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	45%	56%	70%	81%	86%	88%	89%	91%	93%

6% Annual Increase - Combined - 2008 Baseline										
Low Friction Lubricants - Level 1	LUB1	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Engine Friction Reduction - Level 1	EFR1	86%	86%	85%	84%	84%	82%	81%	80%	76%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	85%	88%	88%	88%	87%	85%	84%	82%	79%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	15%	27%	39%	46%	51%	53%	55%	62%	62%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	11%	12%	11%	11%	11%	11%	11%	11%	10%
Cylinder Deactivation on SOHC	DEACS	12%	12%	12%	11%	11%	11%	11%	11%	11%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2%	2%	2%	1%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	3%	2%	3%	2%	2%	2%	2%	2%	2%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	68%	68%	68%	67%	66%	63%	62%	59%	57%
Continuously Variable Valve Lift (CVVL)	CVVL	50%	50%	50%	50%	48%	47%	47%	43%	42%
Cylinder Deactivation on DOHC	DEACD	14%	14%	15%	15%	15%	15%	15%	15%	14%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	3%	1%	1%	1%	0%	0%	0%	0%	0%
Cylinder Deactivation on OHV	DEACO	65%	71%	76%	77%	80%	78%	78%	74%	71%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	5%	4%	1%	0%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	9%	9%	9%	10%	9%	9%	8%	8%	7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	7%	8%	9%	10%	10%	9%	9%	9%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	25%	29%	28%	25%	24%	19%	16%	8%	6%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	31%	34%	34%	28%	21%	18%	16%	7%	5%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	6%	6%	6%	6%	6%	5%	3%	3%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	1%	1%	2%	2%	2%	1%	1%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	1%	1%	1%	1%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	1%	1%	3%	9%	10%	12%	12%	16%	14%

CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	3%	4%	5%	10%	15%	17%	17%	19%	18%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	1%	4%	6%	9%	10%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	2%	4%	5%	6%	11%	10%
Advanced Diesel - Small Displacement	ADSL_SD	1%	1%	4%	5%	5%	5%	7%	7%	5%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	1%	1%	3%	3%	4%	4%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	2%	2%	2%	2%	3%	3%
6-Speed Manual/Improved Internals	6MAN	0%	0%	0%	0%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	3%	2%	2%	1%	0%	0%	0%	0%	0%
Improved Auto. Trans. Controls/Externals	IATC	1%	2%	3%	5%	6%	6%	6%	6%	6%
6-Speed Trans with Improved Internals (Auto)	NAUTO	8%	4%	3%	0%	0%	0%	0%	0%	0%
6-speed DCT	DCT	17%	12%	6%	1%	0%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	26%	19%	14%	8%	2%	0%	0%	0%	0%
High Efficiency Gearbox (Auto or DCT)	HETRANS	27%	27%	25%	18%	8%	5%	4%	4%	2%
Shift Optimizer	SHFTOPT	10%	24%	39%	50%	58%	61%	61%	59%	52%
Electric Power Steering	EPS	12%	30%	51%	67%	82%	85%	84%	80%	71%
Improved Accessories - Level 1	IACC1	82%	86%	94%	96%	96%	96%	96%	96%	96%
Improved Accessories - Level 2	IACC2	64%	67%	75%	85%	88%	90%	94%	97%	97%
12V Micro-Hybrid (Stop-Start)	MHEV	20%	30%	44%	58%	69%	75%	85%	89%	89%
Integrated Starter Generator	ISG	13%	17%	22%	29%	39%	38%	38%	37%	32%
Strong Hybrid - Level 1	SHEV1	3%	6%	10%	17%	20%	25%	28%	37%	38%
Conversion from SHEV1 to SHEV2	SHEV1_2	3%	3%	2%	1%	1%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	1%	1%	1%	2%	2%	2%	2%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	1%	1%	2%	4%	9%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	1%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	1%	2%	4%	4%	6%	7%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	1%	2%	3%

Mass Reduction - Level 1	MR1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 2	MR2	62%	65%	67%	69%	69%	69%	69%	68%	68%
Mass Reduction - Level 3	MR3	29%	37%	51%	57%	60%	62%	64%	64%	64%
Mass Reduction - Level 4	MR4	13%	15%	17%	23%	25%	27%	28%	31%	33%
Mass Reduction - Level 5	MR5	7%	8%	10%	13%	14%	16%	17%	19%	22%
Low Rolling Resistance Tires - Level 1	ROLL1	1%	2%	4%	8%	10%	12%	13%	15%	20%
Low Rolling Resistance Tires - Level 2	ROLL2	96%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 3	ROLL3	16%	32%	49%	67%	77%	86%	88%	91%	92%
Low Drag Brakes	LDB	0%	0%	0%	0%	0%	0%	0%	0%	0%
Secondary Axle Disconnect	SAX	88%	88%	89%	89%	89%	89%	90%	90%	90%
Aero Drag Reduction, Level 1	AERO1	13%	15%	15%	16%	16%	16%	16%	15%	15%
Aero Drag Reduction, Level 2	AERO2	95%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	52%	62%	76%	86%	91%	92%	93%	92%	92%

6% Annual Increase - Combined - 2010 Baseline										
Low Friction Lubricants - Level 1	LUB1	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Engine Friction Reduction - Level 1	EFR1	100%	100%	100%	100 %	99%	99%	98%	95%	94%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	75%	77%	77%	78%	78%	78%	76%	75%	74%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	0%	0%	5%	9%	10%	13%	16%	21%	24%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	19%	19%	18%	18%	18%	18%	18%	17%	17%
Cylinder Deactivation on SOHC	DEACS	17%	18%	17%	17%	16%	16%	16%	16%	16%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	4%	4%	3%	3%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	3%	2%	1%	1%	1%	1%	1%	1%	1%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	59%	61%	61%	58%	57%	56%	55%	53%	52%
Continuously Variable Valve Lift (CVVL)	CVVL	29%	31%	30%	30%	30%	29%	29%	26%	26%
Cylinder Deactivation on DOHC	DEACD	20%	21%	22%	21%	21%	21%	20%	20%	19%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	5%	4%	3%	2%	1%	1%	0%	0%	0%
Cylinder Deactivation on OHV	DEACO	54%	63%	74%	72%	77%	77%	76%	73%	71%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	4%	3%	3%	1%	1%	1%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	7%	7%	7%	7%	7%	7%	7%	7%	7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	4%	5%	6%	7%	7%	7%	8%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	22%	26%	30%	28%	29%	26%	21%	12%	9%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	23%	27%	29%	27%	24%	22%	19%	12%	6%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	7%	8%	9%	10%	7%	7%	6%	6%	4%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	1%	1%	1%	1%	1%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	1%	1%	1%	1%	1%	1%	1%	1%	2%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	2%	3%	6%	7%	11%	13%	16%	21%	23%

CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	3%	3%	4%	4%	7%	9%	10%	13%	15%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	1%	1%	1%	0%	3%	3%	3%	3%	3%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	1%	1%	1%	1%	2%	2%	2%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	2%	2%	3%	4%	4%	3%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	1%	3%	3%	4%	4%	5%	5%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	2%	3%	3%	3%	4%	4%
6-Speed Manual/Improved Internals	6MAN	0%	0%	0%	0%	1%	1%	1%	1%	1%
High Efficiency Gearbox (Manual)	HETRANS M	3%	3%	2%	1%	1%	1%	0%	0%	0%
Improved Auto. Trans. Controls/Externals	IATC	0%	0%	1%	2%	2%	3%	3%	3%	3%
6-Speed Trans with Improved Internals (Auto)	NAUTO	28%	25%	13%	4%	1%	1%	0%	0%	0%
6-speed DCT	DCT	38%	32%	19%	9%	3%	2%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	28%	26%	20%	11%	6%	4%	3%	1%	0%
High Efficiency Gearbox (Auto or DCT)	HETRANS	19%	25%	25%	25%	15%	10%	4%	3%	2%
Shift Optimizer	SHFTOPT	2%	7%	24%	35%	42%	46%	46%	42%	40%
Electric Power Steering	EPS	0%	0%	21%	38%	59%	71%	83%	80%	77%
Improved Accessories - Level 1	IACC1	79%	87%	94%	95%	96%	96%	96%	96%	96%
Improved Accessories - Level 2	IACC2	64%	71%	83%	85%	90%	93%	97%	97%	97%
12V Micro-Hybrid (Stop-Start)	MHEV	10%	20%	34%	41%	52%	58%	66%	67%	68%
Integrated Starter Generator	ISG	12%	18%	32%	40%	50%	52%	50%	44%	39%
Strong Hybrid - Level 1	SHEV1	4%	6%	9%	15%	21%	25%	30%	35%	35%
Conversion from SHEV1 to SHEV2	SHEV1_2	2%	2%	1%	1%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	1%	1%	0%	0%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	1%	1%	3%	7%	11%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	1%	1%	1%	2%	3%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%
Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	1%	2%	3%

Mass Reduction - Level 1	MR1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 2	MR2	57%	62%	70%	72%	74%	74%	74%	74%	74%
Mass Reduction - Level 3	MR3	22%	32%	50%	55%	62%	64%	66%	67%	69%
Mass Reduction - Level 4	MR4	10%	11%	15%	17%	23%	25%	29%	31%	39%
Mass Reduction - Level 5	MR5	4%	4%	7%	10%	13%	14%	16%	18%	26%
Low Rolling Resistance Tires - Level 1	ROLL1	0%	1%	2%	4%	6%	8%	10%	13%	21%
Low Rolling Resistance Tires - Level 2	ROLL2	95%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	20%	36%	50%	59%	72%	80%	89%
Low Drag Brakes	LDB	0%	0%	0%	0%	0%	0%	0%	0%	0%
Secondary Axle Disconnect	SAX	86%	87%	89%	90%	90%	90%	90%	90%	90%
Aero Drag Reduction, Level 1	AERO1	11%	12%	13%	14%	14%	14%	14%	13%	13%
Aero Drag Reduction, Level 2	AERO2	95%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	45%	56%	70%	81%	87%	88%	89%	91%	94%

7% Annual Increase - Combined - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	87%	86%	85%	85%	84%	82%	81%	78%	76%
Engine Friction Reduction - Level 1	EFR1	88%	88%	87%	88%	86%	84%	83%	81%	79%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	15%	27%	39%	45%	47%	48%	50%	56%	56%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	11%	12%	11%	11%	10%	10%	10%	9%	9%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	12%	12%	11%	11%	10%	10%	10%	10%	9%
Cylinder Deactivation on SOHC	DEACS	2%	2%	1%	1%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	3%	2%	3%	2%	2%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	68%	68%	68%	65%	61%	58%	57%	55%	54%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	50%	50%	50%	48%	44%	41%	40%	38%	38%
Continuously Variable Valve Lift (CVVL)	CVVL	14%	14%	15%	15%	15%	14%	15%	15%	14%
Cylinder Deactivation on DOHC	DEACD	5%	2%	1%	1%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	67%	76%	80%	79%	75%	71%	71%	68%	66%
Cylinder Deactivation on OHV	DEACO	4%	3%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	9%	9%	10%	9%	9%	8%	8%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	8%	9%	10%	10%	9%	9%	9%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	28%	32%	30%	26%	21%	16%	13%	10%	9%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	33%	35%	33%	24%	19%	16%	13%	8%	7%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	5%	6%	8%	8%	7%	6%	4%	3%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	1%	1%	1%	1%	1%	1%	1%	1%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	1%	1%	1%	1%	1%	0%	0%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	2%	2%	4%	8%	10%	11%	11%	13%	13%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	3%	4%	8%	12%	13%	15%	14%	15%	15%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	2%	2%	3%	3%	5%	6%	6%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	1%	3%	6%	7%	8%	8%	7%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	1%	1%	2%	3%	3%	3%	4%	4%	3%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	0%	2%	4%	6%	6%	6%	6%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	0%	3%	5%	5%	6%	6%	6%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	2%	3%	5%	6%	6%	6%	6%	6%
Improved Auto. Trans. Controls/Externals	IATC	10%	6%	3%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	20%	12%	4%	1%	0%	0%	0%	0%	0%
6-speed DCT	DCT	26%	19%	14%	7%	1%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	29%	29%	26%	17%	7%	5%	5%	4%	2%
High Efficiency Gearbox (Auto or DCT)	HETRANS	10%	25%	38%	51%	57%	60%	58%	55%	52%
Shift Optimizer	SHFTOPT	14%	34%	54%	73%	84%	83%	80%	73%	69%
Electric Power Steering	EPS	85%	89%	95%	96%	96%	96%	96%	96%	96%
Improved Accessories - Level 1	IACC1	65%	75%	84%	93%	93%	96%	97%	97%	97%
Improved Accessories - Level 2	IACC2	22%	39%	52%	64%	74%	82%	85%	85%	85%
12V Micro-Hybrid (Stop-Start)	MHEV	18%	25%	36%	43%	45%	43%	42%	35%	31%
Integrated Starter Generator	ISG	4%	9%	13%	20%	28%	32%	35%	35%	36%
Strong Hybrid - Level 1	SHEV1	3%	3%	2%	1%	1%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	1%	1%	1%	1%	1%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	2%	2%	5%	9%	12%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	0%	2%	5%	5%	6%	6%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	1%	1%	1%	2%	2%	4%	6%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	63%	66%	68%	69%	69%	69%	69%	68%	68%
Mass Reduction - Level 2	MR2	30%	39%	53%	59%	62%	63%	64%	64%	64%
Mass Reduction - Level 3	MR3	13%	15%	17%	23%	26%	28%	30%	31%	35%
Mass Reduction - Level 4	MR4	7%	8%	10%	15%	18%	20%	22%	24%	28%
Mass Reduction - Level 5	MR5	2%	3%	4%	11%	14%	16%	18%	21%	25%
Low Rolling Resistance Tires - Level 1	ROLL1	96%	98%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	16%	31%	50%	67%	79%	86%	90%	91%	92%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	88%	89%	89%	89%	89%	89%	90%	90%	90%
Secondary Axle Disconnect	SAX	17%	17%	16%	16%	16%	16%	16%	15%	15%
Aero Drag Reduction, Level 1	AERO1	95%	98%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	52%	62%	76%	86%	91%	92%	93%	92%	92%

7% Annual Increase - Combined - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	99%	99%	98%	96%	94%	93%	91%
Engine Friction Reduction - Level 1	EFR1	75%	77%	77%	78%	78%	77%	76%	74%	73%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	4%	9%	10%	11%	14%	18%	20%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	19%	19%	19%	18%	17%	17%	17%	17%	16%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	17%	17%	17%	17%	16%	16%	16%	16%	15%
Cylinder Deactivation on SOHC	DEACS	4%	4%	3%	3%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	3%	2%	1%	1%	1%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	59%	61%	60%	57%	56%	54%	49%	47%	46%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	29%	31%	30%	31%	30%	29%	26%	25%	23%
Continuously Variable Valve Lift (CVVL)	CVVL	20%	21%	21%	21%	21%	21%	20%	19%	19%
Cylinder Deactivation on DOHC	DEACD	6%	4%	3%	2%	1%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	62%	71%	78%	75%	77%	75%	71%	69%	67%
Cylinder Deactivation on OHV	DEACO	5%	4%	3%	1%	1%	1%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	7%	7%	7%	7%	7%	7%	7%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	4%	5%	6%	7%	7%	7%	8%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	31%	34%	38%	34%	32%	29%	24%	15%	11%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	22%	26%	27%	24%	21%	20%	18%	13%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	7%	8%	7%	8%	6%	6%	5%	5%	4%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	1%	0%	0%	0%	0%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	1%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	2%	2%	3%	6%	6%	7%	7%	12%	13%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	4%	5%	6%	9%	10%	11%	12%	16%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	1%	0%	0%	0%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	2%	3%	3%	3%	3%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	1%	1%	2%	2%	2%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	2%	3%	6%	7%	8%	8%	5%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	1%	2%	3%	4%	7%	8%	8%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	1%	3%	3%	3%	3%	3%	3%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	1%	1%	1%	1%	1%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	2%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	2%	2%	3%	3%	3%	3%
Improved Auto. Trans. Controls/Externals	IATC	28%	24%	13%	4%	1%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	39%	31%	18%	7%	2%	1%	0%	0%	0%
6-speed DCT	DCT	28%	25%	19%	9%	5%	3%	1%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	19%	26%	26%	25%	16%	10%	5%	3%	2%
High Efficiency Gearbox (Auto or DCT)	HETRANS	2%	9%	26%	35%	40%	43%	42%	39%	37%
Shift Optimizer	SHFTOPT	0%	0%	22%	42%	64%	72%	83%	79%	74%
Electric Power Steering	EPS	78%	87%	94%	96%	96%	96%	96%	96%	96%
Improved Accessories - Level 1	IACC1	64%	73%	87%	93%	95%	97%	97%	97%	97%
Improved Accessories - Level 2	IACC2	15%	27%	39%	43%	51%	55%	55%	57%	59%
12V Micro-Hybrid (Stop-Start)	MHEV	28%	37%	52%	55%	56%	53%	50%	42%	37%
Integrated Starter Generator	ISG	6%	9%	13%	18%	27%	31%	32%	34%	33%
Strong Hybrid - Level 1	SHEV1	2%	2%	1%	1%	1%	0%	0%	0%	0%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	0%	1%	3%	8%	13%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	1%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	0%	1%	1%	1%	2%	3%	2%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	1%	1%	1%	3%	4%	5%	7%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	58%	64%	70%	73%	74%	74%	74%	74%	74%
Mass Reduction - Level 2	MR2	22%	33%	51%	57%	65%	66%	68%	69%	70%
Mass Reduction - Level 3	MR3	11%	12%	15%	19%	24%	25%	29%	31%	38%
Mass Reduction - Level 4	MR4	4%	5%	7%	11%	13%	14%	16%	20%	27%
Mass Reduction - Level 5	MR5	0%	1%	2%	5%	7%	9%	11%	15%	22%
Low Rolling Resistance Tires - Level 1	ROLL1	95%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	20%	37%	48%	59%	71%	81%	89%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	87%	88%	90%	90%	90%	90%	90%	90%	90%
Secondary Axle Disconnect	SAX	11%	12%	13%	14%	14%	14%	14%	13%	13%
Aero Drag Reduction, Level 1	AERO1	95%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	45%	56%	70%	80%	85%	87%	88%	90%	94%

Max Net Benefits - Combined - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	86%	86%	85%	83%	83%	83%	83%	82%	82%
Engine Friction Reduction - Level 1	EFR1	88%	88%	87%	87%	87%	87%	87%	86%	86%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	18%	22%	30%	41%	56%	60%	67%	73%	76%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	12%	11%	11%	11%	11%	11%	11%	11%	11%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	12%	12%	12%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	1%	1%	1%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2%	2%	3%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	66%	66%	66%	65%	66%	66%	66%	66%	66%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	50%	50%	49%	49%	50%	50%	50%	50%	50%
Continuously Variable Valve Lift (CVVL)	CVVL	14%	14%	15%	15%	15%	15%	15%	15%	15%
Cylinder Deactivation on DOHC	DEACD	3%	2%	1%	1%	1%	1%	1%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	71%	74%	74%	75%	79%	80%	80%	81%	81%
Cylinder Deactivation on OHV	DEACO	1%	1%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	9%	10%	10%	10%	9%	9%	8%	8%	8%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	9%	10%	10%	10%	10%	9%	9%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	28%	30%	27%	27%	22%	19%	16%	6%	4%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	32%	33%	31%	28%	24%	24%	21%	16%	15%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	9%	8%	8%	8%	8%	8%	6%	5%	5%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	1%	1%	1%	2%	6%	6%	7%	13%	12%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	1%	1%	1%	1%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	3%	3%	5%	6%	9%	12%	13%	17%	19%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	6%	6%	9%	11%	14%	15%	17%	20%	21%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	2%	2%	2%	2%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	2%	2%	3%	4%	4%	4%
Advanced Diesel - Small Displacement	ADSL_SD	1%	2%	2%	2%	2%	2%	2%	2%	2%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	1%	1%	1%	1%	1%	1%	1%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	2%	3%	5%	6%	6%	6%	6%	6%
Improved Auto. Trans. Controls/Externals	IATC	9%	4%	3%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	17%	11%	5%	1%	0%	0%	0%	0%	0%
6-speed DCT	DCT	26%	18%	11%	4%	2%	1%	1%	1%	1%
8-Speed Trans (Auto or DCT)	8SPD	35%	35%	31%	23%	9%	7%	6%	5%	4%
High Efficiency Gearbox (Auto or DCT)	HETRANS	8%	24%	39%	52%	60%	63%	65%	62%	62%
Shift Optimizer	SHFTOPT	15%	27%	43%	58%	81%	84%	85%	82%	81%
Electric Power Steering	EPS	90%	91%	94%	95%	96%	96%	96%	96%	96%
Improved Accessories - Level 1	IACC1	82%	83%	83%	84%	87%	87%	88%	91%	93%
Improved Accessories - Level 2	IACC2	39%	44%	50%	56%	59%	61%	64%	67%	69%
12V Micro-Hybrid (Stop-Start)	MHEV	29%	30%	32%	29%	28%	28%	27%	25%	23%
Integrated Starter Generator	ISG	8%	10%	11%	15%	17%	18%	20%	24%	28%
Strong Hybrid - Level 1	SHEV1	3%	3%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	1%	1%	1%	1%	1%	3%	4%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	1%	2%	2%	3%	3%	3%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	66%	66%	68%	69%	69%	69%	69%	68%	68%
Mass Reduction - Level 2	MR2	31%	38%	49%	55%	58%	58%	62%	62%	63%
Mass Reduction - Level 3	MR3	15%	16%	19%	22%	24%	24%	27%	29%	33%
Mass Reduction - Level 4	MR4	9%	9%	12%	13%	15%	16%	17%	19%	23%
Mass Reduction - Level 5	MR5	3%	3%	5%	9%	11%	11%	12%	14%	17%
Low Rolling Resistance Tires - Level 1	ROLL1	96%	97%	99%	100 %	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	20%	30%	46%	58%	78%	85%	87%	90%	91%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	88%	89%	89%	89%	89%	89%	90%	90%	90%
Secondary Axle Disconnect	SAX	17%	17%	17%	16%	16%	16%	16%	15%	15%
Aero Drag Reduction, Level 1	AERO1	95%	98%	99%	100 %	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	52%	62%	76%	85%	90%	92%	93%	92%	92%

Max Net Benefits - Combined - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	99%	99%	99%	99%	98%	98%	98%
Engine Friction Reduction - Level 1	EFR1	76%	77%	76%	77%	77%	77%	77%	77%	76%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	4%	13%	18%	20%	22%	28%	34%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	19%	19%	18%	18%	18%	18%	18%	18%	18%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	17%	18%	17%	17%	17%	17%	17%	17%	17%
Cylinder Deactivation on SOHC	DEACS	6%	5%	3%	3%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2%	2%	2%	1%	1%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	60%	60%	59%	58%	58%	58%	58%	58%	58%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	28%	29%	29%	29%	29%	29%	29%	29%	29%
Continuously Variable Valve Lift (CVVL)	CVVL	21%	21%	20%	19%	20%	20%	20%	20%	20%
Cylinder Deactivation on DOHC	DEACD	5%	3%	1%	1%	1%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	65%	71%	77%	76%	78%	79%	80%	80%	80%
Cylinder Deactivation on OHV	DEACO	5%	4%	3%	1%	1%	1%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	7%	7%	7%	7%	7%	7%	7%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	4%	4%	6%	7%	7%	7%	8%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	33%	34%	37%	34%	33%	31%	25%	15%	13%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	23%	27%	28%	27%	25%	24%	22%	19%	14%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	7%	8%	8%	10%	9%	8%	7%	7%	4%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	0%	0%	1%	1%	1%	1%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	1%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	3%	3%	3%	5%	7%	9%	12%	22%	24%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	4%	5%	6%	9%	10%	12%	13%	17%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	3%	3%	3%	3%	5%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	1%	3%	4%	4%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	0%	0%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	2%	2%	4%	4%	4%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	2%	3%	3%	3%	3%	3%	3%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	1%	2%	2%	2%	2%	2%	2%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	2%	2%	3%	3%	3%	3%
Improved Auto. Trans. Controls/Externals	IATC	30%	27%	15%	6%	1%	1%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	38%	33%	20%	9%	2%	2%	0%	0%	0%
6-speed DCT	DCT	30%	25%	17%	9%	7%	5%	4%	2%	1%
8-Speed Trans (Auto or DCT)	8SPD	19%	24%	27%	27%	23%	17%	13%	9%	9%
High Efficiency Gearbox (Auto or DCT)	HETRANS	2%	8%	22%	31%	39%	42%	47%	51%	52%
Shift Optimizer	SHFTOPT	0%	0%	17%	35%	52%	60%	69%	73%	74%
Electric Power Steering	EPS	90%	94%	95%	96%	96%	96%	96%	96%	96%
Improved Accessories - Level 1	IACC1	72%	76%	86%	90%	93%	93%	93%	94%	94%
Improved Accessories - Level 2	IACC2	14%	18%	27%	29%	40%	44%	47%	51%	56%
12V Micro-Hybrid (Stop-Start)	MHEV	31%	31%	33%	35%	37%	36%	34%	35%	31%
Integrated Starter Generator	ISG	7%	9%	11%	12%	13%	16%	18%	20%	24%
Strong Hybrid - Level 1	SHEV1	2%	2%	1%	1%	1%	1%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	1%	1%	1%	1%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	1%	1%	1%	2%	2%	3%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	1%	1%	1%	1%	1%	2%	2%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	0%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	63%	65%	68%	72%	74%	73%	74%	74%	74%
Mass Reduction - Level 2	MR2	23%	31%	49%	53%	61%	61%	66%	67%	69%
Mass Reduction - Level 3	MR3	11%	12%	15%	18%	24%	24%	28%	30%	36%
Mass Reduction - Level 4	MR4	4%	5%	7%	11%	12%	13%	14%	16%	21%
Mass Reduction - Level 5	MR5	0%	1%	2%	4%	6%	8%	9%	9%	10%
Low Rolling Resistance Tires - Level 1	ROLL1	95%	97%	99%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	18%	34%	51%	60%	71%	83%	90%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	89%	90%	90%	90%	90%	90%	90%	90%	90%
Secondary Axle Disconnect	SAX	12%	13%	13%	14%	14%	14%	13%	13%	13%
Aero Drag Reduction, Level 1	AERO1	95%	97%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	45%	55%	70%	81%	87%	88%	89%	91%	94%

Total Cost = Total Benefits - Combined - 2008 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	85%	84%	84%	82%	82%	82%	82%	81%	80%
Engine Friction Reduction - Level 1	EFR1	86%	86%	86%	86%	86%	86%	85%	85%	84%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	17%	20%	29%	36%	55%	59%	65%	73%	74%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	12%	11%	11%	11%	11%	11%	11%	11%	11%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	12%	12%	12%	11%	11%	11%	11%	11%	11%
Cylinder Deactivation on SOHC	DEACS	2%	1%	1%	1%	0%	0%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2%	2%	3%	2%	2%	2%	2%	2%	2%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	66%	65%	65%	63%	64%	64%	64%	64%	63%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	49%	49%	49%	48%	48%	48%	48%	48%	48%
Continuously Variable Valve Lift (CVVL)	CVVL	14%	14%	14%	15%	15%	15%	15%	15%	15%
Cylinder Deactivation on DOHC	DEACD	2%	2%	1%	1%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	76%	77%	78%	76%	78%	79%	79%	79%	79%
Cylinder Deactivation on OHV	DEACO	1%	1%	0%	0%	0%	0%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	9%	10%	10%	9%	9%	8%	8%	8%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	9%	10%	10%	10%	9%	9%	9%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	33%	32%	31%	28%	21%	17%	14%	4%	2%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	33%	34%	31%	27%	23%	21%	17%	11%	9%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	9%	8%	8%	8%	8%	8%	6%	5%	5%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	2%	2%	2%	3%	4%	2%	2%	2%	2%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	1%	0%	0%	1%	2%	3%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	2%	2%	3%	5%	12%	17%	20%	28%	29%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	6%	6%	9%	11%	15%	17%	17%	20%	20%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	1%	1%	1%	1%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	1%	2%	2%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	1%	2%	2%	3%	4%	5%	4%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	1%	1%	2%	2%	3%	4%	4%	4%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	1%	1%	1%	1%	1%	1%	1%
Advanced Diesel - Medium Displacement	ADSL_MD	1%	1%	1%	2%	3%	3%	3%	3%	3%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	1%	0%	0%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	1%	2%	3%	5%	6%	6%	6%	6%	6%
Improved Auto. Trans. Controls/Externals	IATC	7%	3%	3%	0%	0%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	16%	9%	4%	1%	0%	0%	0%	0%	0%
6-speed DCT	DCT	29%	20%	10%	4%	1%	0%	0%	0%	0%
8-Speed Trans (Auto or DCT)	8SPD	34%	34%	29%	20%	9%	8%	7%	6%	5%
High Efficiency Gearbox (Auto or DCT)	HETRANS	8%	24%	39%	55%	62%	65%	66%	64%	62%
Shift Optimizer	SHFTOPT	15%	27%	45%	60%	81%	86%	84%	81%	78%
Electric Power Steering	EPS	90%	90%	93%	94%	96%	96%	96%	96%	96%
Improved Accessories - Level 1	IACC1	83%	85%	87%	89%	89%	89%	94%	96%	97%
Improved Accessories - Level 2	IACC2	39%	44%	52%	59%	66%	67%	72%	75%	77%
12V Micro-Hybrid (Stop-Start)	MHEV	33%	33%	38%	35%	36%	37%	36%	33%	30%
Integrated Starter Generator	ISG	12%	13%	15%	17%	19%	23%	23%	25%	27%
Strong Hybrid - Level 1	SHEV1	3%	3%	2%	2%	2%	2%	2%	2%	2%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	1%	1%
Strong Hybrid - Level 2	SHEV2	0%	0%	1%	1%	1%	1%	3%	5%	7%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	1%	2%	2%	3%	3%	3%	4%	4%	4%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	0%	1%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	66%	66%	68%	69%	69%	69%	69%	68%	68%
Mass Reduction - Level 2	MR2	31%	38%	50%	55%	58%	58%	62%	62%	63%
Mass Reduction - Level 3	MR3	15%	16%	18%	22%	25%	25%	27%	30%	34%
Mass Reduction - Level 4	MR4	10%	10%	12%	15%	15%	16%	17%	19%	23%
Mass Reduction - Level 5	MR5	4%	4%	4%	11%	12%	12%	13%	14%	18%
Low Rolling Resistance Tires - Level 1	ROLL1	96%	97%	98%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	20%	26%	42%	56%	78%	84%	87%	89%	91%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	88%	89%	89%	89%	89%	89%	90%	90%	90%
Secondary Axle Disconnect	SAX	17%	17%	17%	16%	16%	16%	16%	15%	15%
Aero Drag Reduction, Level 1	AERO1	95%	98%	99%	100%	100%	100%	100%	100%	100%
Aero Drag Reduction, Level 2	AERO2	52%	62%	76%	85%	90%	92%	93%	92%	92%

Total Cost = Total Benefits - Combined - 2010 Baseline										
Technology	**Abbr.**	**MY 2017**	**MY 2018**	**MY 2019**	**MY 2020**	**MY 2021**	**MY 2022**	**MY 2023**	**MY 2024**	**MY 2025**
Low Friction Lubricants - Level 1	LUB1	100%	100%	99%	99%	98%	98%	97%	97%	97%
Engine Friction Reduction - Level 1	EFR1	77%	77%	76%	77%	77%	77%	76%	76%	75%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	0%	0%	4%	12%	17%	17%	19%	26%	31%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	19%	19%	18%	18%	18%	18%	18%	18%	18%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	17%	18%	17%	17%	17%	17%	17%	17%	17%
Cylinder Deactivation on SOHC	DEACS	5%	4%	3%	3%	1%	1%	0%	0%	0%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	2%	2%	1%	1%	1%	1%	1%	1%	1%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	60%	60%	60%	57%	57%	57%	56%	56%	56%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	28%	29%	29%	29%	29%	29%	29%	29%	29%
Continuously Variable Valve Lift (CVVL)	CVVL	21%	21%	20%	20%	20%	20%	20%	20%	20%
Cylinder Deactivation on DOHC	DEACD	5%	4%	2%	2%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	65%	70%	75%	74%	77%	78%	78%	78%	78%
Cylinder Deactivation on OHV	DEACO	5%	4%	3%	2%	1%	1%	0%	0%	0%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	7%	7%	7%	7%	7%	7%	7%	7%	7%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	4%	4%	5%	7%	7%	7%	8%	8%	8%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) – Small Disp.	TRBDS1_SD	31%	32%	35%	33%	31%	27%	22%	12%	10%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Disp.	TRBDS1_MD	24%	26%	28%	26%	23%	22%	21%	16%	12%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Disp.	TRBDS1_LD	7%	8%	9%	10%	10%	10%	10%	10%	9%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Disp.	TRBDS2_SD	0%	1%	0%	1%	0%	0%	0%	0%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Disp.	TRBDS2_MD	0%	0%	0%	0%	0%	0%	0%	0%	1%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Disp.	TRBDS2_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 1 (24 bar BMEP) - Small Displacement	CEGR1_SD	4%	4%	4%	6%	9%	13%	16%	24%	25%

CEGR - Level 1 (24 bar BMEP) - Medium Displacement	CEGR1_MD	4%	4%	5%	6%	9%	10%	12%	15%	17%
CEGR - Level 1 (24 bar BMEP) - Large Displacement	CEGR1_LD	0%	0%	0%	0%	0%	0%	0%	0%	1%
CEGR - Level 2 (27 bar BMEP) - Small Displacement	CEGR2_SD	0%	0%	0%	0%	0%	0%	0%	0%	0%
CEGR - Level 2 (27 bar BMEP) - Medium Displacement	CEGR2_MD	0%	0%	0%	0%	1%	1%	1%	1%	1%
CEGR - Level 2 (27 bar BMEP) - Large Displacement	CEGR2_LD	0%	0%	0%	1%	2%	2%	3%	3%	3%
Advanced Diesel - Small Displacement	ADSL_SD	0%	0%	2%	3%	3%	3%	3%	3%	3%
Advanced Diesel - Medium Displacement	ADSL_MD	0%	0%	1%	2%	2%	2%	2%	2%	2%
Advanced Diesel - Large Displacement	ADSL_LD	0%	0%	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	6MAN	3%	3%	2%	1%	1%	1%	0%	0%	0%
High Efficiency Gearbox (Manual)	HETRANSM	0%	0%	1%	2%	2%	3%	3%	3%	3%
Improved Auto. Trans. Controls/Externals	IATC	30%	26%	14%	5%	1%	0%	0%	0%	0%
6-Speed Trans with Improved Internals (Auto)	NAUTO	37%	31%	18%	8%	2%	1%	0%	0%	0%
6-speed DCT	DCT	33%	27%	19%	9%	4%	3%	2%	1%	0%
8-Speed Trans (Auto or DCT)	8SPD	19%	25%	25%	25%	18%	11%	7%	4%	4%
High Efficiency Gearbox (Auto or DCT)	HETRANS	1%	8%	25%	37%	42%	43%	48%	49%	48%
Shift Optimizer	SHFTOPT	0%	0%	19%	37%	58%	69%	75%	81%	81%
Electric Power Steering	EPS	90%	94%	94%	96%	96%	96%	96%	96%	96%
Improved Accessories - Level 1	IACC1	78%	83%	90%	93%	94%	95%	96%	96%	96%
Improved Accessories - Level 2	IACC2	18%	26%	35%	39%	48%	52%	55%	58%	62%
12V Micro-Hybrid (Stop-Start)	MHEV	33%	33%	39%	40%	39%	39%	36%	32%	30%
Integrated Starter Generator	ISG	8%	9%	11%	14%	17%	20%	22%	24%	25%
Strong Hybrid - Level 1	SHEV1	2%	2%	1%	1%	1%	1%	1%	1%	1%
Conversion from SHEV1 to SHEV2	SHEV1_2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid - Level 2	SHEV2	0%	0%	0%	0%	1%	1%	3%	6%	8%
Plug-in Hybrid - 30 mi range	PHEV1	0%	0%	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	PHEV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 75 mile range	EV1	0%	0%	1%	1%	1%	1%	2%	2%	3%
Electric Vehicle (Early Adopter) - 100 mile range	EV2	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Early Adopter) - 150 mile range	EV3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Electric Vehicle (Broad Market) - 150 mile range	EV4	0%	0%	0%	0%	0%	0%	0%	1%	1%

Fuel Cell Vehicle	FCV	0%	0%	0%	0%	0%	0%	0%	0%	0%
Mass Reduction - Level 1	MR1	64%	65%	68%	72%	74%	74%	74%	74%	74%
Mass Reduction - Level 2	MR2	23%	33%	51%	57%	63%	64%	66%	67%	68%
Mass Reduction - Level 3	MR3	11%	12%	15%	19%	23%	23%	27%	30%	35%
Mass Reduction - Level 4	MR4	4%	5%	6%	11%	11%	12%	15%	17%	23%
Mass Reduction - Level 5	MR5	0%	0%	1%	4%	5%	7%	9%	10%	13%
Low Rolling Resistance Tires - Level 1	ROLL1	95%	97%	98%	100 %	100 %	100 %	100 %	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	0%	0%	17%	36%	46%	55%	66%	81%	86%
Low Rolling Resistance Tires - Level 3	ROLL3	0%	0%	0%	0%	0%	0%	0%	0%	0%
Low Drag Brakes	LDB	89%	90%	90%	90%	90%	90%	90%	90%	90%
Secondary Axle Disconnect	SAX	13%	13%	14%	14%	14%	14%	14%	13%	13%
Aero Drag Reduction, Level 1	AERO1	95%	97%	99%	99%	100 %	100 %	100 %	100%	100%
Aero Drag Reduction, Level 2	AERO2	45%	55%	70%	81%	87%	88%	89%	91%	94%

VI. MANUFACTURER CAFE CAPABILITIES

Table VI-1 shows the agencies' forecast of where the manufacturers' passenger car mpg would be, based on the MY 2008 and MY 2010 baseline vehicles extended into the future with no fuel economy improvements based on application of additional technology. These mpg estimates change for some of the model years, but usually to a minimal extent, and only based on changes in sales forecasts between passenger cars and light trucks.

Table VI-2 shows the **ADJUSTED BASELINES** for passenger cars. Note that when we do cost and benefit analyses, we use the **ADJUSTED BASELINES** throughout the analysis. The adjusted baseline takes each manufacturer's MY 2008 and 2010 fleet and adds fuel economy-improving technologies to each, making both meet the MY 2016 fuel economy standard. The adjusted baselines assume for the analysis that each manufacturer below the MY 2016 standard applicable to that manufacturer in MY 2008 or MY 2010 (except for manufacturers that have historically paid fines for not fully complying with standards, which include Aston Martin, BMW, Daimler, Geely (Volvo), Lotus, Porsche, Spyker, Tata (Jaguar Land Rover), and Volkswagen) would apply technology to achieve the MY 2016 standard. We adjust the baseline because we believe that doing so is appropriate since the costs and benefits of achieving MY 2016 mpg levels have already been analyzed and estimated in the previous analysis used to establish CAFE standards for MYs 2012-2016. The costs of these technologies are therefore not considered part of this rule, and we estimate the costs and benefits of going from the adjusted baseline to the level of the alternatives.[349]

The estimated required standard levels are shown in Table VI-3 for passenger cars for the preferred alternative. The estimated average required mpg levels for cars and trucks under the standards include the expected performance of the manufacturer's fleet based on calculations using the 2-cycle test and also the use of A/C efficiency improvements, but do not reflect a number of flexibilities and credits that manufacturers could use for compliance that NHTSA cannot consider in establishing standards based on EPCA/EISA constraints. The flexibilities and credits that NHTSA cannot consider include the ability of manufacturers to pay civil penalties rather than achieving required CAFE levels, the ability to use statutory FFV credits, the ability to count electric vehicles for compliance, the operation of plug-in hybrid electric vehicles on electricity for compliance prior to MY 2020, and the ability to transfer and carry-forward credits. Table VI-4 provides the estimated achieved mpg levels for passenger cars for each of the alternatives. The estimated average achieved mpg levels do reflect the accounting for the

[349] If a manufacturer's MY 2008 or MY 2010 fleet extended mpg levels are above those of the alternative, its mpg is assumed to remain at that level. Some manufacturers' levels go slightly above the required mpg level since some technologies are applied to all models of a particular manufacturer so that the exact level for each manufacturer may be slightly higher than the level of the standard and costs and benefits are estimated to that level.

flexibilities and credits mentioned above, and are based on the projections of what each manufacturer's fleet will comprise in each year of the program. Tables VI-5 through VI-8 provide the same tables for light trucks as Tables VI-1 through VI-4 show for passenger cars.

Note that not all manufacturers are assumed to attempt to "meet" the alternatives for purposes of this analysis. EPCA/EISA allows manufacturers to pay civil penalties for non-compliance; essentially, to pay civil penalties *instead of* complying with the CAFE standards. Some manufacturers have historically chosen to do this instead of applying technology to improve their fuel economy, whether because civil penalties are cheaper for them than improving fuel economy, or because they would rather invest their money in other vehicle attributes that they believe their customers value more highly than fuel economy, or for some other reason. Other manufacturers may have found it more cost-effective to pay civil penalties than to apply technology, but may have chosen to apply technology anyway for other reasons – the Detroit 3 manufacturers, for example, have historically avoided paying civil penalties. We assume that Aston Martin, BMW, Daimler, Geely, Lotus, Porsche, Spyker, Tata, and Volkswagen would not meet these levels because these manufacturers have shown, in the past, willingness to pay penalties rather than spend more money to apply technologies to improve the fuel economy of their products. Because NHTSA is attempting to analyze the impacts of the CAFE standards, and because the EPCA/EISA provision allowing payment of civil penalties continues indefinitely into the future, we are assuming for purposes of this analysis that these manufacturers will continue to pay civil penalties when the cost of doing so becomes cheaper than applying additional fuel economy-improving technology.

The agency has performed an analysis of how manufacturers could respond to changes in the alternative CAFE levels. The analysis uses a technology application algorithm to systematically apply consistent cost and performance assumptions to the entire industry, as well as consistent assumptions regarding economic decision-making by manufacturers. The resulting computer model (the CAFE Compliance and Effects Model, often referred to as the "CAFE Model" or the "Volpe model"), developed by technical staff of the DOT Volpe National Transportation Systems Center in consultation with NHTSA staff, is used to help estimate the overall economic impact of the alternative CAFE standards. The CAFE model analysis shows the economic impact of the standards in terms of increases in new vehicle prices on a manufacturer-wide, industry-wide, and average per-vehicle basis. Based on these estimates and corresponding estimates of net economic and other benefits, the agency is able to consider alternatives that are economically practicable and technologically feasible.

We note that, as explained above in Chapter V, the CAFE model has been updated to account for manufacturers' ability to apply "multi-year planning" in order to minimize compliance burdens over multiple model years, and to account for manufacturers' use of CAFE credits (when specified as a model input). The model has been peer reviewed. The model documentation, including a description of the input assumptions and process, as well as peer review reports, was made available in the rulemaking docket for the August 2005 NPRM, and updated documentation is also available on NHTSA's website.[350]

Our analyses of the potential effects of alternative CAFE standards were founded on two major elements: (1) projections of the technical characteristics and sales volumes of future product offerings and (2) estimates of the applicability and incremental cost and fuel savings associated with different hardware changes—technologies—that might be utilized in response to alternative CAFE standards.

[350] *See* Docket Nos. NHTSA-2005-22223-0003, NHTSA-2005-22223-0004 and NHTSA-2005-22223-0005, as well as NHTSA's website at http://www.nhtsa.gov/Laws+&+Regulations/CAFE+-+Fuel+Economy/CAFE+Compliance+and+Effects+Modeling+System:+The+Volpe+Model.

Table VI-1
Estimated Fuel Economy (mpg), Without CAFE Standards
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	19.0 - 18.8	19.0 - 18.8	19.0 - 18.8	19.0 - 18.8	19.0 - 18.8	19.0 - 18.8	19.0 - 18.8	19.0 - 18.8	19.0 - 18.8
BMW	2010 2008	27.5 - 27.2	27.4 - 27.2	27.4 - 27.2	27.3 - 27.2	27.3 - 27.2	27.3 - 27.2	27.3 - 27.2	27.3 - 27.2	27.3 - 27.2
Daimler	2010 2008	24.7 - 25.1	24.7 - 25.0	24.8 - 24.9	24.8 - 25.0	24.8 - 25.1	24.8 - 25.1	24.8 - 25.1	24.9 - 24.9	24.9 - 25.0
Fiat	2010 2008	28.2 - 28.2	28.1 - 28.2	28.1 - 28.3	28.1 - 28.2	28.1 - 28.3	28.1 - 28.4	28.1 - 28.4	28.2 - 28.5	28.2 - 28.5
Ford	2010 2008	30.2 - 28.0	30.2 - 28.0	30.2 - 28.0	30.3 - 28.0	30.3 - 28.0	30.3 - 28.0	30.3 - 28.0	30.3 - 28.0	30.3 - 28.0
Geely	2010 2008	28.2 - 26.0	28.1 - 26.0	28.1 - 26.0	28.0 - 26.1	28.0 - 26.1	28.0 - 26.1	28.0 - 26.1	27.9 - 26.1	27.9 - 26.1
General Motors	2010 2008	30.4 - 28.5	30.3 - 28.4	30.3 - 28.4	30.2 - 28.5	30.2 - 28.6	30.2 - 28.6	30.2 - 28.6	30.2 - 28.6	30.1 - 28.6
Honda	2010 2008	34.6 - 34.2	34.7 - 34.3	34.5 - 34.4	34.5 - 34.4	34.5 - 34.4	34.5 - 34.4	34.5 - 34.4	34.5 - 34.4	34.5 - 34.4
Hyundai	2010 2008	33.0 - 31.4	33.0 - 31.4	33.0 - 31.4	33.0 - 31.5	33.0 - 31.5	33.1 - 31.5	33.1 - 31.5	33.1 - 31.5	33.1 - 31.6
Kia	2010 2008	35.2 - 31.8	35.2 - 31.9	35.2 - 31.9	35.2 - 32.0	35.2 - 32.0	35.2 - 32.1	35.2 - 32.0	35.3 - 32.1	35.3 - 32.1
Lotus	2010 2008	26.7 - 29.7	26.7 - 29.7	26.7 - 29.7	26.7 - 29.7	26.7 - 29.7	26.7 - 29.7	26.7 - 29.7	26.7 - 29.7	26.7 - 29.7
Mazda	2010 2008	31.9 - 31.4	31.9 - 31.4	31.9 - 31.4	31.9 - 31.5	31.9 - 31.6	31.9 - 31.6	31.9 - 31.7	31.9 - 31.6	31.9 - 31.6
Mitsubishi	2010 2008	32.4 - 28.0	32.3 - 28.0	32.3 - 28.1	32.4 - 28.1	32.4 - 28.2	32.4 - 28.2	32.4 - 28.2	32.4 - 28.2	32.4 - 28.3
Nissan	2010 2008	32.6 - 31.6	32.6 - 31.6	32.5 - 31.6	32.5 - 31.6	32.4 - 31.6	32.4 - 31.5	32.4 - 31.5	32.4 - 31.5	32.4 - 31.5
Porsche	2010 2008	25.4 - 26.2	25.4 - 26.2	25.4 - 26.2	25.4 - 26.2	25.3 - 26.2	25.3 - 26.2	25.3 - 26.2	25.3 - 26.2	25.3 - 26.2

Spyker	2010 2008	- - 26.6	- - 26.6	- - 26.6	- - 26.6	- - 26.6	- - 26.6	- - 26.6	- - 26.6	- - 26.6
Subaru	2010 2008	29.7 - 29.5	29.7 - 29.5	29.8 - 29.5	29.8 - 29.5	29.8 - 29.5	29.9 - 29.5	29.9 - 29.5	29.9 - 29.5	29.9 - 29.5
Suzuki	2010 2008	33.1 - 30.7	33.1 - 30.8	33.0 - 30.8	33.0 - 30.8	33.0 - 30.8	33.0 - 30.8	33.0 - 30.8	33.0 - 30.8	33.0 - 30.8
Tata	2010 2008	23.3 - 24.6	23.3 - 24.6	23.3 - 24.6	23.4 - 24.6	23.4 - 24.6	23.4 - 24.6	23.4 - 24.6	23.4 - 24.6	23.4 - 24.6
Tesla	2010 2008	- - 244.0	- - 244.0	- - 244.0	- - 244.0	- - 244.0	- - 244.0	- - 244.0	- - 244.0	- - 244.0
Toyota	2010 2008	35.4 - 35.2	35.5 - 35.2	35.3 - 35.3	35.3 - 35.3	35.3 - 35.3	35.3 - 35.4	35.3 - 35.4	35.3 - 35.4	35.3 - 35.4
Volkswagen	2010 2008	31.9 - 28.9	31.9 - 28.9	31.9 - 28.9	31.9 - 28.9	31.9 - 28.9	31.9 - 28.9	31.9 - 28.9	31.9 - 28.9	31.9 - 28.9
Total/Average	2010 2008	31.6 - 30.6	31.6 - 30.6	31.5 - 30.6	31.5 - 30.6	31.5 - 30.6	31.5 - 30.6	31.5 - 30.6	31.5 - 30.6	31.5 - 30.7

Table VI-2
Estimated Fuel Economy (mpg), Adjusted Baseline
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.6 - 28.7	25.6 - 28.7	25.6 - 28.7	25.6 - 28.7	27.6 - 31.0	27.6 - 31.0	30.6 - 31.1	33.6 - 31.1	34.5 - 31.1
BMW	2010 2008	32.9 - 33.5	36.7 - 37.7	37.4 - 37.9	37.5 - 37.9	37.6 - 37.9	37.8 - 37.9	37.9 - 38.0	37.9 - 38.0	37.8 - 38.0
Daimler	2010 2008	33.5 - 35.5	33.6 - 35.8	34.7 - 36.4	36.1 - 36.5	36.2 - 36.6	36.3 - 36.7	36.3 - 37.1	36.4 - 36.9	36.4 - 36.9
Fiat	2010 2008	36.7 - 37.1	37.0 - 37.1	37.2 - 37.1	37.4 - 37.3	37.5 - 37.7	37.5 - 37.8	37.5 - 37.9	37.5 - 37.9	37.5 - 37.9
Ford	2010 2008	37.3 - 36.9	37.3 - 36.9	37.5 - 37.0	38.0 - 37.5	38.1 - 37.7	38.1 - 37.7	38.1 - 37.7	38.2 - 37.6	38.2 - 37.6
Geely	2010 2008	37.1 - 35.4	37.7 - 36.9	37.6 - 37.3	37.5 - 37.3	37.5 - 37.5	37.4 - 37.5	37.4 - 37.5	37.3 - 37.5	37.3 - 37.5
General Motors	2010 2008	37.1 - 37.5	37.7 - 37.7	37.7 - 37.7	37.8 - 37.9	37.8 - 38.3	37.9 - 38.3	37.8 - 38.3	37.9 - 38.3	37.9 - 38.4
Honda	2010 2008	37.1 - 37.1	37.6 - 38.2	38.1 - 38.9	38.1 - 39.0	38.6 - 39.0	38.7 - 39.0	38.7 - 39.0	38.7 - 39.0	38.7 - 39.1
Hyundai	2010 2008	37.8 - 38.2	38.2 - 38.2	38.2 - 38.8	38.3 - 38.9	38.4 - 39.0	38.4 - 39.0	38.5 - 39.0	38.5 - 39.0	38.5 - 39.0
Kia	2010 2008	38.1 - 38.2	39.1 - 39.3	39.1 - 39.6	39.4 - 39.7	39.5 - 39.7	39.5 - 39.8	39.5 - 39.8	39.5 - 39.8	39.5 - 39.9
Lotus	2010 2008	33.1 - 37.0	33.1 - 37.0	35.5 - 39.6	35.5 - 39.6	35.5 - 39.6	35.5 - 39.6	39.3 - 41.5	39.3 - 41.5	39.3 - 41.5
Mazda	2010 2008	38.2 - 39.2	38.2 - 39.5	38.2 - 39.6	38.3 - 40.0	38.2 - 40.1	38.4 - 40.1	38.4 - 40.2	38.4 - 40.2	38.5 - 40.2
Mitsubishi	2010 2008	40.1 - 38.2	40.1 - 38.3	40.1 - 38.4	40.1 - 38.5	40.3 - 39.1	40.3 - 39.1	40.4 - 39.1	40.4 - 39.1	40.4 - 39.1
Nissan	2010 2008	37.0 - 37.3	37.1 - 37.6	37.8 - 38.2	38.1 - 38.3	38.1 - 38.3	38.1 - 38.3	38.1 - 38.3	38.1 - 38.3	38.1 - 38.3
Porsche	2010 2008	33.3 - 34.3	34.8 - 35.3	36.5 - 35.3	36.5 - 35.4	36.5 - 37.0	36.5 - 40.0	36.5 - 40.0	36.5 - 41.4	36.4 - 41.4

Spyker	2010 2008	- - 36.3	- - 38.1	- - 39.6	- - 39.6	- - 39.6	- - 39.6	- - 39.6	- - 39.6	- - 39.6
Subaru	2010 2008	39.4 - 40.1	39.3 - 40.2	39.4 - 40.2	39.4 - 41.6	39.4 - 41.6	39.5 - 41.6	39.5 - 41.6	39.5 - 41.6	39.5 - 41.5
Suzuki	2010 2008	39.8 - 40.1	39.8 - 40.2	40.3 - 41.8	40.6 - 42.0	40.8 - 42.0	40.8 - 42.1	40.8 - 42.1	40.8 - 42.1	40.8 - 42.1
Tata	2010 2008	30.3 - 35.0	34.5 - 35.4	34.3 - 35.4	36.2 - 35.5	36.9 - 35.6	36.9 - 35.6	36.9 - 35.6	37.0 - 35.6	37.0 - 35.6
Tesla	2010 2008	- - 281.2	- - 281.2	- - 281.2	- - 281.2	- - 281.2	- - 281.2	- - 281.2	- - 281.2	- - 281.2
Toyota	2010 2008	37.9 - 38.3	38.4 - 38.4	38.2 - 38.7	38.4 - 39.1	38.3 - 39.2	38.4 - 39.2	38.4 - 39.2	38.4 - 39.3	38.4 - 39.3
Volkswagen	2010 2008	38.0 - 37.8	38.6 - 38.6	38.8 - 39.6	39.0 - 39.9	39.0 - 39.9	39.0 - 39.9	39.0 - 39.9	39.1 - 39.8	39.1 - 39.9
Total/Average	2010 2008	37.2 - 37.5	37.7 - 38.0	37.9 - 38.3	38.1 - 38.6	38.2 - 38.7	38.2 - 38.8	38.2 - 38.8	38.2 - 38.8	38.2 - 38.8

Table VI-3
Estimated Required Fuel Economy Levels for Preferred Alternative
Estimated mpg
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	38.8 - 40.5	40.2 - 41.9	41.6 - 43.5	43.3 - 45.2	45.1 - 47.2	47.3 - 49.4	49.5 - 51.7	51.8 - 54.1	54.2 - 56.6
BMW	2010 2008	39.4 - 39.4	40.8 - 40.9	42.3 - 42.4	43.9 - 44.1	45.8 - 46.0	47.9 - 48.1	50.1 - 50.4	52.5 - 52.7	55.0 - 55.2
Daimler	2010 2008	38.0 - 38.6	39.4 - 39.9	40.9 - 41.4	42.5 - 43.0	44.3 - 44.9	46.4 - 47.0	48.5 - 49.2	50.9 - 51.4	53.2 - 53.9
Fiat	2010 2008	38.7 - 39.1	39.9 - 40.6	41.4 - 42.1	43.0 - 43.7	44.9 - 45.7	47.0 - 47.9	49.2 - 50.2	51.6 - 52.6	54.0 - 55.1
Ford	2010 2008	39.5 - 39.1	41.0 - 40.6	42.5 - 42.1	44.1 - 43.7	46.0 - 45.6	48.2 - 47.7	50.4 - 49.9	52.8 - 52.3	55.3 - 54.7
Geely	2010 2008	40.1 - 38.8	41.5 - 40.3	43.0 - 41.7	44.7 - 43.4	46.6 - 45.3	48.7 - 47.4	50.9 - 49.6	53.3 - 51.9	55.8 - 54.4
General Motors	2010 2008	39.3 - 39.6	40.8 - 41.1	42.2 - 42.6	43.9 - 44.3	45.7 - 46.2	47.9 - 48.4	50.1 - 50.7	52.5 - 53.1	54.9 - 55.6
Honda	2010 2008	39.7 - 40.4	41.1 - 41.9	42.6 - 43.4	44.2 - 45.2	46.1 - 47.1	48.3 - 49.3	50.5 - 51.6	52.9 - 54.0	55.4 - 56.6
Hyundai	2010 2008	39.8 - 40.4	41.3 - 41.9	42.7 - 43.4	44.5 - 45.2	46.4 - 47.1	48.6 - 49.3	50.8 - 51.6	53.2 - 54.1	55.7 - 56.6
Kia	2010 2008	40.8 - 41.1	42.3 - 42.6	43.8 - 44.2	45.6 - 46.0	47.5 - 48.0	49.8 - 50.3	52.1 - 52.6	54.5 - 55.1	57.1 - 57.7
Lotus	2010 2008	41.8 - 43.6	43.3 - 45.2	44.9 - 46.9	46.7 - 48.7	48.7 - 50.8	51.0 - 53.2	53.4 - 55.7	55.9 - 58.3	58.5 - 61.1
Mazda	2010 2008	40.1 - 41.5	41.6 - 43.0	43.0 - 44.5	44.7 - 46.3	46.6 - 48.3	48.8 - 50.6	51.1 - 53.0	53.5 - 55.5	56.0 - 58.1
Mitsubishi	2010 2008	41.8 - 40.5	43.3 - 42.0	44.9 - 43.6	46.7 - 45.3	48.7 - 47.3	51.0 - 49.5	53.4 - 51.8	55.9 - 54.2	58.6 - 56.8
Nissan	2010 2008	39.6 - 39.8	41.0 - 41.2	42.5 - 42.8	44.2 - 44.4	46.0 - 46.3	48.2 - 48.5	50.4 - 50.7	52.8 - 53.1	55.2 - 55.6
Porsche	2010 2008	39.1 - 43.6	40.5 - 45.2	42.0 - 46.9	43.6 - 48.7	45.4 - 50.8	47.5 - 53.2	49.7 - 55.7	52.1 - 58.3	54.5 - 61.1

Spyker	2010 2008	- - 41.1	- - 42.6	- - 44.2	- - 46.0	- - 47.9	- - 50.2	- - 52.5	- - 55.0	- - 57.6
Subaru	2010 2008	41.1 - 42.6	42.6 - 44.2	44.1 - 45.8	45.8 - 47.6	47.7 - 49.7	49.9 - 52.0	52.2 - 54.4	54.7 - 57.0	57.2 - 59.6
Suzuki	2010 2008	42.1 - 43.3	43.6 - 44.9	45.2 - 46.5	46.9 - 48.4	48.9 - 50.5	51.2 - 52.8	53.6 - 55.3	56.1 - 57.9	58.7 - 60.6
Tata	2010 2008	37.4 - 36.9	38.8 - 38.3	40.4 - 39.7	41.9 - 41.2	43.8 - 43.0	45.9 - 45.0	48.0 - 47.1	50.3 - 49.3	52.7 - 51.7
Tesla	2010 2008	- - 43.6	- - 45.2	- - 46.9	- - 48.7	- - 50.8	- - 53.2	- - 55.7	- - 58.3	- - 61.1
Toyota	2010 2008	39.7 - 40.6	41.2 - 42.1	42.7 - 43.7	44.3 - 45.4	46.2 - 47.4	48.4 - 49.6	50.7 - 51.9	53.0 - 54.3	55.5 - 56.9
Volkswagen	2010 2008	40.5 - 41.4	41.9 - 43.0	43.5 - 44.5	45.2 - 46.3	47.1 - 48.3	49.3 - 50.6	51.6 - 52.9	54.1 - 55.4	56.6 - 58.0
Total/Average	2010 2008	39.6 - 40.1	41.1 - 41.6	42.5 - 43.1	44.2 - 44.8	46.1 - 46.8	48.2 - 49.0	50.5 - 51.2	52.9 - 53.6	55.3 - 56.2

Table VI-4
Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
Preferred Alternative

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.5	38.0 - 39.5	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 39.0	36.4 - 39.4	37.8 - 40.6	40.9 - 42.9	41.0 - 42.7	43.1 - 45.7
Fiat	2010 2008	38.6 - 38.9	39.4 - 41.3	42.3 - 41.6	44.8 - 46.4	47.7 - 47.1	48.0 - 48.1	50.3 - 51.1	51.6 - 51.6	51.6 - 53.7
Ford	2010 2008	39.8 - 39.4	39.9 - 39.7	42.1 - 42.2	46.1 - 45.0	47.2 - 47.2	48.7 - 49.5	49.4 - 50.0	51.3 - 49.9	52.4 - 54.1
Geely	2010 2008	37.2 - 36.4	38.9 - 39.4	43.5 - 42.2	44.4 - 42.3	44.7 - 43.5	44.7 - 43.5	45.7 - 44.4	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	39.6 - 38.9	42.5 - 42.5	43.1 - 43.8	45.6 - 47.8	47.2 - 49.3	47.2 - 49.3	50.3 - 50.5	51.2 - 50.7	52.8 - 51.4
Honda	2010 2008	39.0 - 40.0	43.3 - 44.1	44.5 - 46.3	44.6 - 46.8	48.4 - 50.5	48.9 - 51.9	52.2 - 53.3	53.1 - 54.1	53.1 - 54.2
Hyundai	2010 2008	41.6 - 41.6	42.3 - 42.1	44.9 - 47.7	44.9 - 48.2	48.2 - 50.2	50.7 - 52.2	51.5 - 52.7	53.0 - 52.7	53.7 - 52.8
Kia	2010 2008	40.7 - 40.6	41.6 - 40.9	45.2 - 44.6	48.0 - 50.0	49.3 - 50.4	52.3 - 51.8	52.9 - 52.3	52.9 - 52.3	52.9 - 55.7
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	42.0 - 41.8	42.7 - 43.7	43.3 - 43.8	47.2 - 47.5	47.3 - 47.5	51.1 - 52.8	52.6 - 53.0	52.9 - 53.3	52.9 - 53.8
Mitsubishi	2010 2008	42.5 - 39.4	43.1 - 41.1	43.1 - 41.2	48.0 - 45.8	54.1 - 51.6	54.6 - 51.7	54.6 - 51.7	55.0 - 53.7	55.1 - 53.7
Nissan	2010 2008	40.6 - 38.9	41.7 - 40.6	45.5 - 45.6	45.8 - 46.7	47.0 - 47.3	48.6 - 50.3	49.4 - 51.2	52.5 - 53.7	53.2 - 54.0

Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5
Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	39.6 - 41.8	39.6 - 43.1	43.0 - 44.0	49.4 - 50.0	49.5 - 50.0	49.5 - 50.0	50.1 - 50.0	54.5 - 50.4	57.2 - 60.6
Suzuki	2010 2008	44.3 - 41.9	44.3 - 42.0	47.5 - 50.3	48.4 - 51.2	50.5 - 52.7	51.9 - 53.7	52.9 - 53.7	52.9 - 54.4	57.2 - 58.2
Tata	2010 2008	30.3 - 36.4	34.5 - 39.3	34.4 - 39.3	36.3 - 40.5	37.1 - 41.1	37.1 - 42.4	38.7 - 43.1	38.7 - 43.1	39.3 - 43.4
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	40.1 - 40.9	41.4 - 42.9	45.8 - 45.3	46.6 - 47.6	49.6 - 49.4	50.1 - 50.1	50.1 - 50.1	53.0 - 54.9	53.0 - 55.0
Volkswagen	2010 2008	38.8 - 37.9	41.7 - 38.7	42.3 - 40.1	44.2 - 44.1	45.1 - 44.8	45.7 - 45.6	46.0 - 46.1	47.9 - 46.4	50.2 - 48.4
Total/Average	2010 2008	39.4 - 39.5	41.1 - 41.5	43.3 - 43.8	45.1 - 46.3	47.1 - 47.9	48.1 - 49.3	49.6 - 50.0	51.3 - 51.5	52.1 - 52.9

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
2% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.5	38.0 - 39.5	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 45.6	44.2 - 45.6
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 39.0	36.4 - 39.4	37.8 - 40.6	40.9 - 42.9	40.9 - 42.7	43.0 - 44.2
Fiat	2010 2008	38.4 - 38.2	38.6 - 40.0	39.7 - 40.1	41.6 - 42.7	42.4 - 42.9	42.5 - 43.2	43.6 - 44.6	43.8 - 44.8	43.9 - 44.8
Ford	2010 2008	38.5 - 38.7	38.6 - 38.8	40.1 - 40.2	43.3 - 42.1	43.7 - 43.1	44.6 - 43.6	44.8 - 43.7	45.4 - 44.0	45.4 - 44.0
Geely	2010 2008	37.2 - 36.4	38.9 - 39.0	43.0 - 41.4	43.6 - 41.6	43.7 - 42.2	43.7 - 42.2	44.7 - 43.6	46.0 - 44.9	46.4 - 45.0
General Motors	2010 2008	37.1 - 38.5	38.9 - 40.0	39.1 - 40.7	40.9 - 42.1	42.7 - 43.0	42.9 - 43.2	43.3 - 45.0	43.4 - 45.6	43.6 - 46.3
Honda	2010 2008	38.3 - 39.1	41.0 - 41.7	41.6 - 42.2	41.8 - 42.4	42.0 - 43.9	42.5 - 44.2	44.9 - 45.5	45.2 - 46.1	45.4 - 46.5
Hyundai	2010 2008	39.4 - 40.5	40.0 - 41.0	40.4 - 43.1	40.8 - 43.2	43.2 - 44.4	43.8 - 45.8	44.3 - 46.2	45.7 - 47.5	45.8 - 47.6
Kia	2010 2008	40.1 - 39.9	41.2 - 40.9	42.6 - 41.7	44.0 - 43.4	44.4 - 45.1	44.8 - 45.8	45.2 - 46.8	45.3 - 46.9	47.2 - 46.9
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	40.7 - 39.8	41.0 - 41.5	41.1 - 42.0	42.4 - 44.7	42.6 - 44.7	44.7 - 46.7	45.2 - 46.8	45.3 - 46.7	45.3 - 46.7
Mitsubishi	2010 2008	41.2 - 39.3	41.5 - 39.6	41.5 - 39.7	44.1 - 41.0	46.5 - 44.7	46.8 - 44.8	46.8 - 44.8	47.3 - 45.1	47.4 - 45.3
Nissan	2010 2008	38.7 - 38.6	39.1 - 39.6	42.1 - 42.4	43.1 - 43.0	43.1 - 43.2	43.4 - 43.6	43.9 - 43.9	47.1 - 46.3	47.1 - 46.7
Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5

Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 46.7	- - 46.7
Subaru	2010 2008	39.5 - 41.8	39.4 - 42.2	41.4 - 46.4	45.3 - 46.8	45.3 - 46.6	45.7 - 46.5	45.8 - 46.4	46.2 - 46.6	46.2 - 47.3
Suzuki	2010 2008	42.4 - 41.2	42.4 - 41.4	43.8 - 46.3	44.4 - 46.6	45.6 - 47.3	46.9 - 47.7	47.0 - 47.7	47.0 - 48.0	48.3 - 49.8
Tata	2010 2008	30.3 - 36.1	34.5 - 38.8	34.4 - 38.8	36.3 - 39.1	37.1 - 39.7	37.1 - 41.3	38.7 - 42.0	38.7 - 42.0	39.3 - 42.3
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	39.0 - 39.5	40.0 - 40.8	41.8 - 42.2	42.2 - 43.6	43.5 - 44.4	43.8 - 45.1	43.8 - 45.1	45.3 - 46.5	45.4 - 46.8
Volkswagen	2010 2008	38.6 - 37.9	41.3 - 38.7	41.9 - 40.1	43.3 - 43.7	43.8 - 44.3	44.2 - 45.0	44.7 - 45.5	45.7 - 45.6	46.9 - 46.2
Total/Average	2010 2008	38.2 - 38.8	39.4 - 40.1	40.5 - 41.4	41.8 - 42.7	42.8 - 43.6	43.3 - 44.2	44.0 - 44.9	44.9 - 45.8	45.2 - 46.2

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
3% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.5	38.0 - 39.5	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 39.0	36.4 - 39.4	37.8 - 40.6	40.9 - 42.9	40.9 - 42.7	43.0 - 45.7
Fiat	2010 2008	38.7 - 38.8	39.1 - 40.9	41.3 - 41.0	43.8 - 45.5	45.0 - 46.0	45.2 - 46.4	46.8 - 47.6	47.7 - 47.8	47.7 - 47.8
Ford	2010 2008	40.1 - 39.1	40.3 - 40.0	42.3 - 41.8	45.3 - 43.9	45.8 - 45.0	46.6 - 46.4	46.8 - 47.0	47.5 - 47.6	50.4 - 48.5
Geely	2010 2008	37.2 - 36.4	39.0 - 39.2	42.9 - 41.7	43.6 - 41.8	44.9 - 43.4	44.9 - 43.4	45.7 - 44.3	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	37.6 - 38.9	39.7 - 42.1	40.1 - 42.9	43.9 - 46.1	45.6 - 47.4	45.6 - 47.5	46.7 - 47.7	47.3 - 48.5	47.6 - 48.5
Honda	2010 2008	39.3 - 39.8	43.1 - 43.2	44.1 - 44.0	44.2 - 44.4	44.6 - 46.7	45.3 - 48.1	50.0 - 49.0	50.8 - 50.1	50.8 - 50.4
Hyundai	2010 2008	41.1 - 41.2	41.7 - 41.7	43.2 - 45.9	44.5 - 46.1	45.8 - 47.3	48.0 - 48.4	48.7 - 48.5	50.9 - 48.5	51.0 - 48.5
Kia	2010 2008	39.8 - 39.9	41.0 - 40.0	43.9 - 43.1	46.3 - 47.3	47.2 - 48.6	49.2 - 49.4	49.5 - 49.7	49.5 - 49.8	51.2 - 50.7
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	40.7 - 40.6	41.3 - 42.4	41.4 - 42.4	44.1 - 45.5	44.1 - 45.5	48.0 - 50.1	48.9 - 50.4	49.1 - 50.6	49.9 - 50.9
Mitsubishi	2010 2008	41.7 - 39.6	42.3 - 40.7	42.3 - 40.8	44.7 - 43.8	49.7 - 47.9	50.2 - 48.0	50.2 - 48.0	51.1 - 49.6	51.1 - 49.6
Nissan	2010 2008	38.6 - 38.8	39.0 - 39.7	43.7 - 44.2	44.5 - 44.8	44.9 - 45.4	46.4 - 47.6	47.7 - 48.9	51.0 - 50.1	51.6 - 50.3
Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5

Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	39.5 - 40.9	39.4 - 41.9	42.2 - 42.8	47.5 - 49.3	47.6 - 49.2	48.1 - 49.2	48.2 - 49.2	52.0 - 49.2	52.0 - 61.1
Suzuki	2010 2008	42.6 - 43.1	42.7 - 43.3	45.5 - 49.2	47.4 - 49.7	48.9 - 52.0	49.8 - 52.0	49.8 - 52.1	50.0 - 52.0	54.0 - 52.1
Tata	2010 2008	30.3 - 36.4	34.5 - 39.6	34.4 - 39.6	36.3 - 40.2	37.1 - 40.8	37.1 - 42.1	38.7 - 44.3	38.7 - 44.3	39.3 - 44.7
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	40.0 - 40.3	41.4 - 42.4	43.7 - 44.7	44.3 - 46.9	45.8 - 47.7	46.2 - 48.3	46.4 - 48.6	50.7 - 48.6	50.7 - 48.7
Volkswagen	2010 2008	38.8 - 37.9	41.5 - 38.7	42.1 - 40.1	44.0 - 44.0	44.9 - 44.7	45.4 - 45.5	45.8 - 46.0	47.8 - 46.2	50.2 - 48.4
Total/Average	2010 2008	38.9 - 39.2	40.3 - 41.1	42.1 - 42.9	43.9 - 45.1	44.9 - 46.1	45.8 - 47.2	47.0 - 47.7	48.7 - 48.4	49.5 - 49.1

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
4% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.5	38.0 - 39.5	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 39.0	36.4 - 39.4	37.8 - 40.6	40.9 - 42.9	40.9 - 42.7	43.0 - 45.7
Fiat	2010 2008	39.6 - 39.1	40.2 - 41.9	42.9 - 42.1	45.9 - 47.7	47.8 - 48.4	48.3 - 49.4	51.0 - 52.4	52.2 - 53.2	53.4 - 53.2
Ford	2010 2008	39.9 - 39.9	40.1 - 40.8	42.2 - 42.5	47.4 - 46.1	48.5 - 47.9	50.4 - 49.5	50.6 - 50.3	51.3 - 51.0	55.5 - 54.9
Geely	2010 2008	37.2 - 36.4	39.0 - 39.5	43.6 - 42.2	44.5 - 42.3	44.9 - 43.5	44.9 - 43.5	45.8 - 44.3	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	39.1 - 39.2	41.4 - 42.9	42.1 - 44.3	46.9 - 48.1	48.9 - 49.6	48.9 - 49.8	51.0 - 51.3	51.8 - 51.3	54.9 - 51.3
Honda	2010 2008	39.4 - 40.6	44.1 - 45.5	45.5 - 46.8	45.6 - 47.2	49.5 - 51.8	50.0 - 53.3	53.0 - 54.6	53.9 - 55.4	54.2 - 56.9
Hyundai	2010 2008	41.8 - 42.4	42.5 - 43.0	45.4 - 46.9	46.5 - 47.2	49.0 - 49.0	51.4 - 50.3	51.9 - 50.5	53.7 - 55.2	54.8 - 56.3
Kia	2010 2008	41.9 - 41.4	42.5 - 41.6	46.6 - 45.7	49.7 - 50.9	50.7 - 51.8	53.6 - 52.6	54.0 - 53.8	54.1 - 53.9	54.1 - 56.2
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	42.3 - 42.7	42.9 - 44.9	43.3 - 44.9	47.4 - 47.5	47.4 - 47.5	51.4 - 54.4	53.2 - 55.5	53.5 - 55.9	53.5 - 56.0
Mitsubishi	2010 2008	41.4 - 40.1	41.8 - 41.3	41.8 - 41.4	49.9 - 45.3	54.6 - 51.0	55.0 - 51.0	55.0 - 51.1	55.1 - 52.1	55.1 - 57.2
Nissan	2010 2008	41.4 - 40.3	42.1 - 41.7	46.4 - 46.7	46.8 - 47.6	48.9 - 48.5	50.0 - 49.5	51.3 - 51.9	53.1 - 54.3	53.8 - 55.0
Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5

Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	39.8 - 41.5	39.7 - 43.2	44.4 - 44.1	50.0 - 50.4	49.9 - 50.4	49.9 - 50.3	50.4 - 50.3	51.5 - 50.9	53.3 - 62.6
Suzuki	2010 2008	42.5 - 43.8	42.5 - 44.0	48.2 - 50.7	51.1 - 51.4	54.2 - 54.3	54.2 - 54.3	54.4 - 54.3	54.3 - 55.3	54.3 - 58.8
Tata	2010 2008	30.3 - 36.4	34.5 - 39.4	34.4 - 39.4	36.3 - 40.7	37.1 - 41.2	37.1 - 42.3	38.7 - 43.1	38.7 - 43.1	39.3 - 43.5
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	40.2 - 41.2	42.0 - 43.4	46.5 - 46.3	47.4 - 48.4	50.9 - 50.2	51.7 - 51.7	51.7 - 51.7	53.5 - 54.6	54.0 - 55.0
Volkswagen	2010 2008	38.8 - 37.9	41.7 - 38.7	42.2 - 40.1	44.2 - 44.1	45.3 - 44.8	45.7 - 45.6	46.1 - 46.1	47.9 - 46.4	50.2 - 48.4
Total/Average	2010 2008	39.6 - 39.9	41.3 - 42.2	43.6 - 44.3	46.1 - 46.8	48.1 - 48.5	49.2 - 49.7	50.5 - 50.7	51.7 - 52.2	53.3 - 53.6

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
5% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.5	38.0 - 39.5	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 38.5	36.4 - 38.9	37.8 - 40.1	40.9 - 42.2	40.9 - 41.9	43.0 - 45.5
Fiat	2010 2008	39.4 - 40.2	40.4 - 42.2	44.7 - 42.8	49.1 - 49.9	51.2 - 51.4	52.3 - 52.7	54.2 - 57.9	54.6 - 58.6	63.1 - 58.6
Ford	2010 2008	41.1 - 39.9	41.4 - 41.3	44.1 - 43.3	49.9 - 49.2	51.5 - 51.7	53.7 - 53.3	54.4 - 53.4	54.6 - 54.0	60.0 - 54.5
Geely	2010 2008	37.2 - 36.4	39.0 - 39.5	43.7 - 42.2	44.5 - 42.3	44.9 - 43.5	44.9 - 43.5	45.8 - 44.3	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	39.9 - 40.1	43.0 - 43.9	43.7 - 45.4	48.5 - 49.5	50.4 - 52.5	50.7 - 52.7	53.5 - 54.3	55.6 - 56.4	60.7 - 58.7
Honda	2010 2008	40.6 - 41.7	46.5 - 46.5	48.0 - 48.3	48.1 - 49.0	51.5 - 54.1	52.1 - 55.0	58.3 - 59.1	60.0 - 60.9	60.8 - 62.3
Hyundai	2010 2008	42.6 - 42.1	43.4 - 42.7	47.2 - 49.3	48.4 - 50.3	51.3 - 52.0	54.9 - 55.2	55.4 - 55.5	59.7 - 61.0	60.1 - 61.4
Kia	2010 2008	42.6 - 41.9	43.4 - 42.0	49.1 - 44.8	52.6 - 52.3	53.3 - 55.0	58.1 - 57.3	58.4 - 59.7	58.7 - 59.8	58.7 - 59.9
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	42.7 - 43.9	43.6 - 46.5	44.1 - 46.5	48.4 - 50.0	48.7 - 50.0	54.9 - 57.3	57.6 - 58.4	58.2 - 60.8	59.2 - 64.1
Mitsubishi	2010 2008	42.6 - 40.6	42.7 - 41.9	42.8 - 42.0	51.0 - 55.0	54.9 - 61.0	55.3 - 61.4	55.3 - 61.7	55.4 - 61.5	76.4 - 61.7
Nissan	2010 2008	41.9 - 40.7	43.1 - 42.7	48.8 - 48.9	49.6 - 49.8	50.0 - 51.0	51.2 - 52.9	52.4 - 54.3	57.9 - 60.2	61.3 - 61.2
Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5

Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	40.6 - 42.5	41.0 - 44.3	45.7 - 45.2	51.8 - 49.7	51.8 - 49.7	51.8 - 49.9	52.6 - 49.9	53.8 - 50.0	55.3 - 69.6
Suzuki	2010 2008	43.3 - 45.1	43.3 - 45.4	49.4 - 52.6	53.4 - 53.1	55.8 - 58.9	56.2 - 59.0	56.2 - 59.0	56.4 - 59.0	64.3 - 68.7
Tata	2010 2008	30.3 - 36.4	34.5 - 39.4	34.4 - 39.4	36.3 - 40.7	37.1 - 41.2	37.1 - 42.3	38.7 - 43.1	38.7 - 43.1	39.3 - 43.5
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	41.0 - 42.0	42.5 - 44.7	48.5 - 47.6	49.7 - 50.8	53.7 - 53.7	54.7 - 54.9	54.7 - 54.9	58.5 - 58.4	58.7 - 61.6
Volkswagen	2010 2008	38.8 - 37.9	41.7 - 38.7	42.2 - 40.1	44.2 - 44.1	45.3 - 44.8	45.7 - 45.6	46.1 - 46.1	47.9 - 46.4	50.2 - 48.4
Total/Average	2010 2008	40.2 - 40.5	42.3 - 42.9	45.3 - 45.3	48.0 - 48.6	50.0 - 50.9	51.4 - 52.3	53.2 - 53.5	55.4 - 55.8	58.3 - 57.8

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
6% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.5	38.0 - 39.5	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 38.5	36.4 - 38.9	37.8 - 40.1	40.9 - 42.2	40.9 - 41.9	43.0 - 45.5
Fiat	2010 2008	40.1 - 40.5	41.3 - 43.1	45.6 - 43.7	49.7 - 51.4	51.4 - 53.6	51.8 - 57.1	52.7 - 60.0	58.2 - 64.3	59.8 - 65.5
Ford	2010 2008	42.0 - 41.0	42.5 - 42.5	45.1 - 44.4	50.7 - 48.0	52.0 - 50.1	52.7 - 57.7	52.8 - 57.7	61.7 - 64.7	65.9 - 65.3
Geely	2010 2008	37.2 - 36.4	39.0 - 39.5	43.7 - 42.2	44.5 - 42.3	44.9 - 43.5	44.9 - 43.5	45.8 - 44.3	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	41.3 - 40.5	44.9 - 44.7	45.8 - 46.4	49.4 - 50.7	54.0 - 59.2	54.3 - 59.6	60.2 - 59.5	61.3 - 60.6	64.6 - 67.2
Honda	2010 2008	40.8 - 43.1	47.1 - 48.3	49.1 - 50.4	49.2 - 51.0	54.4 - 55.7	55.1 - 56.7	63.4 - 61.9	64.9 - 63.0	67.5 - 69.1
Hyundai	2010 2008	44.7 - 44.0	45.5 - 44.6	50.0 - 51.3	50.7 - 52.4	55.0 - 54.3	58.9 - 58.3	61.0 - 59.8	63.7 - 63.0	63.8 - 63.1
Kia	2010 2008	43.5 - 42.6	44.2 - 42.7	50.1 - 45.9	55.4 - 54.4	56.7 - 57.8	63.1 - 59.5	63.8 - 60.6	64.2 - 60.7	64.2 - 72.9
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	44.2 - 44.3	45.4 - 46.7	45.9 - 47.6	50.6 - 50.3	51.1 - 50.6	55.3 - 62.1	56.2 - 62.9	56.3 - 62.8	63.2 - 79.4
Mitsubishi	2010 2008	44.5 - 40.6	44.5 - 41.9	44.5 - 42.0	49.2 - 55.2	60.1 - 59.6	60.5 - 60.0	60.6 - 60.3	60.5 - 61.0	67.3 - 66.2
Nissan	2010 2008	40.1 - 42.9	41.3 - 45.7	51.3 - 50.3	52.0 - 51.3	52.6 - 51.8	55.2 - 55.0	60.6 - 63.6	62.7 - 66.4	67.3 - 67.1
Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5

Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	40.7 - 42.6	41.2 - 44.4	46.0 - 45.0	52.8 - 50.2	52.8 - 50.2	52.8 - 50.3	53.4 - 50.3	54.6 - 54.2	55.8 - 70.9
Suzuki	2010 2008	43.7 - 46.7	43.7 - 47.0	50.2 - 51.4	53.6 - 51.8	56.0 - 53.8	56.2 - 54.0	56.2 - 54.0	56.4 - 66.4	72.2 - 74.5
Tata	2010 2008	30.3 - 36.4	34.5 - 39.4	34.4 - 39.4	36.3 - 40.8	37.1 - 41.3	37.1 - 42.4	38.7 - 43.1	38.7 - 43.1	39.3 - 43.5
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	41.4 - 42.1	43.2 - 45.0	49.9 - 48.7	51.4 - 53.6	56.0 - 56.0	57.2 - 58.0	57.3 - 58.1	64.9 - 63.7	67.1 - 69.2
Volkswagen	2010 2008	38.8 - 37.9	41.7 - 38.7	42.2 - 40.1	44.2 - 44.1	45.3 - 44.8	45.7 - 45.6	46.1 - 46.1	47.9 - 46.4	50.2 - 48.4
Total/Average	2010 2008	40.8 - 41.2	43.0 - 43.9	46.6 - 46.3	49.1 - 49.7	52.0 - 52.5	53.3 - 55.1	55.8 - 56.7	59.6 - 59.8	62.2 - 63.9

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
7% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.4	38.0 - 39.4	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 38.5	36.4 - 38.9	37.8 - 40.1	40.9 - 42.2	40.9 - 41.9	43.0 - 45.5
Fiat	2010 2008	40.8 - 41.3	42.1 - 44.1	46.6 - 44.7	49.3 - 52.5	50.9 - 54.4	51.9 - 57.2	59.0 - 64.1	59.6 - 69.1	72.0 - 69.7
Ford	2010 2008	42.7 - 41.6	43.3 - 43.8	45.6 - 45.2	50.8 - 48.8	51.9 - 51.5	53.3 - 52.2	53.3 - 52.2	58.5 - 58.5	63.5 - 60.7
Geely	2010 2008	37.2 - 36.4	39.0 - 39.5	43.7 - 42.2	44.5 - 42.3	44.9 - 43.5	44.9 - 43.5	45.8 - 44.3	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	42.3 - 41.3	46.0 - 45.5	48.6 - 47.1	51.7 - 51.0	55.1 - 60.1	55.4 - 60.4	60.1 - 60.6	60.5 - 68.2	63.2 - 71.1
Honda	2010 2008	42.4 - 44.4	50.4 - 50.4	52.9 - 53.5	53.0 - 54.0	56.9 - 59.6	60.1 - 60.6	65.5 - 64.6	68.4 - 70.9	68.7 - 70.8
Hyundai	2010 2008	44.9 - 44.6	45.8 - 45.7	49.7 - 52.6	51.1 - 53.8	55.1 - 55.5	66.0 - 68.1	68.9 - 69.9	70.8 - 69.9	71.0 - 70.0
Kia	2010 2008	45.3 - 42.6	46.0 - 42.7	52.0 - 46.9	56.0 - 56.5	57.6 - 59.8	63.3 - 61.2	66.4 - 63.1	66.6 - 63.2	68.5 - 79.7
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	44.4 - 45.8	45.6 - 47.9	46.3 - 49.2	51.1 - 51.4	51.2 - 51.5	54.8 - 80.3	56.2 - 81.9	56.3 - 82.1	62.8 - 82.6
Mitsubishi	2010 2008	44.5 - 40.6	44.5 - 42.0	44.5 - 42.1	50.1 - 55.1	53.8 - 59.5	53.8 - 59.9	53.9 - 60.2	54.0 - 63.0	71.0 - 64.2
Nissan	2010 2008	42.0 - 43.3	43.6 - 46.1	50.4 - 51.3	51.9 - 52.4	52.4 - 53.3	58.9 - 61.2	59.6 - 65.4	64.2 - 69.7	64.6 - 69.9
Porsche	2010	33.2 -	34.8 -	36.5 -	36.5 -	37.3 -	40.1 -	40.5 -	40.6 -	40.6 -

	2008	34.4	35.7	35.7	35.8	37.5	40.3	40.3	41.5	41.5
Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	41.2 - 42.2	41.7 - 43.7	44.7 - 47.7	54.1 - 53.3	54.1 - 53.1	54.3 - 53.0	54.9 - 52.9	55.2 - 52.9	75.2 - 66.1
Suzuki	2010 2008	43.8 - 46.7	43.8 - 47.0	49.7 - 51.9	53.2 - 52.3	55.6 - 57.9	55.9 - 58.0	55.9 - 57.9	56.1 - 71.5	83.6 - 81.4
Tata	2010 2008	30.3 - 36.4	34.5 - 39.4	34.4 - 39.4	36.3 - 40.8	37.1 - 41.3	37.1 - 42.4	38.7 - 43.1	38.7 - 43.1	39.3 - 43.5
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	42.3 - 43.8	44.5 - 47.3	51.9 - 51.8	53.6 - 57.9	58.0 - 60.8	63.8 - 68.5	63.8 - 68.4	75.1 - 68.5	77.2 - 68.7
Volkswagen	2010 2008	38.8 - 37.9	41.7 - 38.7	42.2 - 40.1	44.2 - 44.1	45.3 - 44.8	45.7 - 45.6	46.1 - 46.1	47.9 - 46.4	50.2 - 48.4
Total/Average	2010 2008	41.7 - 42.0	44.1 - 44.9	47.7 - 47.6	50.3 - 51.1	52.6 - 54.3	55.6 - 57.8	58.0 - 59.2	61.3 - 62.8	64.8 - 64.7

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
Max Net Benefits, 3% Discount Rate

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.4	38.0 - 39.4	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 38.5	36.4 - 38.9	37.8 - 40.1	40.9 - 42.2	40.9 - 41.9	43.0 - 45.5
Fiat	2010 2008	41.8 - 44.0	42.8 - 46.4	46.4 - 46.6	49.2 - 50.8	50.7 - 52.1	51.7 - 52.5	53.3 - 54.0	53.9 - 54.8	56.3 - 55.7
Ford	2010 2008	42.7 - 42.2	43.1 - 42.5	48.6 - 47.9	51.8 - 50.2	52.2 - 51.7	53.8 - 52.2	54.0 - 52.8	55.5 - 53.6	57.0 - 53.5
Geely	2010 2008	37.2 - 36.4	39.0 - 39.5	43.7 - 42.3	44.5 - 42.4	44.9 - 43.6	44.9 - 43.6	45.8 - 44.4	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	42.7 - 44.0	45.5 - 46.5	45.7 - 47.4	50.3 - 49.9	51.7 - 52.9	52.0 - 53.0	53.5 - 53.4	55.7 - 55.2	57.8 - 56.4
Honda	2010 2008	45.7 - 46.9	48.7 - 51.1	49.6 - 52.2	49.8 - 52.4	52.7 - 55.1	53.3 - 55.6	56.4 - 56.3	56.9 - 56.6	57.1 - 57.4
Hyundai	2010 2008	46.2 - 46.1	46.5 - 46.3	50.1 - 51.5	51.3 - 52.2	53.2 - 53.1	55.3 - 54.8	56.4 - 55.1	58.1 - 57.2	58.3 - 57.3
Kia	2010 2008	46.5 - 44.9	46.5 - 45.1	52.3 - 46.4	53.7 - 54.5	54.9 - 55.8	56.1 - 56.3	56.4 - 56.4	56.4 - 56.5	56.8 - 56.6
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	44.6 - 45.5	45.9 - 47.4	46.0 - 47.4	50.3 - 58.5	50.8 - 58.6	55.1 - 58.8	55.3 - 59.2	55.4 - 58.8	62.0 - 58.6
Mitsubishi	2010 2008	44.5 - 40.6	44.3 - 42.0	44.4 - 42.1	55.9 - 55.1	58.8 - 55.2	58.8 - 55.6	58.8 - 55.9	59.0 - 55.8	59.0 - 56.2
Nissan	2010 2008	42.6 - 44.2	44.1 - 46.0	49.9 - 50.0	50.9 - 50.9	51.6 - 51.1	52.8 - 51.8	54.4 - 52.7	57.6 - 56.2	58.1 - 56.4
Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5

Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	41.4 - 42.7	41.6 - 43.5	65.1 - 47.3	72.5 - 53.2	71.1 - 53.1	70.1 - 52.9	69.0 - 52.9	68.4 - 52.8	67.6 - 61.7
Suzuki	2010 2008	45.4 - 44.8	45.4 - 44.9	50.4 - 55.9	53.5 - 56.8	56.3 - 57.9	56.5 - 58.0	56.5 - 58.0	56.7 - 58.1	61.6 - 59.4
Tata	2010 2008	30.3 - 36.4	34.5 - 39.4	34.4 - 39.4	36.3 - 40.8	37.1 - 41.3	37.1 - 42.4	38.7 - 43.1	38.7 - 43.1	39.3 - 43.5
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	43.1 - 45.1	44.4 - 47.2	50.1 - 48.3	51.0 - 50.8	53.8 - 54.1	54.2 - 54.9	54.4 - 54.9	57.3 - 56.5	57.6 - 56.5
Volkswagen	2010 2008	38.8 - 37.9	41.7 - 38.7	42.2 - 40.1	44.2 - 44.1	45.3 - 44.8	45.7 - 45.6	46.1 - 46.1	47.9 - 46.4	50.2 - 48.4
Total/Average	2010 2008	42.4 - 43.2	44.1 - 45.1	47.4 - 47.3	49.6 - 49.7	51.1 - 51.5	52.1 - 52.2	53.2 - 52.7	55.0 - 54.1	56.2 - 54.9

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
Max Net Benefits, 7% Discount Rate

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.4	38.0 - 39.4	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 38.5	36.4 - 38.9	37.8 - 40.1	40.9 - 42.2	40.9 - 41.9	43.0 - 45.5
Fiat	2010 2008	41.8 - 44.0	42.8 - 45.9	45.8 - 46.1	49.1 - 49.1	50.1 - 50.0	50.5 - 50.2	51.9 - 51.7	52.8 - 52.1	54.1 - 53.3
Ford	2010 2008	42.6 - 42.2	43.0 - 42.4	46.9 - 46.3	50.1 - 49.2	51.3 - 50.5	52.1 - 50.7	52.2 - 51.2	54.1 - 52.0	54.7 - 51.9
Geely	2010 2008	37.2 - 36.4	39.0 - 39.5	43.7 - 42.3	44.5 - 42.4	44.9 - 43.6	44.9 - 43.6	45.8 - 44.4	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	42.2 - 43.8	44.8 - 45.9	45.1 - 46.5	49.6 - 48.2	50.8 - 50.5	50.8 - 50.6	51.9 - 51.3	53.7 - 52.5	55.2 - 54.3
Honda	2010 2008	44.3 - 46.3	47.1 - 49.6	47.8 - 50.9	47.9 - 51.0	52.3 - 53.2	52.5 - 53.5	54.0 - 54.5	54.6 - 54.9	54.9 - 55.5
Hyundai	2010 2008	45.9 - 46.1	46.1 - 46.2	49.0 - 50.4	49.8 - 50.7	51.8 - 51.7	53.0 - 52.8	53.6 - 53.1	55.6 - 54.2	55.7 - 54.3
Kia	2010 2008	45.8 - 44.6	45.9 - 44.8	51.2 - 45.9	52.7 - 51.7	53.3 - 52.9	54.0 - 53.4	54.2 - 53.4	54.3 - 53.6	56.7 - 56.3
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	44.5 - 45.9	45.9 - 48.2	46.0 - 48.2	50.2 - 51.6	50.7 - 51.7	55.0 - 54.0	55.2 - 54.7	55.3 - 54.7	55.4 - 55.7
Mitsubishi	2010 2008	44.5 - 40.6	44.3 - 42.0	44.4 - 42.1	52.8 - 55.3	55.8 - 55.4	55.8 - 55.8	55.8 - 56.1	56.0 - 56.0	57.1 - 56.4
Nissan	2010 2008	42.4 - 43.8	43.8 - 45.1	49.3 - 48.7	50.3 - 49.2	50.5 - 49.5	51.6 - 50.4	52.1 - 51.6	55.2 - 53.7	55.5 - 54.4
Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5

Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	41.4 - 42.7	41.6 - 43.5	46.1 - 47.3	61.5 - 53.2	61.5 - 53.1	61.9 - 52.9	62.0 - 52.9	62.4 - 52.8	62.5 - 61.7
Suzuki	2010 2008	45.4 - 44.8	45.4 - 44.8	50.3 - 53.6	53.4 - 54.8	57.5 - 55.9	57.7 - 55.9	57.7 - 55.9	57.7 - 57.0	57.7 - 60.5
Tata	2010 2008	30.3 - 36.4	34.5 - 39.4	34.4 - 39.4	36.3 - 40.8	37.1 - 41.3	37.1 - 42.4	38.7 - 43.1	38.7 - 43.1	39.3 - 43.5
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	42.8 - 45.1	44.0 - 46.5	49.5 - 47.4	50.4 - 49.2	52.3 - 52.2	52.6 - 53.1	52.6 - 53.1	54.5 - 54.8	54.6 - 55.3
Volkswagen	2010 2008	38.8 - 37.9	41.7 - 38.7	42.2 - 40.1	44.2 - 44.1	45.3 - 44.8	45.7 - 45.6	46.1 - 46.1	47.9 - 46.4	50.2 - 48.4
Total/Average	2010 2008	42.1 - 43.1	43.7 - 44.6	46.4 - 46.4	48.7 - 48.4	50.2 - 49.9	50.8 - 50.6	51.6 - 51.2	53.2 - 52.3	54.0 - 53.4

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
Total Cost=Total Benefit, 3% Discount Rate

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.4	38.0 - 39.4	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 38.5	36.4 - 38.9	37.8 - 40.1	40.9 - 42.2	40.9 - 41.9	43.0 - 45.5
Fiat	2010 2008	41.8 - 44.7	42.8 - 47.2	46.4 - 47.6	49.2 - 52.2	50.7 - 54.0	51.7 - 54.6	57.5 - 56.6	58.1 - 59.4	58.1 - 59.3
Ford	2010 2008	42.6 - 47.1	42.9 - 47.3	48.8 - 49.6	52.3 - 54.1	52.8 - 55.4	55.0 - 55.4	55.4 - 55.5	56.8 - 55.7	59.7 - 56.4
Geely	2010 2008	37.2 - 36.4	39.0 - 39.5	43.7 - 42.3	44.5 - 42.4	44.9 - 43.6	44.9 - 43.6	45.8 - 44.4	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	43.0 - 45.3	45.7 - 47.5	45.9 - 48.3	50.1 - 50.7	53.1 - 53.8	53.6 - 53.8	57.8 - 55.9	58.8 - 58.5	58.8 - 59.7
Honda	2010 2008	45.9 - 48.4	49.4 - 51.6	50.4 - 52.5	50.5 - 52.9	53.5 - 56.1	54.2 - 56.4	58.4 - 58.4	59.5 - 59.3	60.0 - 59.8
Hyundai	2010 2008	46.2 - 47.4	46.5 - 47.6	50.4 - 51.9	51.6 - 53.3	53.6 - 54.5	55.8 - 56.8	56.2 - 57.7	58.9 - 60.5	58.9 - 60.6
Kia	2010 2008	46.3 - 47.3	46.3 - 47.5	50.0 - 49.0	54.7 - 56.7	55.3 - 57.7	58.6 - 58.4	59.1 - 58.9	59.2 - 59.0	59.2 - 59.1
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	45.1 - 46.4	45.9 - 48.0	46.0 - 48.0	49.1 - 51.6	49.5 - 51.6	55.4 - 62.8	56.9 - 63.1	57.9 - 62.9	60.8 - 63.0
Mitsubishi	2010 2008	44.5 - 40.6	44.3 - 42.0	44.4 - 42.1	58.0 - 55.1	61.5 - 59.5	61.4 - 59.9	61.4 - 60.2	61.7 - 60.3	61.7 - 60.6
Nissan	2010 2008	43.2 - 45.1	44.2 - 46.6	50.6 - 50.0	51.8 - 50.8	52.4 - 52.4	53.3 - 55.2	54.5 - 56.7	61.6 - 58.5	61.8 - 58.6

Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5
Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	41.6 - 42.7	41.6 - 43.5	65.2 - 47.3	69.6 - 53.2	68.4 - 53.1	67.3 - 52.9	66.2 - 52.9	65.6 - 52.8	64.9 - 66.1
Suzuki	2010 2008	45.7 - 46.8	45.7 - 46.8	50.2 - 52.5	53.7 - 55.0	56.3 - 56.3	56.6 - 56.8	56.6 - 56.9	56.8 - 56.9	65.6 - 66.5
Tata	2010 2008	30.3 - 36.4	34.5 - 39.4	34.4 - 39.4	36.3 - 40.8	37.1 - 41.3	37.1 - 42.4	38.7 - 43.1	38.7 - 43.1	39.3 - 43.5
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	43.5 - 47.0	44.9 - 48.8	51.1 - 50.8	52.1 - 53.4	54.9 - 55.5	55.8 - 57.5	56.0 - 57.6	59.1 - 59.3	60.8 - 61.6
Volkswagen	2010 2008	38.8 - 37.9	41.7 - 38.7	42.2 - 40.1	44.2 - 44.1	45.3 - 44.8	45.7 - 45.6	46.1 - 46.1	47.9 - 46.4	50.2 - 48.4
Total/Average	2010 2008	42.6 - 44.8	44.2 - 46.4	47.7 - 48.2	49.9 - 50.8	51.7 - 52.6	52.9 - 53.8	54.9 - 54.8	56.9 - 56.3	58.0 - 57.6

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Passenger Cars
Total Cost=Total Benefit, 7% Discount Rate

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	25.7 - 28.7	27.7 - 31.1	27.7 - 31.1	30.7 - 31.1	33.8 - 31.1	34.7 - 31.1
BMW	2010 2008	32.9 - 33.5	37.2 - 38.3	37.9 - 39.4	38.0 - 39.4	39.3 - 40.0	40.1 - 40.7	40.2 - 41.0	44.1 - 46.4	44.2 - 46.4
Daimler	2010 2008	33.6 - 35.7	33.7 - 35.9	34.9 - 36.7	36.3 - 38.5	36.4 - 38.9	37.8 - 40.1	40.9 - 42.2	40.9 - 41.9	43.0 - 45.5
Fiat	2010 2008	41.8 - 44.7	42.8 - 47.2	46.4 - 47.6	49.2 - 52.2	50.7 - 54.0	51.7 - 54.6	57.5 - 56.6	58.1 - 59.4	58.1 - 59.3
Ford	2010 2008	42.6 - 47.1	42.9 - 47.3	48.8 - 49.6	52.3 - 54.1	52.8 - 55.4	55.0 - 55.4	55.4 - 55.5	56.8 - 55.7	59.7 - 56.4
Geely	2010 2008	37.2 - 36.4	39.0 - 39.5	43.7 - 42.3	44.5 - 42.4	44.9 - 43.6	44.9 - 43.6	45.8 - 44.4	47.4 - 45.0	51.7 - 45.1
General Motors	2010 2008	43.0 - 45.3	45.7 - 47.5	45.9 - 48.3	50.1 - 50.7	53.1 - 53.8	53.6 - 53.8	57.8 - 55.9	58.8 - 58.5	58.8 - 59.7
Honda	2010 2008	45.9 - 48.4	49.4 - 51.6	50.4 - 52.5	50.5 - 52.9	53.5 - 56.1	54.2 - 56.4	58.4 - 58.4	59.5 - 59.3	60.0 - 59.8
Hyundai	2010 2008	46.2 - 47.4	46.5 - 47.6	50.4 - 51.9	51.6 - 53.3	53.6 - 54.5	55.8 - 56.8	56.2 - 57.7	58.9 - 60.5	58.9 - 60.6
Kia	2010 2008	46.3 - 47.3	46.3 - 47.5	50.0 - 49.0	54.7 - 56.7	55.3 - 57.7	58.6 - 58.4	59.1 - 58.9	59.2 - 59.0	59.2 - 59.1
Lotus	2010 2008	33.8 - 37.0	33.8 - 37.0	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.2 - 39.9	39.8 - 41.8	39.8 - 41.8	39.8 - 41.8
Mazda	2010 2008	45.1 - 46.4	45.9 - 48.0	46.0 - 48.0	49.1 - 51.6	49.5 - 51.6	55.4 - 62.8	56.9 - 63.1	57.9 - 62.9	60.8 - 63.0
Mitsubishi	2010 2008	44.5 - 40.6	44.3 - 42.0	44.4 - 42.1	58.0 - 55.1	61.5 - 59.5	61.4 - 59.9	61.4 - 60.2	61.7 - 60.3	61.7 - 60.6
Nissan	2010 2008	43.2 - 45.1	44.2 - 46.6	50.6 - 50.0	51.8 - 50.8	52.4 - 52.4	53.3 - 55.2	54.5 - 56.7	61.6 - 58.5	61.8 - 58.6
Porsche	2010 2008	33.2 - 34.4	34.8 - 35.7	36.5 - 35.7	36.5 - 35.8	37.3 - 37.5	40.1 - 40.3	40.5 - 40.3	40.6 - 41.5	40.6 - 41.5

Spyker	2010 2008	- - 36.4	- - 38.5	- - 40.7	- - 40.7	- - 41.4	- - 42.2	- - 44.1	- - 47.6	- - 47.6
Subaru	2010 2008	41.6 - 42.7	41.6 - 43.5	65.2 - 47.3	69.6 - 53.2	68.4 - 53.1	67.3 - 52.9	66.2 - 52.9	65.6 - 52.8	64.9 - 66.1
Suzuki	2010 2008	45.7 - 46.8	45.7 - 46.8	50.2 - 52.5	53.7 - 55.0	56.3 - 56.3	56.6 - 56.8	56.6 - 56.9	56.8 - 56.9	65.6 - 66.5
Tata	2010 2008	30.3 - 36.4	34.5 - 39.4	34.4 - 39.4	36.3 - 40.8	37.1 - 41.3	37.1 - 42.4	38.7 - 43.1	38.7 - 43.1	39.3 - 43.5
Tesla	2010 2008	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0	- - 283.0
Toyota	2010 2008	43.5 - 47.0	44.9 - 48.8	51.1 - 50.8	52.1 - 53.4	54.9 - 55.5	55.8 - 57.5	56.0 - 57.6	59.1 - 59.3	60.8 - 61.6
Volkswagen	2010 2008	38.8 - 37.9	41.7 - 38.7	42.2 - 40.1	44.2 - 44.1	45.3 - 44.8	45.7 - 45.6	46.1 - 46.1	47.9 - 46.4	50.2 - 48.4
Total/Average	2010 2008	42.6 - 44.8	44.2 - 46.4	47.7 - 48.2	49.9 - 50.8	51.7 - 52.6	52.9 - 53.8	54.9 - 54.8	56.9 - 56.3	58.0 - 57.6

Table VI-5
Estimated Fuel Economy (mpg), Without CAFE Standards
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	24.1 - 22.7	24.0 - 22.7	24.1 - 22.6	24.1 - 22.6	24.0 - 22.6	24.1 - 22.6	24.1 - 22.5	24.1 - 22.5	24.0 - 22.5
Daimler	2010 2008	21.1 - 20.8	21.1 - 20.8	21.1 - 20.8	21.1 - 20.8	21.1 - 20.7	21.1 - 20.7	21.1 - 20.6	21.2 - 20.7	21.2 - 20.7
Fiat	2010 2008	21.7 - 22.2	21.7 - 22.3	21.7 - 22.3	21.6 - 22.3	21.6 - 22.4	21.6 - 22.4	21.6 - 22.4	21.6 - 22.4	21.6 - 22.4
Ford	2010 2008	22.3 - 21.2	22.2 - 21.3	22.2 - 21.4	22.1 - 21.4	22.1 - 21.4	22.1 - 21.3	22.1 - 21.4	22.1 - 21.5	22.1 - 21.5
Geely	2010 2008	22.8 - 21.1	22.8 - 21.1	22.8 - 21.1	22.8 - 21.1	22.8 - 21.1	22.8 - 21.1	22.8 - 21.1	22.8 - 21.1	22.8 - 21.1
General Motors	2010 2008	22.4 - 21.6	22.4 - 21.6	22.4 - 21.7	22.4 - 21.7	22.4 - 21.8	22.4 - 21.8	22.4 - 21.9	22.4 - 21.9	22.4 - 21.9
Honda	2010 2008	25.2 - 24.8	25.1 - 24.8	25.1 - 24.8	25.1 - 24.8	25.1 - 24.8	25.1 - 24.8	25.1 - 24.8	25.1 - 24.8	25.1 - 24.8
Hyundai	2010 2008	28.2 - 24.2	28.2 - 24.2	28.2 - 24.2	28.2 - 24.2	28.2 - 24.2	28.2 - 24.2	28.2 - 24.2	28.2 - 24.2	28.2 - 24.2
Kia	2010 2008	25.0 - 23.8	25.0 - 23.8	25.0 - 23.8	25.0 - 23.8	25.0 - 23.8	25.0 - 23.8	25.1 - 23.8	25.1 - 23.8	25.1 - 23.8
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	25.3 - 24.7	25.3 - 24.8	25.2 - 24.7	25.1 - 24.6	25.1 - 24.4	25.1 - 24.3	25.1 - 24.2	25.1 - 24.2	25.1 - 24.3
Mitsubishi	2010 2008	28.1 - 23.7	28.1 - 23.7	28.1 - 23.7	28.1 - 23.7	28.1 - 23.7	28.1 - 23.7	28.1 - 23.7	28.1 - 23.7	28.1 - 23.7
Nissan	2010 2008	23.7 - 21.9	23.6 - 22.0	23.5 - 22.1	23.4 - 22.1	23.4 - 22.1	23.4 - 22.1	23.3 - 22.1	23.3 - 22.2	23.3 - 22.2
Porsche	2010 2008	20.5 - 20.0	20.5 - 20.0	20.5 - 20.0	20.5 - 20.0	20.5 - 20.0	20.5 - 20.0	20.5 - 20.0	20.5 - 20.0	20.5 - 20.0

Spyker	2010 2008	- - 19.8	- - 19.8	- - 19.8	- - 19.8	- - 19.8	- - 19.8	- - 19.8	- - 19.8	- - 19.8
Subaru	2010 2008	30.7 - 27.2	30.7 - 27.2	30.7 - 27.1	30.7 - 27.2	30.7 - 27.2	30.7 - 27.2	30.7 - 27.1	30.7 - 27.2	30.7 - 27.2
Suzuki	2010 2008	26.1 - 23.3	26.1 - 23.3	26.1 - 23.3	26.1 - 23.3	26.1 - 23.3	26.1 - 23.3	26.1 - 23.3	26.1 - 23.3	26.1 - 23.3
Tata	2010 2008	18.9 - 19.5	18.9 - 19.5	18.9 - 19.5	18.9 - 19.6	18.9 - 19.6	18.9 - 19.6	18.9 - 19.6	18.9 - 19.6	18.9 - 19.6
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	24.2 - 24.1	24.2 - 24.1	24.2 - 24.2	24.2 - 24.2	24.2 - 24.2	24.2 - 24.2	24.2 - 24.2	24.2 - 24.3	24.2 - 24.3
Volkswagen	2010 2008	24.0 - 20.1	24.0 - 20.1	24.1 - 20.1	24.1 - 20.1	24.1 - 20.1	24.1 - 20.1	24.1 - 20.1	24.2 - 20.1	24.1 - 20.1
Total/Average	2010 2008	23.2 - 22.6	23.1 - 22.6	23.1 - 22.6	23.1 - 22.6	23.1 - 22.6	23.1 - 22.7	23.1 - 22.7	23.1 - 22.7	23.1 - 22.7

Table VI-6
Estimated Fuel Economy (mpg), Adjusted Baseline
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	31.2 - 30.7	31.0 - 30.7	31.1 - 30.7	31.2 - 30.6	31.1 - 30.5	31.2 - 30.4	31.2 - 30.3	31.2 - 30.3	31.1 - 30.4
Daimler	2010 2008	29.6 - 29.6	30.2 - 29.7	30.2 - 29.7	30.3 - 29.6	30.5 - 29.4	30.5 - 29.2	30.5 - 29.1	30.6 - 29.3	30.6 - 29.4
Fiat	2010 2008	28.8 - 28.9	28.8 - 28.9	28.8 - 28.9	28.8 - 28.9	28.8 - 28.9	29.2 - 29.6	29.2 - 29.6	29.2 - 29.7	29.3 - 29.7
Ford	2010 2008	26.6 - 27.6	26.5 - 27.7	26.6 - 27.8	26.8 - 27.9	27.7 - 28.6	27.7 - 28.6	27.7 - 28.7	27.7 - 28.8	27.7 - 28.8
Geely	2010 2008	28.2 - 30.6	32.7 - 31.0	32.8 - 31.0	32.8 - 31.0	32.8 - 31.0	32.8 - 31.0	32.8 - 31.0	32.8 - 31.0	32.8 - 31.0
General Motors	2010 2008	26.6 - 27.3	26.6 - 27.4	26.9 - 27.9	27.9 - 27.9	27.9 - 28.1	27.9 - 28.1	28.0 - 28.2	28.1 - 28.3	28.1 - 28.3
Honda	2010 2008	30.0 - 29.8	30.0 - 29.8	30.4 - 30.2	30.4 - 30.8	30.4 - 30.8	30.4 - 30.8	30.4 - 30.7	30.4 - 30.8	30.4 - 30.8
Hyundai	2010 2008	30.3 - 31.4	31.4 - 31.4	31.6 - 31.4	31.8 - 31.4	31.8 - 31.4	31.8 - 31.4	31.8 - 31.4	31.8 - 31.4	31.8 - 31.4
Kia	2010 2008	29.6 - 29.4	29.6 - 29.4	29.6 - 29.6	29.6 - 29.8	29.6 - 29.8	29.6 - 29.8	29.6 - 29.8	29.6 - 29.8	29.6 - 29.8
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	29.7 - 29.7	31.9 - 30.9	31.7 - 30.9	31.8 - 30.9	31.7 - 31.0	31.8 - 30.9	31.7 - 30.7	31.7 - 30.8	31.7 - 30.8
Mitsubishi	2010 2008	32.4 - 32.3	32.4 - 32.3	32.4 - 32.3	32.4 - 32.3	33.2 - 32.5	33.2 - 32.5	33.2 - 32.5	33.2 - 32.5	33.2 - 32.5
Nissan	2010 2008	29.3 - 29.1	29.1 - 29.2	29.1 - 29.3	29.2 - 29.4	29.3 - 29.6	29.3 - 29.6	29.2 - 29.7	29.2 - 29.8	29.2 - 29.8
Porsche	2010 2008	27.9 - 30.3	28.1 - 30.9	30.8 - 30.9	30.8 - 30.9	30.8 - 30.9	30.8 - 30.9	30.8 - 30.9	30.8 - 30.9	30.8 - 30.9

Spyker	2010 2008	- - 30.9	- - 30.9	- - 30.9	- - 30.9	- - 31.8	- - 31.8	- - 31.8	- - 31.8	- - 31.8
Subaru	2010 2008	32.1 - 33.2	32.2 - 33.5	34.6 - 33.6	34.6 - 33.6	34.7 - 33.6	34.9 - 33.6	34.9 - 33.6	34.9 - 33.6	34.9 - 33.6
Suzuki	2010 2008	33.3 - 30.7	33.3 - 30.7	33.3 - 31.7	33.3 - 31.7	33.5 - 31.7	33.5 - 31.7	33.5 - 31.7	33.5 - 31.7	33.5 - 31.7
Tata	2010 2008	28.2 - 30.4	28.2 - 30.4	28.7 - 31.3	28.7 - 31.4	31.2 - 32.1	31.1 - 32.1	31.1 - 32.1	31.1 - 32.1	31.1 - 32.1
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	27.7 - 29.0	28.7 - 29.2	29.0 - 29.4	29.3 - 29.4	29.3 - 29.6	29.3 - 29.6	29.3 - 29.8	29.3 - 29.8	29.3 - 29.9
Volkswagen	2010 2008	29.4 - 27.8	30.1 - 29.0	30.6 - 29.6	30.7 - 29.4	30.7 - 29.6	30.7 - 29.5	30.7 - 29.4	30.7 - 29.5	30.7 - 29.5
Total/Average	2010 2008	28.0 - 28.7	28.2 - 28.8	28.4 - 29.0	28.8 - 29.1	29.0 - 29.3	29.0 - 29.4	29.0 - 29.4	29.1 - 29.5	29.1 - 29.5

Table VI-7
Estimated Required Fuel Economy Levels for Preferred Alternative
Estimated mpg
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	31.2 - 30.6	32.0 - 31.4	32.7 - 32.1	33.5 - 32.9	35.8 - 35.1	37.5 - 36.7	39.3 - 38.4	41.1 - 40.2	43.1 - 42.1
Daimler	2010 2008	30.1 - 29.1	30.8 - 29.6	31.4 - 30.2	32.2 - 30.9	34.4 - 32.9	36.0 - 34.5	37.7 - 36.1	39.5 - 37.8	41.4 - 39.5
Fiat	2010 2008	29.6 - 29.6	30.2 - 30.2	30.7 - 30.8	31.5 - 31.5	33.6 - 33.7	35.2 - 35.3	36.9 - 37.0	38.6 - 38.8	40.4 - 40.6
Ford	2010 2008	27.5 - 28.6	27.8 - 29.1	28.0 - 29.6	28.4 - 30.0	30.2 - 32.0	31.7 - 33.5	33.1 - 35.2	34.7 - 37.0	36.4 - 38.8
Geely	2010 2008	31.4 - 31.1	32.4 - 32.1	33.0 - 32.7	33.9 - 33.5	36.2 - 35.8	37.9 - 37.5	39.7 - 39.3	41.6 - 41.2	43.6 - 43.1
General Motors	2010 2008	27.8 - 28.0	28.1 - 28.5	28.6 - 29.1	29.2 - 29.6	31.2 - 31.7	32.8 - 33.2	34.3 - 34.9	36.0 - 36.6	37.8 - 38.4
Honda	2010 2008	30.4 - 31.0	31.1 - 31.7	31.7 - 32.3	32.5 - 33.1	34.7 - 35.4	36.4 - 37.0	38.1 - 38.8	39.9 - 40.7	41.8 - 42.6
Hyundai	2010 2008	32.1 - 31.3	33.0 - 32.1	33.7 - 32.8	34.6 - 33.6	36.9 - 35.9	38.7 - 37.6	40.5 - 39.4	42.5 - 41.3	44.5 - 43.2
Kia	2010 2008	30.3 - 30.0	31.0 - 30.6	31.7 - 31.2	32.5 - 32.0	34.8 - 34.2	36.5 - 35.8	38.3 - 37.5	40.1 - 39.3	42.1 - 41.1
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	31.6 - 31.4	32.5 - 32.4	33.1 - 33.1	33.9 - 33.8	36.2 - 35.9	38.0 - 37.6	39.8 - 39.3	41.7 - 41.2	43.6 - 43.2
Mitsubishi	2010 2008	34.1 - 32.9	35.1 - 33.9	35.9 - 34.6	36.7 - 35.5	39.3 - 37.9	41.1 - 39.7	43.1 - 41.6	45.2 - 43.6	47.3 - 45.7
Nissan	2010 2008	29.6 - 29.6	30.1 - 30.3	30.5 - 30.9	31.1 - 31.6	33.1 - 33.5	34.6 - 35.1	36.2 - 36.8	37.9 - 38.7	39.7 - 40.6
Porsche	2010 2008	30.3 - 30.3	31.1 - 31.2	31.8 - 31.8	32.6 - 32.6	34.8 - 34.8	36.4 - 36.5	38.2 - 38.2	40.0 - 40.0	41.9 - 41.9

Spyker	2010 2008	- - 31.2	- - 32.1	- - 32.8	- - 33.6	- - 35.9	- - 37.6	- - 39.4	- - 41.3	- - 43.3
Subaru	2010 2008	34.9 - 34.4	35.9 - 35.4	36.7 - 36.1	37.6 - 37.1	40.2 - 39.6	42.1 - 41.5	44.1 - 43.5	46.2 - 45.5	48.4 - 47.7
Suzuki	2010 2008	34.2 - 32.2	35.2 - 33.2	36.0 - 33.9	36.9 - 34.7	39.4 - 37.1	41.3 - 38.9	43.3 - 40.7	45.3 - 42.7	47.5 - 44.7
Tata	2010 2008	31.6 - 32.1	32.5 - 33.1	33.2 - 33.8	34.0 - 34.6	36.3 - 37.0	38.1 - 38.8	39.9 - 40.6	41.8 - 42.6	43.8 - 44.6
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	29.4 - 29.7	30.0 - 30.4	30.5 - 31.0	31.1 - 31.6	32.9 - 33.7	34.4 - 35.3	36.1 - 37.0	37.8 - 38.9	39.6 - 40.7
Volkswagen	2010 2008	30.9 - 29.5	31.7 - 30.1	32.4 - 30.8	33.2 - 31.5	35.4 - 33.5	37.1 - 35.1	38.9 - 36.7	40.8 - 38.5	42.7 - 40.3
Total/Average	2010 2008	29.1 - 29.4	29.6 - 30.0	30.0 - 30.6	30.6 - 31.2	32.6 - 33.3	34.2 - 34.9	35.8 - 36.6	37.5 - 38.5	39.3 - 40.3

Table VI-8
Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
Preferred Alternative

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	34.5 - 35.0	34.6 - 35.2	34.7 - 35.5	35.3 - 35.4	36.7 - 36.8	39.5 - 39.6	39.4 - 39.5	39.4 - 39.5	39.5 - 39.4
Daimler	2010 2008	30.5 - 31.8	32.3 - 32.0	32.4 - 32.1	32.4 - 32.8	32.7 - 32.6	37.2 - 37.6	37.4 - 37.5	37.4 - 37.6	37.8 - 37.8
Fiat	2010 2008	30.1 - 29.2	30.1 - 29.2	30.1 - 29.2	30.1 - 29.2	30.1 - 29.2	33.9 - 35.3	38.5 - 38.2	38.6 - 38.4	38.5 - 40.6
Ford	2010 2008	27.4 - 28.5	27.5 - 28.9	28.2 - 29.2	28.8 - 30.5	34.4 - 34.6	34.4 - 35.3	34.5 - 35.5	34.8 - 36.5	34.7 - 36.5
Geely	2010 2008	28.2 - 31.0	34.9 - 34.8	35.1 - 35.1	35.1 - 35.1	35.9 - 35.1	36.6 - 38.8	40.8 - 41.0	40.8 - 41.0	40.8 - 41.0
General Motors	2010 2008	27.1 - 27.4	27.4 - 28.4	30.6 - 30.7	34.8 - 32.9	34.9 - 33.3	34.9 - 33.6	35.1 - 34.6	36.0 - 34.7	36.0 - 36.9
Honda	2010 2008	30.2 - 32.1	30.5 - 32.3	33.3 - 34.2	33.3 - 34.5	35.2 - 37.1	38.4 - 40.5	38.8 - 40.5	39.1 - 41.5	39.1 - 41.5
Hyundai	2010 2008	32.2 - 32.1	32.4 - 32.3	37.7 - 35.9	38.1 - 36.1	38.1 - 36.1	42.6 - 39.0	43.4 - 39.0	45.5 - 40.7	45.7 - 41.2
Kia	2010 2008	30.4 - 30.3	30.6 - 30.9	32.6 - 32.4	32.6 - 33.6	37.6 - 41.1	37.5 - 41.1	40.0 - 41.6	40.7 - 41.8	40.9 - 41.8
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	29.8 - 29.8	37.6 - 38.9	37.5 - 39.0	37.6 - 39.7	38.3 - 39.7	38.3 - 39.8	40.2 - 39.8	41.9 - 39.8	41.8 - 39.8
Mitsubishi	2010 2008	34.1 - 33.5	34.8 - 33.7	35.0 - 33.8	35.0 - 33.8	45.3 - 43.9	45.3 - 43.9	45.3 - 43.9	45.3 - 43.9	45.3 - 43.9
Nissan	2010 2008	29.1 - 29.7	29.1 - 30.0	33.6 - 31.5	34.8 - 32.1	35.8 - 35.5	36.8 - 38.0	36.9 - 38.2	36.9 - 39.3	36.8 - 40.7

Porsche	2010 2008	28.0 - 30.4	28.5 - 31.2	34.3 - 34.0	34.3 - 34.0	34.3 - 34.0	35.0 - 34.5	38.1 - 37.6	38.1 - 37.6	38.1 - 37.6
Spyker	2010 2008	- - 32.5	- - 33.6	- - 33.7	- - 33.7	- - 36.9	- - 36.9	- - 36.9	- - 36.9	- - 36.9
Subaru	2010 2008	38.2 - 33.2	38.7 - 35.4	42.0 - 43.8	42.0 - 43.9	42.0 - 44.5	42.0 - 44.5	42.0 - 44.5	48.5 - 44.5	48.5 - 44.5
Suzuki	2010 2008	34.9 - 31.0	35.1 - 31.1	35.2 - 39.8	35.2 - 39.8	45.4 - 40.8	45.4 - 40.8	45.4 - 40.8	45.4 - 40.8	45.4 - 40.8
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	28.5 - 29.2	30.0 - 31.1	31.7 - 32.7	32.3 - 33.6	34.1 - 35.5	34.6 - 35.7	35.6 - 36.3	38.4 - 39.6	39.4 - 40.6
Volkswagen	2010 2008	30.2 - 27.9	31.6 - 29.8	34.2 - 35.3	38.1 - 35.3	38.7 - 36.6	38.8 - 36.6	39.6 - 37.6	40.0 - 38.0	40.7 - 38.0
Total/Average	2010 2008	28.8 - 29.3	29.3 - 30.3	31.3 - 31.9	32.8 - 33.3	34.9 - 35.2	35.5 - 36.1	36.5 - 36.8	37.4 - 37.9	37.6 - 39.0

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
2% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	35.0 - 32.3	35.0 - 32.5	35.2 - 32.6	35.8 - 33.9	37.1 - 34.9	38.0 - 37.7	37.9 - 37.6	38.0 - 37.5	38.3 - 37.5
Daimler	2010 2008	31.5 - 30.9	32.9 - 31.1	33.0 - 31.2	33.6 - 31.9	33.6 - 31.6	35.5 - 35.9	36.5 - 35.9	36.5 - 36.0	37.0 - 36.1
Fiat	2010 2008	30.4 - 29.9	30.4 - 29.9	30.4 - 29.9	30.4 - 29.9	30.4 - 29.9	33.8 - 34.2	35.5 - 35.1	35.4 - 35.4	35.4 - 35.4
Ford	2010 2008	28.9 - 28.9	29.1 - 29.2	29.9 - 29.6	30.1 - 30.4	30.7 - 33.1	30.7 - 33.5	30.7 - 33.7	31.2 - 33.9	31.1 - 33.9
Geely	2010 2008	28.2 - 31.5	34.1 - 34.7	34.5 - 34.8	34.5 - 34.8	34.9 - 34.8	36.1 - 36.7	38.7 - 37.6	38.7 - 37.6	38.7 - 37.6
General Motors	2010 2008	28.1 - 28.0	28.4 - 28.9	30.0 - 30.8	32.1 - 31.9	32.1 - 32.2	32.3 - 32.3	32.8 - 32.8	32.9 - 33.0	32.9 - 33.6
Honda	2010 2008	32.2 - 32.8	32.6 - 33.0	33.5 - 33.8	33.7 - 34.7	34.4 - 35.6	35.0 - 37.2	35.5 - 37.2	37.1 - 37.4	37.1 - 37.4
Hyundai	2010 2008	33.0 - 32.6	33.2 - 32.8	37.4 - 35.4	37.9 - 35.5	37.9 - 35.5	39.7 - 36.7	39.7 - 36.7	40.6 - 36.9	40.6 - 36.9
Kia	2010 2008	33.1 - 32.2	33.3 - 32.9	33.6 - 33.6	33.6 - 34.3	35.2 - 34.3	35.2 - 34.3	35.9 - 34.9	35.9 - 35.9	35.9 - 35.9
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	30.4 - 29.9	34.7 - 35.1	34.6 - 35.2	34.7 - 35.6	36.1 - 36.3	36.1 - 36.1	40.7 - 41.6	41.4 - 42.1	41.4 - 42.1
Mitsubishi	2010 2008	34.1 - 33.5	35.4 - 33.7	35.6 - 33.8	35.6 - 33.8	40.7 - 40.1	40.7 - 40.1	40.7 - 40.0	40.7 - 40.1	40.7 - 40.1
Nissan	2010 2008	29.5 - 30.7	29.5 - 31.0	31.7 - 32.3	32.4 - 32.9	32.7 - 33.7	34.1 - 34.5	34.2 - 34.6	34.6 - 35.4	34.5 - 35.4
Porsche	2010 2008	28.0 - 30.4	28.5 - 31.7	35.1 - 34.0	35.1 - 34.0	35.1 - 34.0	35.7 - 34.5	37.6 - 36.9	37.6 - 36.9	37.6 - 36.9

Spyker	2010 2008	- - 31.9	- - 32.6	- - 32.7	- - 32.7	- - 36.9	0.0 - 36.9	0.0 - 36.9	0.0 - 36.9	0.0 - 36.9
Subaru	2010 2008	34.1 - 33.9	34.4 - 35.9	39.0 - 41.2	39.0 - 41.3	39.0 - 41.3	40.3 - 41.3	40.3 - 41.2	42.1 - 41.3	42.1 - 41.3
Suzuki	2010 2008	35.9 - 31.0	36.1 - 31.1	36.5 - 37.3	36.5 - 37.3	40.2 - 37.6	40.2 - 37.6	40.2 - 37.6	40.2 - 37.6	40.2 - 39.9
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	29.8 - 30.5	30.7 - 31.8	31.5 - 32.6	31.8 - 33.1	32.9 - 34.0	33.3 - 34.2	33.6 - 34.4	34.7 - 35.7	35.0 - 35.7
Volkswagen	2010 2008	30.2 - 28.1	31.4 - 30.5	33.6 - 35.5	35.7 - 35.4	35.7 - 35.9	36.5 - 35.9	36.7 - 35.9	37.1 - 35.9	37.1 - 35.9
Total/Average	2010 2008	29.8 - 30.0	30.2 - 30.7	31.4 - 31.9	32.3 - 32.8	32.9 - 33.8	33.3 - 34.3	33.8 - 34.6	34.3 - 35.1	34.3 - 35.3

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
3% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	33.6 - 34.6	33.6 - 34.8	34.4 - 34.9	34.5 - 35.6	35.1 - 37.3	40.5 - 40.3	40.4 - 40.2	40.4 - 40.1	40.7 - 40.0
Daimler	2010 2008	32.2 - 34.4	33.7 - 34.6	33.8 - 34.7	35.0 - 34.6	35.0 - 34.6	37.2 - 37.3	38.2 - 37.2	38.3 - 37.3	38.3 - 37.5
Fiat	2010 2008	30.4 - 29.9	30.4 - 29.9	30.4 - 29.9	30.4 - 29.9	30.4 - 29.9	34.2 - 36.4	38.6 - 38.3	38.7 - 38.5	38.6 - 38.5
Ford	2010 2008	28.9 - 29.9	29.2 - 30.3	29.8 - 30.9	30.1 - 31.7	34.0 - 34.9	34.1 - 35.6	34.1 - 35.9	34.3 - 36.2	35.6 - 37.8
Geely	2010 2008	28.7 - 31.3	36.2 - 36.0	36.9 - 36.3	36.8 - 36.3	37.7 - 37.2	38.3 - 39.8	41.7 - 39.8	41.7 - 39.8	41.7 - 39.8
General Motors	2010 2008	28.5 - 28.0	28.9 - 29.1	30.9 - 32.3	35.4 - 34.4	35.4 - 34.8	35.8 - 35.0	35.8 - 35.6	36.3 - 36.3	36.3 - 36.3
Honda	2010 2008	32.6 - 34.0	33.0 - 34.2	35.4 - 35.6	35.6 - 36.5	37.2 - 38.0	38.9 - 39.8	39.0 - 40.1	39.7 - 40.5	39.7 - 41.7
Hyundai	2010 2008	32.4 - 34.2	32.6 - 34.4	38.0 - 37.5	38.7 - 37.5	38.7 - 37.5	41.6 - 39.2	41.7 - 39.2	43.2 - 41.6	43.5 - 42.3
Kia	2010 2008	33.1 - 30.7	33.3 - 30.9	34.3 - 33.0	34.3 - 34.0	38.0 - 38.3	38.0 - 38.3	40.6 - 39.6	40.7 - 39.6	40.9 - 39.8
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	30.4 - 29.9	37.9 - 38.8	37.8 - 38.9	37.9 - 39.6	37.9 - 39.6	37.9 - 39.6	40.7 - 42.2	42.6 - 42.4	42.5 - 42.7
Mitsubishi	2010 2008	35.2 - 34.0	36.0 - 34.2	36.1 - 34.3	36.1 - 34.3	44.7 - 43.3	44.7 - 43.3	44.7 - 43.3	44.7 - 43.3	44.7 - 43.3
Nissan	2010 2008	30.8 - 30.7	30.8 - 31.0	32.6 - 32.9	33.8 - 33.4	34.4 - 35.7	36.9 - 37.4	36.9 - 38.0	38.1 - 39.0	38.8 - 39.8
Porsche	2010 2008	28.0 - 30.4	28.5 - 32.0	36.7 - 34.0	36.7 - 34.0	36.7 - 34.0	37.6 - 34.5	37.6 - 37.6	37.6 - 37.6	37.6 - 37.6

Spyker	2010 2008	- - 32.9	- - 34.2	- - 34.3	- - 34.3	- - 37.2	- - 37.2	- - 37.2	- - 37.2	- - 37.2
Subaru	2010 2008	38.5 - 35.6	38.9 - 38.3	43.4 - 43.6	43.4 - 43.6	43.4 - 44.1	43.4 - 44.1	43.4 - 44.1	45.3 - 46.7	45.3 - 46.6
Suzuki	2010 2008	36.3 - 31.9	36.5 - 32.1	36.6 - 38.6	36.6 - 38.6	45.3 - 39.6	45.3 - 41.1	45.3 - 41.1	45.3 - 41.1	45.3 - 41.1
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	30.6 - 31.0	31.7 - 32.6	33.5 - 34.4	34.3 - 35.6	35.5 - 36.8	35.7 - 36.9	37.2 - 37.9	38.3 - 38.7	38.7 - 39.1
Volkswagen	2010 2008	30.3 - 28.1	32.0 - 30.9	34.8 - 36.0	37.6 - 35.9	37.7 - 36.2	38.2 - 36.1	39.2 - 36.1	40.0 - 39.2	41.8 - 39.2
Total/Average	2010 2008	30.2 - 30.5	30.7 - 31.4	32.3 - 33.3	33.9 - 34.7	35.3 - 36.1	36.0 - 36.8	36.9 - 37.4	37.5 - 38.2	37.9 - 38.6

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
4% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	36.3 - 35.6	36.4 - 35.8	36.9 - 36.3	37.6 - 36.6	38.8 - 37.3	41.3 - 39.7	41.3 - 39.6	41.3 - 39.5	41.7 - 39.5
Daimler	2010 2008	32.2 - 35.6	33.7 - 35.8	33.8 - 36.0	35.1 - 35.9	35.2 - 35.8	37.1 - 37.2	38.0 - 37.2	38.1 - 37.3	38.5 - 37.5
Fiat	2010 2008	30.7 - 31.3	30.7 - 31.3	30.7 - 31.3	30.7 - 31.3	30.7 - 31.3	35.0 - 39.5	40.5 - 41.4	40.7 - 41.9	44.4 - 42.0
Ford	2010 2008	29.3 - 29.5	29.7 - 30.3	30.0 - 30.7	30.7 - 31.7	35.5 - 37.0	35.8 - 38.0	35.8 - 38.6	36.6 - 38.8	37.9 - 41.8
Geely	2010 2008	28.7 - 31.3	36.9 - 36.8	37.6 - 37.0	37.5 - 37.0	39.0 - 37.3	39.6 - 40.0	42.3 - 40.0	42.3 - 40.0	42.3 - 40.0
General Motors	2010 2008	28.5 - 28.3	28.9 - 29.7	31.2 - 34.2	36.5 - 37.1	36.6 - 37.3	36.6 - 37.4	36.9 - 37.9	37.6 - 37.9	38.7 - 37.9
Honda	2010 2008	32.9 - 35.4	33.3 - 35.6	36.1 - 36.7	36.5 - 37.8	38.8 - 40.0	41.3 - 43.4	41.6 - 43.4	43.1 - 44.3	43.1 - 44.5
Hyundai	2010 2008	32.7 - 36.1	33.2 - 36.3	38.5 - 39.4	39.1 - 39.4	39.1 - 39.4	44.6 - 41.5	45.0 - 41.5	48.1 - 45.8	48.1 - 46.5
Kia	2010 2008	33.0 - 31.2	33.2 - 31.4	35.9 - 34.3	36.0 - 35.9	41.6 - 41.2	41.6 - 41.2	42.1 - 41.2	43.0 - 41.3	43.0 - 41.3
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	31.2 - 29.9	39.9 - 40.1	39.8 - 40.2	40.1 - 41.2	40.1 - 41.3	40.1 - 41.3	43.2 - 43.7	45.5 - 44.0	45.4 - 44.2
Mitsubishi	2010 2008	38.9 - 34.6	39.2 - 34.8	39.3 - 35.0	39.3 - 34.9	48.8 - 47.5	48.8 - 47.5	48.8 - 47.5	48.8 - 47.5	48.8 - 47.5
Nissan	2010 2008	29.9 - 32.2	29.9 - 32.5	34.4 - 35.4	35.9 - 36.3	37.4 - 39.3	39.7 - 40.2	39.7 - 41.0	40.8 - 42.1	42.4 - 43.6
Porsche	2010 2008	28.0 - 30.4	28.5 - 32.0	36.8 - 34.0	36.8 - 34.0	36.8 - 34.0	37.6 - 34.5	37.6 - 37.6	37.6 - 37.6	37.6 - 37.6

Spyker	2010 2008	- - 32.9	- - 34.2	- - 34.3	- - 34.3	- - 37.2	- - 37.2	- - 37.2	- - 37.2	- - 37.2
Subaru	2010 2008	38.8 - 35.6	39.5 - 39.0	45.1 - 44.4	45.1 - 44.4	45.1 - 44.9	46.6 - 44.9	46.6 - 44.9	52.1 - 51.4	52.1 - 51.4
Suzuki	2010 2008	39.1 - 32.8	39.4 - 33.1	39.7 - 41.9	39.7 - 41.9	47.6 - 44.3	47.6 - 44.3	47.6 - 44.3	47.6 - 44.3	47.6 - 44.3
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	30.2 - 31.5	32.6 - 33.6	35.0 - 35.8	35.6 - 37.2	37.7 - 38.1	38.3 - 38.4	39.1 - 41.1	41.4 - 43.0	42.4 - 43.5
Volkswagen	2010 2008	30.3 - 28.1	32.4 - 30.9	35.0 - 36.5	38.9 - 36.4	39.0 - 36.2	39.3 - 36.2	40.1 - 36.4	41.7 - 39.5	43.8 - 39.5
Total/Average	2010 2008	30.2 - 31.0	31.1 - 32.2	32.9 - 34.6	34.9 - 36.4	36.9 - 38.1	37.6 - 38.9	38.6 - 39.9	39.7 - 40.8	41.0 - 41.4

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
5% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	34.4 - 36.2	34.4 - 36.4	35.3 - 36.5	35.3 - 37.5	36.0 - 38.3	41.6 - 39.5	41.6 - 39.5	41.6 - 39.5	42.1 - 39.5
Daimler	2010 2008	32.2 - 35.3	33.7 - 35.5	33.8 - 35.7	35.1 - 36.3	35.2 - 36.2	37.1 - 37.6	38.0 - 37.5	38.1 - 37.6	38.5 - 37.8
Fiat	2010 2008	30.7 - 31.7	30.7 - 31.7	30.7 - 31.7	30.7 - 31.7	30.7 - 31.7	35.0 - 41.9	41.9 - 43.8	42.1 - 44.6	43.5 - 44.7
Ford	2010 2008	29.1 - 29.6	29.6 - 30.9	30.2 - 31.3	31.4 - 34.8	38.9 - 39.5	39.2 - 41.0	39.4 - 41.6	40.2 - 42.2	40.2 - 47.0
Geely	2010 2008	28.7 - 31.7	37.2 - 36.4	37.9 - 36.7	37.8 - 36.7	39.3 - 36.7	40.3 - 40.2	42.4 - 41.6	42.4 - 41.6	42.4 - 41.6
General Motors	2010 2008	28.5 - 28.6	29.1 - 30.2	32.0 - 35.8	38.7 - 39.3	38.9 - 39.6	39.1 - 39.7	39.7 - 40.8	40.4 - 40.8	42.8 - 40.8
Honda	2010 2008	33.2 - 36.6	33.7 - 36.9	37.7 - 38.4	38.2 - 39.6	41.1 - 42.1	45.0 - 46.5	46.1 - 47.6	47.2 - 49.0	47.7 - 50.6
Hyundai	2010 2008	34.6 - 35.9	35.5 - 36.1	42.3 - 39.8	42.8 - 40.2	42.8 - 40.2	46.9 - 45.0	46.9 - 45.0	52.5 - 51.4	52.9 - 51.5
Kia	2010 2008	33.7 - 33.7	33.9 - 34.0	39.1 - 36.9	39.1 - 38.7	43.4 - 44.0	43.4 - 44.0	45.5 - 45.4	47.2 - 46.4	47.2 - 46.4
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	31.6 - 29.9	39.9 - 40.7	39.9 - 40.9	40.1 - 41.8	40.1 - 41.8	40.1 - 41.8	45.7 - 47.3	50.4 - 50.4	50.3 - 51.9
Mitsubishi	2010 2008	38.8 - 34.6	39.5 - 34.8	39.7 - 35.0	39.7 - 35.4	48.8 - 48.0	48.8 - 48.0	48.8 - 47.9	48.8 - 48.0	48.8 - 48.0
Nissan	2010 2008	31.0 - 32.8	31.0 - 33.1	36.6 - 36.2	38.3 - 37.8	38.9 - 41.0	40.7 - 42.8	40.8 - 42.8	45.0 - 44.7	47.0 - 44.7
Porsche	2010 2008	28.0 - 30.4	28.5 - 32.0	36.8 - 34.2	36.8 - 34.2	36.8 - 34.2	37.6 - 34.7	37.6 - 37.6	37.6 - 37.6	37.6 - 37.6

Spyker	2010 2008	- - 32.9	- - 34.5	- - 34.6	- - 34.6	- - 37.2	- - 37.2	- - 37.2	- - 37.2	- - 37.2
Subaru	2010 2008	39.2 - 37.0	40.3 - 40.8	51.2 - 48.6	51.2 - 48.6	51.3 - 49.6	51.3 - 50.4	51.3 - 50.4	51.3 - 55.9	51.3 - 55.8
Suzuki	2010 2008	39.4 - 33.4	39.6 - 33.6	41.0 - 42.8	41.0 - 42.8	48.9 - 45.4	48.9 - 45.4	48.9 - 45.4	48.9 - 45.4	48.9 - 51.9
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	31.0 - 31.6	33.2 - 34.6	36.3 - 37.4	37.3 - 39.0	39.3 - 40.7	40.4 - 41.6	42.4 - 43.6	46.3 - 46.8	47.0 - 48.1
Volkswagen	2010 2008	30.3 - 28.1	32.9 - 30.9	35.6 - 37.3	39.4 - 37.3	39.5 - 37.2	39.8 - 37.1	40.4 - 37.4	41.7 - 39.5	43.8 - 39.5
Total/Average	2010 2008	30.5 - 31.3	31.3 - 32.9	33.7 - 35.8	36.2 - 38.4	38.7 - 40.3	39.6 - 41.4	41.4 - 42.5	42.8 - 43.9	43.9 - 44.9

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
6% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	34.4 - 36.5	34.4 - 36.7	35.3 - 37.2	35.3 - 37.6	36.0 - 38.5	41.6 - 40.0	41.6 - 39.9	41.6 - 39.9	42.1 - 39.8
Daimler	2010 2008	32.2 - 35.5	33.7 - 35.8	33.8 - 35.9	35.1 - 36.5	35.2 - 36.3	37.1 - 37.6	38.0 - 37.5	38.1 - 37.6	38.5 - 37.8
Fiat	2010 2008	30.7 - 32.4	30.7 - 32.4	30.7 - 32.4	30.7 - 32.4	30.7 - 32.4	35.0 - 44.2	42.0 - 45.8	42.1 - 46.4	43.6 - 47.9
Ford	2010 2008	29.5 - 30.5	30.1 - 32.0	30.5 - 32.2	31.8 - 39.1	40.2 - 43.0	40.5 - 43.5	40.6 - 44.2	41.3 - 45.4	45.0 - 45.6
Geely	2010 2008	28.7 - 31.5	37.2 - 36.1	37.9 - 36.6	37.8 - 36.6	39.3 - 36.6	40.3 - 40.3	42.4 - 41.6	42.4 - 41.6	42.4 - 41.6
General Motors	2010 2008	28.5 - 28.9	29.1 - 30.5	32.0 - 35.8	38.8 - 40.0	38.9 - 40.4	39.3 - 40.7	39.8 - 42.1	40.7 - 42.8	45.0 - 47.0
Honda	2010 2008	34.9 - 36.8	35.4 - 37.1	38.2 - 38.9	38.8 - 40.1	42.7 - 43.5	46.7 - 49.9	47.5 - 49.9	50.0 - 50.5	50.3 - 52.2
Hyundai	2010 2008	35.1 - 36.3	35.3 - 36.5	44.7 - 42.3	44.9 - 43.2	44.9 - 43.2	50.4 - 47.9	52.1 - 47.9	58.1 - 51.3	58.1 - 51.4
Kia	2010 2008	35.1 - 34.5	35.4 - 35.0	40.6 - 37.4	40.6 - 40.0	47.2 - 49.0	47.2 - 49.1	51.8 - 50.4	51.9 - 50.4	51.9 - 50.4
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	32.0 - 30.0	39.9 - 45.3	39.9 - 45.5	40.5 - 46.3	40.5 - 46.4	40.5 - 46.8	50.2 - 50.3	53.8 - 51.6	53.8 - 53.9
Mitsubishi	2010 2008	38.9 - 37.6	39.2 - 37.8	39.3 - 37.9	39.3 - 39.6	56.8 - 45.4	56.8 - 45.4	56.8 - 45.4	56.8 - 45.4	56.8 - 45.4
Nissan	2010 2008	32.2 - 33.2	32.2 - 33.5	36.7 - 37.0	39.4 - 38.3	41.0 - 42.7	43.5 - 44.1	43.6 - 44.1	47.1 - 44.4	47.5 - 45.0
Porsche	2010 2008	28.0 - 30.4	28.5 - 32.0	36.9 - 34.6	36.9 - 34.6	36.9 - 34.6	37.6 - 35.1	37.6 - 37.6	37.6 - 37.6	37.6 - 37.6

Spyker	2010 2008	- - 32.9	- - 34.5	- - 34.6	- - 34.6	- - 37.2	- - 37.2	- - 37.2	- - 37.2	- - 37.2
Subaru	2010 2008	39.3 - 37.5	39.9 - 42.4	50.5 - 52.1	50.5 - 52.2	50.6 - 53.2	50.6 - 53.2	50.6 - 53.2	63.6 - 57.3	63.6 - 57.3
Suzuki	2010 2008	38.2 - 34.9	38.4 - 35.1	40.3 - 42.7	40.3 - 42.7	49.6 - 52.6	49.6 - 52.6	49.6 - 52.6	49.6 - 52.6	49.6 - 58.7
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	31.5 - 32.4	34.0 - 35.6	38.0 - 38.8	39.2 - 40.8	41.1 - 43.0	42.6 - 44.4	44.8 - 45.3	51.6 - 51.8	52.0 - 52.2
Volkswagen	2010 2008	30.3 - 28.1	32.9 - 30.9	35.6 - 37.3	40.1 - 37.3	40.1 - 37.7	40.2 - 37.6	40.9 - 37.9	42.3 - 39.5	43.9 - 39.5
Total/Average	2010 2008	30.8 - 31.9	31.8 - 33.5	34.1 - 36.5	36.8 - 39.9	39.5 - 42.0	40.6 - 43.4	42.4 - 44.3	44.4 - 46.1	46.6 - 47.7

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
7% Annual Increase

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	34.4 - 36.3	34.4 - 36.5	35.3 - 36.6	35.3 - 37.4	36.0 - 38.6	41.6 - 39.9	41.6 - 39.8	41.6 - 39.9	42.1 - 39.8
Daimler	2010 2008	32.2 - 35.6	33.7 - 35.8	33.8 - 35.9	35.1 - 36.5	35.2 - 36.3	37.1 - 37.6	38.0 - 37.5	38.1 - 37.6	38.5 - 37.8
Fiat	2010 2008	30.7 - 32.3	30.7 - 32.3	30.7 - 32.3	30.7 - 32.3	30.7 - 32.3	35.0 - 43.4	42.0 - 46.7	42.1 - 47.1	43.6 - 49.0
Ford	2010 2008	29.8 - 30.6	30.4 - 32.5	31.0 - 32.8	34.2 - 36.4	41.9 - 42.1	42.1 - 43.0	42.0 - 44.4	42.6 - 45.1	43.0 - 51.5
Geely	2010 2008	28.7 - 31.0	37.2 - 36.5	37.9 - 37.1	37.8 - 37.1	39.3 - 37.1	40.3 - 41.0	42.4 - 41.0	42.4 - 41.0	42.4 - 41.0
General Motors	2010 2008	28.9 - 29.3	29.5 - 30.9	32.9 - 36.1	39.2 - 40.9	39.4 - 41.5	39.8 - 41.7	40.4 - 42.9	40.7 - 43.7	44.4 - 46.0
Honda	2010 2008	36.0 - 37.6	36.7 - 37.8	39.9 - 40.0	40.5 - 40.7	42.5 - 45.3	45.8 - 52.0	46.2 - 52.1	48.5 - 53.1	48.7 - 54.7
Hyundai	2010 2008	36.5 - 37.4	37.1 - 37.6	46.6 - 43.0	47.3 - 43.7	47.3 - 43.7	50.8 - 51.7	51.3 - 51.7	75.3 - 55.7	75.3 - 55.8
Kia	2010 2008	34.9 - 35.5	35.2 - 36.0	41.7 - 38.8	41.7 - 41.6	48.3 - 49.5	48.3 - 49.5	69.8 - 62.0	70.5 - 62.6	70.7 - 62.6
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	32.1 - 30.0	42.0 - 44.2	41.9 - 44.3	42.6 - 45.1	44.3 - 45.6	44.3 - 45.6	51.1 - 52.7	54.1 - 53.2	54.1 - 53.5
Mitsubishi	2010 2008	38.9 - 37.9	39.2 - 38.1	39.3 - 38.2	39.3 - 39.6	56.8 - 45.0	56.8 - 45.0	56.8 - 45.0	56.8 - 45.0	56.8 - 45.0
Nissan	2010 2008	33.2 - 33.7	33.3 - 34.0	37.7 - 37.4	40.7 - 38.6	42.7 - 42.9	44.5 - 43.4	44.6 - 43.6	46.1 - 45.6	47.1 - 45.7
Porsche	2010 2008	28.0 - 30.4	28.5 - 32.0	36.9 - 34.6	36.9 - 34.6	36.9 - 34.6	37.6 - 35.1	37.6 - 37.6	37.6 - 37.6	37.6 - 37.6

Spyker	2010 2008	- - 32.9	- - 34.5	- - 34.6	- - 34.6	- - 37.2	- - 37.2	- - 37.2	- - 37.2	- - 37.2
Subaru	2010 2008	39.3 - 37.5	39.8 - 43.0	50.4 - 53.1	50.4 - 53.1	50.5 - 53.2	51.5 - 53.2	51.5 - 53.2	77.6 - 65.0	77.6 - 65.0
Suzuki	2010 2008	38.2 - 35.0	38.4 - 35.2	40.3 - 42.6	40.3 - 42.6	49.6 - 52.4	49.6 - 52.4	49.6 - 52.4	49.6 - 52.4	49.6 - 65.3
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	31.6 - 32.7	34.4 - 37.0	38.5 - 40.9	39.7 - 42.8	43.8 - 45.2	44.8 - 46.7	46.5 - 48.9	50.5 - 50.9	50.8 - 51.5
Volkswagen	2010 2008	30.3 - 28.1	32.9 - 30.9	35.6 - 37.3	40.1 - 37.3	40.1 - 37.7	40.2 - 37.6	40.9 - 37.9	42.3 - 39.5	43.9 - 39.5
Total/Average	2010 2008	31.1 - 32.2	32.2 - 34.1	34.7 - 37.2	37.8 - 40.2	40.5 - 42.8	41.4 - 44.2	43.1 - 45.6	44.7 - 46.8	46.1 - 48.6

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
Max Net Benefits, 3% Discount Rate

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	34.4 - 37.4	34.4 - 37.6	35.3 - 38.0	35.3 - 38.2	36.0 - 39.1	41.6 - 39.9	41.6 - 39.8	41.6 - 39.9	42.1 - 39.8
Daimler	2010 2008	32.2 - 35.8	33.7 - 36.1	33.8 - 36.2	35.1 - 36.5	35.2 - 36.4	37.1 - 37.6	38.0 - 37.5	38.1 - 37.6	38.5 - 37.8
Fiat	2010 2008	30.7 - 33.5	30.7 - 33.5	30.7 - 33.5	30.7 - 33.5	30.7 - 33.5	35.0 - 39.7	42.0 - 43.9	42.1 - 44.7	43.6 - 46.6
Ford	2010 2008	30.0 - 32.0	30.2 - 32.6	31.5 - 33.3	32.4 - 39.3	39.2 - 43.0	39.3 - 43.0	39.3 - 43.4	39.6 - 44.4	40.0 - 44.5
Geely	2010 2008	28.7 - 31.8	37.2 - 36.5	37.9 - 36.6	37.8 - 36.6	39.3 - 36.6	40.3 - 40.2	42.4 - 41.6	42.4 - 41.6	42.4 - 41.6
General Motors	2010 2008	29.4 - 31.7	29.9 - 33.1	32.5 - 36.9	38.5 - 39.6	38.6 - 40.3	38.6 - 40.7	39.0 - 41.6	40.3 - 42.5	43.1 - 44.3
Honda	2010 2008	34.2 - 37.8	34.6 - 38.1	39.1 - 40.2	39.8 - 41.1	42.0 - 44.6	45.1 - 47.7	45.6 - 47.7	46.8 - 48.6	46.9 - 48.7
Hyundai	2010 2008	36.7 - 37.7	36.9 - 37.9	44.8 - 43.6	44.9 - 44.4	44.9 - 44.4	47.5 - 46.7	47.5 - 46.7	50.6 - 49.4	51.1 - 49.5
Kia	2010 2008	35.2 - 36.5	35.4 - 36.9	39.2 - 37.1	39.3 - 39.1	45.5 - 44.6	45.4 - 44.7	47.8 - 45.7	47.8 - 45.7	48.2 - 45.7
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	33.4 - 33.3	41.3 - 42.3	41.3 - 42.5	41.9 - 43.6	42.8 - 44.0	42.8 - 44.0	46.3 - 47.0	49.0 - 48.1	49.0 - 48.1
Mitsubishi	2010 2008	38.9 - 38.0	39.2 - 38.2	39.3 - 38.3	39.3 - 39.6	51.9 - 48.0	51.9 - 48.0	51.9 - 47.9	51.9 - 48.0	51.9 - 48.0
Nissan	2010 2008	32.9 - 35.7	32.9 - 35.9	37.2 - 38.0	39.6 - 44.5	41.3 - 46.5	42.7 - 46.5	42.8 - 46.4	43.5 - 46.8	44.9 - 46.8
Porsche	2010 2008	28.0 - 30.4	28.5 - 32.0	36.9 - 34.6	36.9 - 34.6	36.9 - 34.6	37.6 - 35.1	37.6 - 37.6	37.6 - 37.6	37.6 - 37.6

Spyker	2010 2008	- - 32.9	- - 34.5	- - 34.6	- - 34.6	- - 37.2	- - 37.2	- - 37.2	- - 37.2	- - 37.2
Subaru	2010 2008	39.3 - 39.2	39.9 - 42.4	50.3 - 52.2	50.3 - 52.3	50.5 - 52.3	50.5 - 52.4	50.5 - 52.3	51.0 - 55.3	51.0 - 55.3
Suzuki	2010 2008	38.9 - 34.3	39.2 - 34.5	40.3 - 46.3	40.3 - 46.3	67.7 - 47.1	67.7 - 47.1	67.7 - 47.1	67.7 - 47.2	67.7 - 52.2
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	31.8 - 35.4	34.4 - 38.1	36.7 - 40.1	37.8 - 40.8	40.3 - 43.0	41.6 - 43.9	42.7 - 44.7	44.1 - 46.3	44.5 - 47.1
Volkswagen	2010 2008	30.3 - 28.1	32.9 - 30.9	35.6 - 37.3	40.1 - 37.3	40.1 - 37.7	40.2 - 37.6	40.9 - 37.9	42.3 - 39.5	43.9 - 39.5
Total/Average	2010 2008	31.2 - 34.0	32.1 - 35.2	34.3 - 37.5	36.7 - 40.2	39.1 - 42.1	39.9 - 42.8	41.3 - 43.6	42.2 - 44.6	43.3 - 45.4

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
Max Net Benefits, 7% Discount Rate

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	34.4 - 37.4	34.4 - 37.6	35.3 - 38.0	35.3 - 38.2	36.0 - 39.1	41.6 - 39.9	41.6 - 39.8	41.6 - 39.9	42.1 - 39.8
Daimler	2010 2008	32.2 - 35.8	33.7 - 36.1	33.8 - 36.2	35.1 - 36.5	35.2 - 36.4	37.1 - 37.6	38.0 - 37.5	38.1 - 37.6	38.5 - 37.8
Fiat	2010 2008	30.7 - 33.5	30.7 - 33.5	30.7 - 33.5	30.7 - 33.5	30.7 - 33.5	35.0 - 39.3	42.0 - 43.0	42.1 - 43.6	43.6 - 45.1
Ford	2010 2008	30.0 - 31.8	30.2 - 32.4	31.5 - 33.1	32.2 - 35.5	38.6 - 40.6	38.7 - 40.8	38.7 - 41.1	38.9 - 41.6	42.1 - 41.6
Geely	2010 2008	28.7 - 31.8	37.2 - 36.5	37.9 - 36.6	37.8 - 36.6	39.3 - 36.6	40.3 - 40.2	42.4 - 41.6	42.4 - 41.6	42.4 - 41.6
General Motors	2010 2008	29.4 - 31.7	29.9 - 33.0	32.5 - 36.6	38.4 - 38.8	38.6 - 39.5	38.6 - 39.8	38.7 - 40.4	39.9 - 41.2	42.9 - 42.7
Honda	2010 2008	34.2 - 37.3	34.6 - 37.5	39.1 - 40.3	39.8 - 41.3	42.4 - 43.7	45.4 - 46.6	46.2 - 46.6	47.0 - 47.4	47.2 - 47.6
Hyundai	2010 2008	36.9 - 37.4	37.2 - 37.6	44.3 - 43.4	44.9 - 43.6	44.9 - 43.6	46.3 - 45.2	46.3 - 45.2	50.9 - 46.2	50.9 - 46.2
Kia	2010 2008	35.1 - 35.8	35.4 - 36.2	39.5 - 36.9	39.5 - 38.7	44.9 - 44.5	44.9 - 44.5	45.9 - 45.3	46.3 - 45.4	46.3 - 45.7
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	33.4 - 32.8	40.5 - 42.0	40.4 - 42.1	40.5 - 44.8	41.9 - 44.6	41.9 - 44.6	45.9 - 46.8	47.8 - 48.0	47.7 - 48.0
Mitsubishi	2010 2008	38.9 - 38.0	39.2 - 38.2	39.3 - 38.3	39.3 - 39.6	52.1 - 47.2	52.1 - 47.2	52.1 - 47.1	52.1 - 47.2	52.1 - 47.1
Nissan	2010 2008	32.7 - 35.3	32.8 - 35.5	36.4 - 37.8	38.5 - 44.6	40.6 - 44.5	41.6 - 44.5	41.5 - 44.4	44.0 - 44.6	45.1 - 44.5
Porsche	2010 2008	28.0 - 30.4	28.5 - 32.0	36.9 - 34.6	36.9 - 34.6	36.9 - 34.6	37.6 - 35.1	37.6 - 37.6	37.6 - 37.6	37.6 - 37.6

Spyker	2010 2008	- - 32.9	- - 34.5	- - 34.6	- - 34.6	- - 37.2	- - 37.2	- - 37.2	- - 37.2	- - 37.2
Subaru	2010 2008	39.3 - 38.1	39.9 - 41.1	49.7 - 49.8	49.7 - 49.9	49.9 - 49.9	49.9 - 50.0	49.9 - 49.9	54.0 - 53.3	54.0 - 53.3
Suzuki	2010 2008	38.7 - 33.2	38.9 - 33.4	40.3 - 45.6	40.3 - 45.6	49.6 - 47.1	49.6 - 47.1	49.6 - 47.1	49.6 - 47.1	49.6 - 48.5
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	32.1 - 35.2	34.4 - 38.0	37.0 - 39.9	38.1 - 40.3	40.1 - 41.8	41.1 - 42.5	42.8 - 42.8	44.3 - 44.3	44.6 - 45.2
Volkswagen	2010 2008	30.3 - 28.1	32.9 - 30.9	35.6 - 37.3	40.1 - 37.3	40.1 - 37.7	40.2 - 37.6	40.9 - 37.9	42.3 - 39.5	43.9 - 39.5
Total/Average	2010 2008	31.3 - 33.8	32.1 - 35.0	34.3 - 37.4	36.6 - 39.3	38.9 - 41.0	39.6 - 41.7	41.1 - 42.2	42.0 - 43.0	43.8 - 43.8

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
Total Cost=Total Benefit, 3% Discount Rate

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	34.4 - 37.4	34.4 - 37.6	35.3 - 38.0	35.3 - 38.2	36.0 - 39.1	41.6 - 39.9	41.6 - 39.8	41.6 - 39.9	42.1 - 39.8
Daimler	2010 2008	32.2 - 35.8	33.7 - 36.1	33.8 - 36.2	35.1 - 36.5	35.2 - 36.4	37.1 - 37.6	38.0 - 37.5	38.1 - 37.6	38.5 - 37.8
Fiat	2010 2008	30.7 - 33.7	30.7 - 33.7	30.7 - 33.7	30.7 - 33.7	30.7 - 33.7	35.0 - 40.0	42.0 - 43.5	42.1 - 44.2	43.6 - 46.9
Ford	2010 2008	29.8 - 32.5	29.9 - 33.0	30.9 - 33.7	33.1 - 39.5	39.2 - 43.6	39.3 - 43.6	39.3 - 44.2	39.5 - 44.8	41.4 - 45.2
Geely	2010 2008	28.7 - 31.8	37.2 - 36.5	37.9 - 36.6	37.8 - 36.6	39.3 - 36.6	40.3 - 40.2	42.4 - 41.6	42.4 - 41.6	42.4 - 41.6
General Motors	2010 2008	29.4 - 31.7	29.9 - 33.1	32.5 - 36.9	38.5 - 39.9	38.6 - 40.7	38.6 - 40.9	39.0 - 42.1	40.3 - 42.8	42.5 - 44.6
Honda	2010 2008	36.1 - 38.2	36.6 - 38.4	39.1 - 41.8	39.9 - 42.7	42.1 - 45.1	44.8 - 49.0	45.5 - 49.0	46.9 - 49.6	47.1 - 49.7
Hyundai	2010 2008	37.2 - 38.9	37.4 - 39.2	44.8 - 44.4	45.1 - 44.9	45.1 - 44.9	47.5 - 48.2	47.5 - 48.2	50.6 - 50.3	51.1 - 50.4
Kia	2010 2008	35.2 - 36.8	35.4 - 37.2	40.0 - 37.5	40.0 - 39.6	44.4 - 45.2	44.3 - 45.2	45.7 - 45.5	46.7 - 45.5	46.7 - 46.1
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	33.4 - 33.4	41.3 - 42.5	41.3 - 42.7	41.9 - 45.4	43.6 - 45.0	43.6 - 44.8	47.6 - 46.7	49.6 - 48.3	49.6 - 48.3
Mitsubishi	2010 2008	38.9 - 38.0	39.2 - 38.2	39.3 - 38.3	39.3 - 39.6	51.9 - 48.0	51.9 - 48.0	51.9 - 47.9	51.9 - 48.0	51.9 - 48.0
Nissan	2010 2008	32.9 - 35.8	32.9 - 36.0	37.1 - 37.9	39.7 - 44.3	41.7 - 46.2	42.2 - 46.1	42.1 - 46.3	44.0 - 46.7	44.5 - 46.6

Porsche	2010 2008	28.0 - 30.4	28.5 - 32.0	36.9 - 34.6	36.9 - 34.6	36.9 - 34.6	37.6 - 35.1	37.6 - 37.6	37.6 - 37.6	37.6 - 37.6
Spyker	2010 2008	- - 32.9	- - 34.5	- - 34.6	- - 34.6	- - 37.2				
Subaru	2010 2008	39.3 - 39.4	39.9 - 42.5	49.7 - 51.9	49.7 - 52.0	49.9 - 52.1	49.9 - 52.1	49.9 - 52.1	54.0 - 55.9	54.0 - 55.9
Suzuki	2010 2008	39.1 - 34.4	39.4 - 34.6	39.5 - 45.0	39.5 - 45.0	52.5 - 46.9	52.5 - 46.9	52.5 - 46.9	52.5 - 46.9	52.5 - 52.0
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	32.0 - 35.5	34.5 - 38.1	36.8 - 40.1	37.9 - 40.6	41.9 - 43.0	42.2 - 43.7	43.2 - 44.8	44.8 - 46.5	45.1 - 47.2
Volkswagen	2010 2008	30.3 - 28.1	32.9 - 30.9	35.6 - 37.3	40.1 - 37.3	40.1 - 37.7	40.2 - 37.6	40.9 - 37.9	42.3 - 39.5	43.9 - 39.5
Total/Average	2010 2008	31.4 - 34.2	32.2 - 35.4	34.2 - 37.8	36.9 - 40.4	39.4 - 42.3	39.9 - 43.0	41.3 - 43.9	42.3 - 44.8	43.6 - 45.7

Estimated Achievable Fuel Economy Levels, by Alternative
Estimated mpg
Light Trucks
Total Cost=Total Benefit, 7% Discount Rate

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	34.4 - 37.4	34.4 - 37.6	35.3 - 38.0	35.3 - 38.2	36.0 - 39.1	41.6 - 39.9	41.6 - 39.8	41.6 - 39.9	42.1 - 39.8
Daimler	2010 2008	32.2 - 35.8	33.7 - 36.1	33.8 - 36.2	35.1 - 36.5	35.2 - 36.4	37.1 - 37.6	38.0 - 37.5	38.1 - 37.6	38.5 - 37.8
Fiat	2010 2008	30.7 - 33.7	30.7 - 33.7	30.7 - 33.7	30.7 - 33.7	30.7 - 33.7	35.0 - 40.0	42.0 - 43.5	42.1 - 44.2	43.6 - 46.9
Ford	2010 2008	29.8 - 32.5	29.9 - 33.0	30.9 - 33.7	33.1 - 39.5	39.2 - 43.6	39.3 - 43.6	39.3 - 44.2	39.5 - 44.8	41.4 - 45.2
Geely	2010 2008	28.7 - 31.8	37.2 - 36.5	37.9 - 36.6	37.8 - 36.6	39.3 - 36.6	40.3 - 40.2	42.4 - 41.6	42.4 - 41.6	42.4 - 41.6
General Motors	2010 2008	29.4 - 31.7	29.9 - 33.1	32.5 - 36.9	38.5 - 39.9	38.6 - 40.7	38.6 - 40.9	39.0 - 42.1	40.3 - 42.8	42.5 - 44.6
Honda	2010 2008	36.1 - 38.2	36.6 - 38.4	39.1 - 41.8	39.9 - 42.7	42.1 - 45.1	44.8 - 49.0	45.5 - 49.0	46.9 - 49.6	47.1 - 49.7
Hyundai	2010 2008	37.2 - 38.9	37.4 - 39.2	44.8 - 44.4	45.1 - 44.9	45.1 - 44.9	47.5 - 48.2	47.5 - 48.2	50.6 - 50.3	51.1 - 50.4
Kia	2010 2008	35.2 - 36.8	35.4 - 37.2	40.0 - 37.5	40.0 - 39.6	44.4 - 45.2	44.3 - 45.2	45.7 - 45.5	46.7 - 45.5	46.7 - 46.1
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	33.4 - 33.4	41.3 - 42.5	41.3 - 42.7	41.9 - 45.4	43.6 - 45.0	43.6 - 44.8	47.6 - 46.7	49.6 - 48.3	49.6 - 48.3
Mitsubishi	2010 2008	38.9 - 38.0	39.2 - 38.2	39.3 - 38.3	39.3 - 39.6	51.9 - 48.0	51.9 - 48.0	51.9 - 47.9	51.9 - 48.0	51.9 - 48.0
Nissan	2010 2008	32.9 - 35.8	32.9 - 36.0	37.1 - 37.9	39.7 - 44.3	41.7 - 46.2	42.2 - 46.1	42.1 - 46.3	44.0 - 46.7	44.5 - 46.6
Porsche	2010 2008	28.0 - 30.4	28.5 - 32.0	36.9 - 34.6	36.9 - 34.6	36.9 - 34.6	37.6 - 35.1	37.6 - 37.6	37.6 - 37.6	37.6 - 37.6

Spyker	2010 2008	- - 32.9	- - 34.5	- - 34.6	- - 34.6	- - 37.2	- - 37.2	- - 37.2	- - 37.2	- - 37.2
Subaru	2010 2008	39.3 - 39.4	39.9 - 42.5	49.7 - 51.9	49.7 - 52.0	49.9 - 52.1	49.9 - 52.1	49.9 - 52.1	54.0 - 55.9	54.0 - 55.9
Suzuki	2010 2008	39.1 - 34.4	39.4 - 34.6	39.5 - 45.0	39.5 - 45.0	52.5 - 46.9	52.5 - 46.9	52.5 - 46.9	52.5 - 46.9	52.5 - 52.0
Tata	2010 2008	28.3 - 30.5	28.4 - 30.7	29.0 - 31.6	29.0 - 31.7	33.5 - 35.8	33.7 - 35.8	33.7 - 35.8	33.7 - 35.9	33.7 - 35.8
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	32.0 - 35.5	34.5 - 38.1	36.8 - 40.1	37.9 - 40.6	41.9 - 43.0	42.2 - 43.7	43.2 - 44.8	44.8 - 46.5	45.1 - 47.2
Volkswagen	2010 2008	30.3 - 28.1	32.9 - 30.9	35.6 - 37.3	40.1 - 37.3	40.1 - 37.7	40.2 - 37.6	40.9 - 37.9	42.3 - 39.5	43.9 - 39.5
Total/Average	2010 2008	31.4 - 34.2	32.2 - 35.4	34.2 - 37.8	36.9 - 40.4	39.4 - 42.3	39.9 - 43.0	41.3 - 43.9	42.3 - 44.8	43.6 - 45.7

VII. COST AND SALES IMPACTS

The technology application algorithm implemented with the Volpe model was used as the basis for estimating costs for the fleet. Here, costs refer to costs or fines to manufacturers relative to the adjusted baseline of MY 2016. Manufacturers' costs or fines to bring light duty fleets into compliance with MY 2016 standards are outside the scope of these costs as they have been addressed in the final CAFE rulemaking for MYs 2012 to 2016.

Tables VII-1a to 1v show the estimated cost per vehicle and incremental total costs in millions for the various alternatives for passenger cars. Tables VII-2a to 2v show the estimated cost per vehicle and incremental total costs in millions for the various alternatives for light trucks.

The costs for several manufacturers are the fines that these manufacturers would have to pay in addition to the technology improvements on an average vehicle basis. We assume that the costs of fines will be passed on to consumers. The incremental total cost tables show the estimated total manufacturer costs and fines in millions of dollars. Later in the analysis, when we are considering total societal costs and benefits, fines are not included, since fines are transfer payments and not technology costs.

Note that the choice of the discount rate (3% or 7%) impacts only the Max Net Benefits and Total Cost = Total Benefit scenarios. Therefore, additional detail is given in Tables VII-1 and VII-2 for these scenarios to highlight the results under both discount rates.

Table VII-1a
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Preferred Alternative
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$73 - $84	$150 - $161	$227 - $249	$321 - $343	$420 - $447	$541 - $568	$662 - $700	$783 - $832	$915 - $970
BMW	2010 2008	$87 - $78	$251 - $302	$307 - $320	$388 - $336	$535 - $610	$814 - $771	$961 - $939	$1,808 - $2,141	$1,706 - $1,930
Daimler	2010 2008	$68 - $90	$141 - $157	$218 - $253	$303 - $694	$429 - $789	$715 - $1,010	$1,054 - $1,413	$1,162 - $1,555	$1,601 - $2,059
Fiat	2010 2008	$324 - $257	$400 - $495	$656 - $491	$885 - $916	$1,160 - $956	$1,159 - $1,057	$1,415 - $1,357	$1,614 - $1,399	$1,523 - $1,657
Ford	2010 2008	$321 - $141	$328 - $162	$458 - $467	$803 - $902	$914 - $1,278	$1,084 - $1,612	$1,074 - $1,637	$1,460 - $1,616	$1,422 - $2,136
Geely	2010 2008	$73 - $189	$313 - $370	$767 - $726	$809 - $707	$815 - $857	$954 - $970	$1,159 - $1,240	$1,426 - $1,421	$2,072 - $1,497
General Motors	2010 2008	$207 - $235	$476 - $556	$500 - $692	$721 - $1,058	$915 - $1,175	$898 - $1,165	$1,131 - $1,298	$1,154 - $1,293	$1,340 - $1,363
Honda	2010 2008	$250 - $157	$663 - $428	$728 - $474	$720 - $512	$1,028 - $1,001	$1,018 - $1,101	$1,196 - $1,188	$1,204 - $1,204	$1,163 - $1,146
Hyundai	2010 2008	$561 - $551	$591 - $607	$756 - $899	$737 - $933	$892 - $1,005	$1,091 - $1,114	$1,114 - $1,115	$1,222 - $1,091	$1,257 - $1,051
Kia	2010 2008	$339 - $186	$322 - $106	$636 - $543	$876 - $932	$953 - $982	$1,111 - $1,056	$1,125 - $1,098	$1,107 - $1,074	$1,076 - $1,561
Lotus	2010 2008	$242 - $90	$322 - $178	$1,228 - $255	$1,306 - $354	$1,396 - $469	$1,503 - $601	$758 - $739	$894 - $882	$1,025 - $1,036
Mazda	2010 2008	$458 - $417	$508 - $599	$512 - $542	$880 - $955	$856 - $924	$1,219 - $1,461	$1,307 - $1,438	$1,300 - $1,479	$1,234 - $1,481
Mitsubishi	2010 2008	$397 - $267	$503 - $630	$456 - $601	$1,357 - $1,429	$2,121 - $2,156	$2,102 - $2,110	$2,065 - $2,081	$2,063 - $2,407	$1,880 - $2,121

Nissan	2010 2008	$361 - $190	$437 - $318	$656 - $868	$655 - $975	$717 - $979	$898 - $1,330	$941 - $1,406	$1,235 - $1,621	$1,193 - $1,570
Porsche	2010 2008	$62 - $79	$110 - $310	$168 - $410	$283 - $493	$518 - $603	$1,200 - $635	$1,388 - $774	$1,521 - $886	$1,488 - $1,044
Spyker	2010 2008	- - $79	- - $203	- - $334	- - $453	- - $572	- - $742	- - $1,259	- - $1,965	- - $1,798
Subaru	2010 2008	$13 - $321	$15 - $351	$590 - $593	$1,498 - $1,437	$1,469 - $1,384	$1,467 - $1,342	$1,480 - $1,498	$2,065 - $1,674	$2,197 - $2,892
Suzuki	2010 2008	$349 - $5	$346 - $16	$682 - $1,002	$813 - $1,096	$1,085 - $1,210	$1,185 - $1,288	$1,210 - $1,268	$1,192 - $1,313	$1,635 - $1,791
Tata	2010 2008	$73 - $342	$153 - $676	$231 - $621	$313 - $649	$378 - $789	$484 - $1,036	$849 - $1,260	$962 - $1,367	$1,196 - $1,490
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$257 - $205	$319 - $414	$755 - $558	$811 - $718	$1,006 - $926	$1,014 - $929	$1,003 - $915	$1,291 - $1,506	$1,225 - $1,426
Volkswagen	2010 2008	$170 - $82	$493 - $171	$570 - $251	$757 - $776	$920 - $953	$1,037 - $1,130	$1,183 - $1,328	$1,337 - $1,392	$1,773 - $1,783
Total/Average	2010 2008	$284 - $208	$424 - $377	$603 - $571	$762 - $837	$934 - $1,034	$1,024 - $1,168	$1,129 - $1,255	$1,328 - $1,440	$1,361 - $1,577

Table VII-1b
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Preferred Alternative
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $1	$0 - $1	$0 - $1	$1 - $1
BMW	2010 2008	$28 - $24	$80 - $98	$100 - $111	$128 - $120	$180 - $219	$278 - $278	$333 - $339	$647 - $831	$620 - $782
Daimler	2010 2008	$17 - $26	$34 - $43	$54 - $71	$74 - $202	$107 - $237	$180 - $308	$267 - $442	$301 - $517	$418 - $702
Fiat	2010 2008	$237 - $110	$295 - $202	$506 - $197	$697 - $390	$936 - $413	$962 - $460	$1,206 - $591	$1,420 - $612	$1,373 - $742
Ford	2010 2008	$433 - $184	$442 - $212	$615 - $623	$1,083 - $1,243	$1,244 - $1,791	$1,494 - $2,281	$1,499 - $2,414	$2,071 - $2,430	$2,049 - $3,289
Geely	2010 2008	$4 - $17	$18 - $33	$46 - $67	$49 - $66	$50 - $79	$60 - $90	$73 - $120	$93 - $141	$136 - $151
General Motors	2010 2008	$342 - $357	$770 - $856	$806 - $1,082	$1,163 - $1,704	$1,487 - $1,914	$1,471 - $1,911	$1,869 - $2,165	$1,934 - $2,196	$2,273 - $2,368
Honda	2010 2008	$280 - $181	$755 - $487	$835 - $542	$841 - $596	$1,221 - $1,200	$1,235 - $1,362	$1,481 - $1,503	$1,526 - $1,574	$1,507 - $1,536
Hyundai	2010 2008	$485 - $326	$502 - $351	$648 - $524	$635 - $558	$779 - $616	$968 - $700	$1,002 - $707	$1,123 - $717	$1,176 - $712
Kia	2010 2008	$117 - $60	$109 - $33	$209 - $171	$287 - $302	$315 - $325	$373 - $358	$381 - $376	$384 - $378	$377 - $566
Lotus	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$1 - $0	$1 - $0	$0 - $0	$0 - $0	$0 - $0
Mazda	2010 2008	$117 - $98	$126 - $145	$127 - $134	$219 - $237	$213 - $231	$308 - $371	$333 - $385	$337 - $403	$324 - $413

Mitsubishi	2010 2008	$24 - $21	$29 - $47	$28 - $45	$82 - $109	$131 - $166	$133 - $165	$132 - $164	$138 - $198	$128 - $180
Nissan	2010 2008	$321 - $166	$380 - $270	$573 - $742	$572 - $860	$631 - $894	$795 - $1,247	$841 - $1,342	$1,121 - $1,593	$1,098 - $1,594
Porsche	2010 2008	$1 - $3	$2 - $11	$3 - $15	$5 - $18	$9 - $22	$21 - $23	$24 - $29	$27 - $35	$26 - $42
Spyker	2010 2008	- - $2	- - $4	- - $7	- - $10	- - $12	- - $16	- - $28	- - $45	- - $42
Subaru	2010 2008	$3 - $72	$3 - $76	$121 - $129	$308 - $321	$304 - $319	$308 - $320	$313 - $362	$445 - $416	$481 - $743
Suzuki	2010 2008	$15 - $0	$15 - $1	$30 - $91	$36 - $103	$49 - $116	$54 - $126	$56 - $126	$57 - $132	$80 - $185
Tata	2010 2008	$2 - $19	$4 - $38	$7 - $36	$9 - $38	$11 - $46	$14 - $61	$25 - $76	$29 - $87	$37 - $97
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$392 - $379	$479 - $760	$1,140 - $1,025	$1,228 - $1,352	$1,539 - $1,763	$1,569 - $1,845	$1,572 - $1,863	$2,064 - $3,133	$1,987 - $3,007
Volkswagen	2010 2008	$82 - $45	$232 - $92	$264 - $135	$348 - $430	$424 - $558	$482 - $670	$553 - $793	$636 - $842	$850 - $1,124
Total/Average	2010 2008	$2,901 - $2,089	$4,276 - $3,761	$6,111 - $5,745	$7,764 - $8,659	$9,630 - $10,923	$10,705 - $12,593	$11,962 - $13,825	$14,356 - $16,280	$14,942 - $18,276

Table VII-1c
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2009 Dollars)
2% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$40 - $51	$84 - $95	$128 - $139	$172 - $189	$222 - $233	$266 - $282	$315 - $337	$359 - $392	$409 - $442
BMW	2010 2008	$52 - $74	$200 - $219	$240 - $218	$256 - $286	$326 - $440	$520 - $606	$596 - $667	$1,377 - $1,608	$1,195 - $1,325
Daimler	2010 2008	$40 - $54	$68 - $101	$123 - $166	$143 - $546	$152 - $586	$449 - $851	$707 - $1,074	$740 - $1,119	$1,098 - $1,272
Fiat	2010 2008	$302 - $101	$281 - $374	$359 - $359	$520 - $630	$636 - $607	$633 - $604	$696 - $770	$693 - $772	$684 - $744
Ford	2010 2008	$230 - $18	$237 - $25	$357 - $107	$559 - $313	$587 - $431	$688 - $492	$694 - $479	$704 - $536	$675 - $493
Geely	2010 2008	$40 - $181	$300 - $335	$746 - $640	$745 - $640	$743 - $709	$729 - $700	$812 - $892	$850 - $1,021	$842 - $957
General Motors	2010 2008	$2 - $153	$181 - $347	$188 - $394	$390 - $542	$632 - $621	$626 - $624	$676 - $677	$672 - $731	$676 - $757
Honda	2010 2008	$151 - $43	$496 - $75	$498 - $0	$509 - $21	$518 - $271	$546 - $308	$684 - $459	$693 - $521	$693 - $560
Hyundai	2010 2008	$234 - $438	$260 - $492	$281 - $558	$299 - $554	$565 - $565	$601 - $588	$613 - $612	$729 - $555	$704 - $541
Kia	2010 2008	$275 - $159	$272 - $143	$427 - $158	$550 - $263	$592 - $444	$651 - $505	$680 - $585	$685 - $561	$868 - $547
Lotus	2010 2008	$209 - $51	$250 - $101	$1,118 - $139	$1,147 - $189	$1,176 - $244	$1,212 - $293	$384 - $348	$437 - $409	$481 - $464
Mazda	2010 2008	$234 - $68	$247 - $259	$227 - $266	$289 - $559	$297 - $528	$471 - $786	$502 - $772	$502 - $762	$487 - $724

Mitsubishi	2010 2008	$174 - $239	$236 - $284	$215 - $269	$468 - $433	$686 - $827	$681 - $794	$664 - $784	$690 - $777	$666 - $721
Nissan	2010 2008	$38 - $188	$46 - $278	$356 - $633	$426 - $677	$403 - $679	$457 - $730	$500 - $792	$845 - $1,078	$814 - $1,066
Porsche	2010 2008	$29 - $78	$44 - $247	$91 - $317	$153 - $323	$274 - $378	$912 - $327	$932 - $380	$1,040 - $402	$941 - $453
Spyker	2010 2008	- - $49	- - $153	- - $251	- - $295	- - $360	- - $448	- - $891	- - $1,370	- - $1,171
Subaru	2010 2008	$5 - $402	$5 - $409	$296 - $1,838	$635 - $1,506	$616 - $1,465	$608 - $1,420	$599 - $1,400	$627 - $1,396	$576 - $1,128
Suzuki	2010 2008	$440 - $35	$434 - $45	$328 - $133	$276 - $140	$310 - $170	$441 - $188	$437 - $186	$433 - $190	$603 - $336
Tata	2010 2008	$46 - $271	$87 - $582	$126 - $527	$170 - $546	$180 - $599	$220 - $742	$513 - $880	$555 - $857	$706 - $906
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$78 - $107	$131 - $250	$361 - $338	$409 - $428	$561 - $447	$567 - $488	$559 - $482	$776 - $530	$733 - $532
Volkswagen	2010 2008	$99 - $65	$436 - $96	$454 - $150	$627 - $606	$682 - $703	$695 - $754	$740 - $841	$850 - $834	$956 - $818
Total/Average	2010 2008	$130 - $125	$232 - $224	$333 - $322	$443 - $449	$546 - $529	$592 - $578	$638 - $631	$744 - $719	$741 - $708

Table VII-1d
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
2% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $1
BMW	2010 2008	$17 - $23	$64 - $71	$79 - $75	$84 - $102	$110 - $158	$178 - $218	$207 - $241	$493 - $624	$434 - $537
Daimler	2010 2008	$10 - $15	$16 - $28	$30 - $47	$35 - $159	$38 - $176	$113 - $259	$179 - $336	$191 - $372	$287 - $433
Fiat	2010 2008	$221 - $43	$208 - $153	$277 - $144	$409 - $268	$514 - $262	$525 - $263	$593 - $335	$610 - $338	$617 - $333
Ford	2010 2008	$310 - $23	$319 - $33	$478 - $142	$753 - $432	$798 - $604	$947 - $696	$968 - $706	$998 - $806	$973 - $760
Geely	2010 2008	$2 - $16	$17 - $30	$45 - $59	$45 - $59	$46 - $66	$46 - $65	$51 - $86	$55 - $101	$55 - $97
General Motors	2010 2008	$3 - $233	$293 - $534	$304 - $617	$629 - $873	$1,026 - $1,011	$1,026 - $1,024	$1,117 - $1,129	$1,127 - $1,243	$1,146 - $1,315
Honda	2010 2008	$170 - $50	$566 - $85	$572 - $0	$594 - $24	$615 - $325	$662 - $381	$847 - $580	$879 - $681	$897 - $750
Hyundai	2010 2008	$203 - $259	$221 - $284	$241 - $325	$257 - $331	$493 - $346	$533 - $369	$551 - $388	$670 - $365	$658 - $366
Kia	2010 2008	$95 - $51	$92 - $45	$141 - $50	$180 - $85	$195 - $147	$219 - $171	$230 - $201	$238 - $197	$304 - $198
Lotus	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0
Mazda	2010 2008	$59 - $16	$62 - $63	$56 - $66	$72 - $139	$74 - $132	$119 - $200	$128 - $207	$130 - $207	$128 - $202

Mitsubishi	2010 2008	$11 - $18	$14 - $21	$13 - $20	$28 - $33	$42 - $64	$43 - $62	$42 - $62	$46 - $64	$45 - $61
Nissan	2010 2008	$34 - $164	$40 - $236	$311 - $540	$372 - $597	$354 - $619	$404 - $684	$447 - $756	$767 - $1,060	$749 - $1,082
Porsche	2010 2008	$1 - $3	$1 - $9	$2 - $11	$3 - $12	$5 - $14	$16 - $12	$16 - $14	$18 - $16	$17 - $18
Spyker	2010 2008	- - $1	- - $3	- - $5	- - $6	- - $8	- - $10	- - $20	- - $31	- - $27
Subaru	2010 2008	$1 - $90	$1 - $89	$61 - $399	$131 - $336	$127 - $338	$127 - $339	$127 - $338	$135 - $347	$126 - $290
Suzuki	2010 2008	$19 - $3	$18 - $4	$14 - $12	$12 - $13	$14 - $16	$20 - $18	$20 - $18	$21 - $19	$29 - $35
Tata	2010 2008	$1 - $15	$2 - $33	$4 - $30	$5 - $32	$5 - $35	$6 - $44	$15 - $53	$17 - $55	$22 - $59
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$119 - $197	$197 - $458	$545 - $620	$620 - $806	$858 - $851	$877 - $970	$877 - $981	$1,240 - $1,102	$1,188 - $1,122
Volkswagen	2010 2008	$48 - $36	$205 - $52	$210 - $80	$288 - $336	$314 - $412	$323 - $447	$346 - $502	$404 - $505	$459 - $516
Total/Average	2010 2008	$1,323 - $1,257	$2,336 - $2,230	$3,382 - $3,244	$4,519 - $4,646	$5,630 - $5,584	$6,186 - $6,233	$6,763 - $6,954	$8,040 - $8,134	$8,136 - $8,203

Table VII-1e
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
3% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$62 - $73	$128 - $139	$194 - $216	$266 - $288	$343 - $359	$420 - $442	$497 - $530	$574 - $612	$656 - $700
BMW	2010 2008	$46 - $75	$252 - $260	$328 - $304	$387 - $375	$563 - $482	$683 - $760	$798 - $850	$1,599 - $1,922	$1,438 - $1,666
Daimler	2010 2008	$57 - $59	$123 - $156	$189 - $226	$254 - $585	$257 - $708	$597 - $889	$886 - $1,251	$951 - $1,346	$1,348 - $1,801
Fiat	2010 2008	$337 - $242	$338 - $478	$490 - $449	$699 - $864	$871 - $858	$872 - $899	$955 - $958	$957 - $957	$924 - $913
Ford	2010 2008	$352 - $94	$365 - $193	$486 - $318	$671 - $586	$707 - $743	$795 - $917	$788 - $875	$838 - $937	$1,111 - $1,025
Geely	2010 2008	$62 - $220	$357 - $372	$769 - $727	$786 - $724	$831 - $809	$822 - $846	$1,001 - $1,083	$1,206 - $1,211	$1,846 - $1,225
General Motors	2010 2008	$69 - $234	$308 - $506	$343 - $545	$528 - $818	$693 - $917	$680 - $922	$725 - $923	$771 - $996	$789 - $965
Honda	2010 2008	$109 - $144	$358 - $338	$402 - $274	$403 - $290	$403 - $596	$462 - $713	$788 - $735	$827 - $779	$787 - $809
Hyundai	2010 2008	$579 - $533	$610 - $590	$757 - $678	$854 - $679	$824 - $693	$973 - $669	$998 - $657	$1,119 - $651	$1,069 - $633
Kia	2010 2008	$235 - $11	$232 - ($75)	$605 - $316	$927 - $636	$998 - $812	$1,199 - $821	$1,197 - $820	$1,177 - $813	$1,212 - $834
Lotus	2010 2008	$231 - $79	$300 - $156	$1,195 - $216	$1,251 - $299	$1,314 - $381	$1,377 - $464	$582 - $557	$668 - $645	$745 - $744
Mazda	2010 2008	$234 - $191	$283 - $378	$261 - $345	$451 - $679	$421 - $652	$809 - $1,165	$905 - $1,178	$908 - $1,187	$981 - $1,176

Mitsubishi	2010 2008	$168 - $373	$280 - $474	$250 - $442	$576 - $864	$1,064 - $1,277	$1,078 - $1,235	$1,059 - $1,217	$1,070 - $1,487	$1,013 - $1,369
Nissan	2010 2008	$9 - $170	$19 - $260	$540 - $798	$592 - $861	$589 - $868	$799 - $1,132	$867 - $1,146	$1,023 - $1,153	$1,007 - $1,122
Porsche	2010 2008	$51 - $116	$88 - $302	$191 - $422	$301 - $442	$481 - $515	$1,096 - $498	$1,113 - $592	$1,307 - $650	$1,224 - $753
Spyker	2010 2008	- - $71	- - $180	- - $318	- - $400	- - $492	- - $616	- - $1,088	- - $1,740	- - $1,523
Subaru	2010 2008	$5 - $81	$5 - $97	$463 - $278	$1,176 - $1,198	$1,155 - $1,148	$1,158 - $1,112	$1,130 - $1,096	$1,663 - $1,099	$1,486 - $2,735
Suzuki	2010 2008	$443 - ($69)	$437 - ($56)	$573 - $771	$661 - $786	$716 - $889	$730 - $859	$717 - $854	$729 - $843	$1,070 - $777
Tata	2010 2008	$68 - $342	$131 - $737	$198 - $667	$264 - $696	$301 - $781	$363 - $860	$689 - $1,330	$759 - $1,371	$943 - $1,407
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$254 - $156	$316 - $378	$545 - $522	$582 - $629	$631 - $694	$643 - $727	$645 - $721	$1,060 - $710	$1,034 - $682
Volkswagen	2010 2008	$161 - $92	$469 - $152	$508 - $244	$679 - $697	$805 - $839	$896 - $991	$999 - $1,030	$1,222 - $1,237	$1,510 - $1,512
Total/Average	2010 2008	$209 - $172	$317 - $330	$476 - $455	$608 - $656	$673 - $764	$755 - $865	$833 - $885	$986 - $962	$1,029 - $1,018

Table VII-1f
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
3% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $1	$0 - $1	$0 - $1
BMW	2010 2008	$15 - $24	$80 - $84	$107 - $105	$128 - $134	$189 - $173	$233 - $274	$277 - $306	$573 - $746	$523 - $675
Daimler	2010 2008	$14 - $17	$30 - $43	$46 - $64	$62 - $170	$64 - $213	$150 - $271	$225 - $391	$246 - $447	$352 - $614
Fiat	2010 2008	$246 - $104	$250 - $195	$378 - $181	$551 - $368	$703 - $371	$724 - $391	$814 - $417	$842 - $418	$833 - $409
Ford	2010 2008	$474 - $122	$492 - $253	$651 - $423	$905 - $808	$961 - $1,042	$1,095 - $1,297	$1,099 - $1,290	$1,189 - $1,409	$1,601 - $1,579
Geely	2010 2008	$4 - $19	$21 - $33	$46 - $67	$47 - $67	$51 - $75	$51 - $78	$63 - $105	$79 - $120	$122 - $124
General Motors	2010 2008	$114 - $355	$498 - $778	$552 - $851	$852 - $1,317	$1,125 - $1,494	$1,114 - $1,513	$1,198 - $1,539	$1,292 - $1,693	$1,338 - $1,676
Honda	2010 2008	$122 - $166	$408 - $385	$461 - $314	$470 - $337	$479 - $715	$560 - $883	$976 - $930	$1,049 - $1,018	$1,020 - $1,084
Hyundai	2010 2008	$501 - $316	$519 - $341	$649 - $395	$735 - $406	$720 - $425	$863 - $420	$898 - $417	$1,029 - $428	$1,000 - $429
Kia	2010 2008	$81 - $4	$79 - ($23)	$199 - $99	$304 - $206	$330 - $269	$403 - $278	$406 - $281	$408 - $286	$425 - $303
Lotus	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$1 - $0	$0 - $0	$0 - $0	$0 - $0
Mazda	2010 2008	$59 - $45	$71 - $92	$65 - $85	$112 - $168	$105 - $163	$204 - $296	$231 - $315	$236 - $323	$258 - $328

Mitsubishi	2010 2008	$10 - $29	$16 - $36	$15 - $33	$35 - $66	$66 - $98	$68 - $97	$68 - $96	$72 - $122	$69 - $116
Nissan	2010 2008	$8 - $148	$16 - $221	$471 - $682	$517 - $760	$518 - $793	$707 - $1,061	$775 - $1,094	$929 - $1,133	$926 - $1,139
Porsche	2010 2008	$1 - $4	$2 - $11	$3 - $15	$5 - $16	$8 - $19	$19 - $18	$19 - $22	$23 - $26	$22 - $31
Spyker	2010 2008	- - $1	- - $4	- - $6	- - $8	- - $10	- - $13	- - $24	- - $40	- - $35
Subaru	2010 2008	$1 - $18	$1 - $21	$95 - $60	$242 - $268	$239 - $265	$243 - $265	$239 - $265	$358 - $273	$325 - $703
Suzuki	2010 2008	$19 - ($6)	$19 - ($5)	$25 - $70	$29 - $73	$32 - $85	$33 - $84	$33 - $85	$35 - $85	$52 - $80
Tata	2010 2008	$2 - $19	$4 - $41	$6 - $38	$7 - $40	$9 - $46	$11 - $51	$21 - $81	$23 - $87	$29 - $92
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$388 - $289	$474 - $693	$823 - $958	$882 - $1,185	$966 - $1,322	$995 - $1,445	$1,011 - $1,470	$1,694 - $1,478	$1,677 - $1,438
Volkswagen	2010 2008	$78 - $51	$221 - $82	$235 - $131	$312 - $387	$371 - $491	$417 - $588	$467 - $615	$582 - $749	$724 - $953
Total/Average	2010 2008	$2,138 - $1,724	$3,198 - $3,285	$4,830 - $4,579	$6,196 - $6,787	$6,937 - $8,069	$7,892 - $9,325	$8,820 - $9,744	$10,658 - $10,882	$11,296 - $11,806

Table VII-1g
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
4% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$84 - $95	$172 - $189	$271 - $293	$370 - $392	$475 - $497	$579 - $612	$695 - $733	$805 - $860	$931 - $986
BMW	2010 2008	$96 - $112	$301 - $330	$397 - $389	$486 - $476	$598 - $596	$868 - $925	$1,002 - $1,059	$1,836 - $2,168	$1,723 - $1,947
Daimler	2010 2008	$84 - $90	$172 - $200	$260 - $287	$367 - $703	$479 - $852	$762 - $1,054	$1,084 - $1,453	$1,182 - $1,582	$1,617 - $2,070
Fiat	2010 2008	$529 - $277	$575 - $579	$823 - $539	$1,147 - $1,121	$1,335 - $1,149	$1,380 - $1,283	$1,641 - $1,686	$1,799 - $1,767	$1,844 - $1,632
Ford	2010 2008	$295 - $150	$315 - $249	$493 - $521	$1,032 - $988	$1,153 - $1,220	$1,384 - $1,495	$1,387 - $1,649	$1,422 - $1,767	$1,905 - $2,205
Geely	2010 2008	$90 - $254	$412 - $385	$793 - $716	$896 - $760	$991 - $954	$1,087 - $1,030	$1,244 - $1,289	$1,464 - $1,450	$2,088 - $1,509
General Motors	2010 2008	$318 - $272	$538 - $603	$571 - $724	$818 - $1,108	$1,028 - $1,237	$1,005 - $1,233	$1,200 - $1,450	$1,229 - $1,411	$1,665 - $1,333
Honda	2010 2008	$266 - $149	$613 - $532	$667 - $502	$660 - $512	$966 - $1,025	$962 - $1,125	$1,138 - $1,152	$1,194 - $1,172	$1,167 - $1,239
Hyundai	2010 2008	$689 - $548	$720 - $602	$885 - $663	$932 - $685	$1,048 - $791	$1,186 - $966	$1,184 - $985	$1,400 - $1,548	$1,386 - $1,469
Kia	2010 2008	$545 - $254	$525 - $167	$867 - $564	$1,117 - $930	$1,167 - $1,042	$1,264 - $1,107	$1,263 - $1,187	$1,246 - $1,163	$1,216 - $1,333
Lotus	2010 2008	$259 - $106	$355 - $205	$1,272 - $299	$1,361 - $409	$1,451 - $530	$1,553 - $651	$796 - $777	$921 - $915	$1,042 - $1,052
Mazda	2010 2008	$500 - $586	$549 - $791	$510 - $719	$876 - $1,041	$849 - $1,018	$1,264 - $2,051	$1,387 - $2,131	$1,394 - $2,179	$1,319 - $2,027

Mitsubishi	2010 2008	$188 - $527	$250 - $720	$228 - $670	$1,513 - $1,547	$1,947 - $2,259	$1,934 - $2,205	$1,899 - $2,177	$1,888 - $2,322	$1,710 - $3,038
Nissan	2010 2008	$474 - $495	$570 - $596	$874 - $1,069	$869 - $1,126	$928 - $1,149	$1,048 - $1,265	$1,101 - $1,485	$1,279 - $1,758	$1,263 - $1,727
Porsche	2010 2008	$73 - $148	$138 - $352	$281 - $523	$389 - $552	$564 - $664	$1,288 - $685	$1,427 - $812	$1,543 - $919	$1,499 - $1,061
Spyker	2010 2008	- - $98	- - $241	- - $405	- - $504	- - $630	- - $786	- - $1,297	- - $1,993	- - $1,814
Subaru	2010 2008	$59 - $247	$61 - $326	$1,275 - $562	$2,014 - $1,568	$1,950 - $1,496	$1,900 - $1,467	$1,885 - $1,704	$2,302 - $1,905	$2,247 - $3,004
Suzuki	2010 2008	$456 - ($9)	$449 - $3	$1,135 - $1,109	$1,362 - $1,203	$1,537 - $1,488	$1,514 - $1,432	$1,501 - $1,459	$1,474 - $1,378	$1,395 - $1,583
Tata	2010 2008	$90 - $347	$181 - $690	$269 - $667	$363 - $779	$427 - $859	$523 - $1,089	$882 - $1,327	$990 - $1,428	$1,212 - $1,534
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$261 - $229	$380 - $468	$826 - $655	$878 - $738	$1,108 - $936	$1,115 - $981	$1,096 - $963	$1,245 - $1,191	$1,222 - $1,147
Volkswagen	2010 2008	$181 - $114	$506 - $202	$610 - $329	$792 - $810	$1,002 - $965	$1,112 - $1,201	$1,246 - $1,382	$1,483 - $1,529	$1,803 - $1,806
Total/Average	2010 2008	$346 - $255	$482 - $455	$693 - $623	$894 - $882	$1,062 - $1,064	$1,149 - $1,201	$1,246 - $1,332	$1,380 - $1,503	$1,525 - $1,594

Table VII-1h
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
4% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$0 - $1	$0 - $1	$0 - $1	$1 - $1	$1 - $1
BMW	2010 2008	$31 - $35	$96 - $106	$130 - $135	$160 - $170	$201 - $214	$296 - $333	$347 - $382	$657 - $842	$626 - $789
Daimler	2010 2008	$21 - $26	$41 - $55	$64 - $81	$90 - $205	$119 - $256	$192 - $321	$275 - $454	$306 - $526	$422 - $705
Fiat	2010 2008	$386 - $119	$424 - $236	$635 - $217	$904 - $477	$1,077 - $496	$1,146 - $558	$1,399 - $733	$1,582 - $773	$1,663 - $731
Ford	2010 2008	$398 - $195	$425 - $327	$661 - $694	$1,391 - $1,362	$1,569 - $1,709	$1,907 - $2,116	$1,935 - $2,433	$2,017 - $2,657	$2,746 - $3,396
Geely	2010 2008	$5 - $22	$24 - $34	$48 - $66	$54 - $71	$61 - $88	$68 - $95	$78 - $125	$95 - $144	$138 - $153
General Motors	2010 2008	$525 - $412	$869 - $928	$921 - $1,131	$1,320 - $1,784	$1,670 - $2,015	$1,646 - $2,023	$1,984 - $2,418	$2,061 - $2,397	$2,824 - $2,315
Honda	2010 2008	$298 - $172	$699 - $605	$765 - $574	$771 - $595	$1,148 - $1,228	$1,167 - $1,392	$1,410 - $1,457	$1,514 - $1,532	$1,512 - $1,660
Hyundai	2010 2008	$596 - $324	$612 - $348	$759 - $387	$803 - $410	$915 - $485	$1,052 - $607	$1,065 - $625	$1,287 - $1,018	$1,297 - $995
Kia	2010 2008	$188 - $82	$178 - $52	$285 - $178	$366 - $301	$386 - $345	$424 - $375	$428 - $407	$432 - $409	$426 - $484
Lotus	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $0	$1 - $0	$1 - $0	$0 - $0	$0 - $0	$0 - $0
Mazda	2010 2008	$127 - $137	$137 - $192	$126 - $177	$218 - $258	$212 - $254	$319 - $521	$353 - $570	$362 - $593	$347 - $565

Mitsubishi	2010 2008	$11 - $41	$15 - $54	$14 - $50	$92 - $118	$120 - $174	$123 - $173	$121 - $172	$127 - $191	$116 - $258
Nissan	2010 2008	$422 - $431	$495 - $506	$763 - $913	$760 - $994	$816 - $1,049	$927 - $1,186	$984 - $1,417	$1,161 - $1,727	$1,161 - $1,753
Porsche	2010 2008	$1 - $5	$3 - $12	$5 - $19	$7 - $20	$10 - $24	$22 - $25	$25 - $30	$27 - $36	$26 - $43
Spyker	2010 2008	- - $2	- - $5	- - $8	- - $11	- - $13	- - $17	- - $29	- - $45	- - $42
Subaru	2010 2008	$12 - $55	$13 - $71	$263 - $122	$414 - $350	$403 - $345	$399 - $350	$399 - $412	$496 - $473	$492 - $772
Suzuki	2010 2008	$20 - ($1)	$19 - $0	$49 - $100	$60 - $113	$69 - $142	$69 - $140	$70 - $145	$70 - $138	$68 - $163
Tata	2010 2008	$3 - $19	$5 - $39	$8 - $38	$10 - $45	$12 - $50	$15 - $65	$26 - $80	$30 - $91	$38 - $100
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$399 - $423	$570 - $858	$1,246 - $1,202	$1,330 - $1,391	$1,696 - $1,782	$1,727 - $1,948	$1,719 - $1,962	$1,990 - $2,477	$1,982 - $2,417
Volkswagen	2010 2008	$87 - $63	$238 - $109	$283 - $177	$364 - $449	$462 - $565	$517 - $713	$582 - $824	$706 - $926	$864 - $1,138
Total/Average	2010 2008	$3,533 - $2,564	$4,863 - $4,540	$7,024 - $6,270	$9,114 - $9,125	$10,947 - $11,240	$12,018 - $12,959	$13,201 - $14,676	$14,922 - $16,998	$16,750 - $18,481

Table VII-1i
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
5% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$106 - $117	$222 - $244	$348 - $370	$475 - $508	$612 - $645	$755 - $794	$909 - $959	$1,069 - $1,129	$1,239 - $1,305
BMW	2010 2008	$120 - $145	$351 - $355	$482 - $425	$596 - $599	$838 - $841	$1,053 - $1,107	$1,222 - $1,279	$2,100 - $2,432	$2,031 - $2,260
Daimler	2010 2008	$106 - $123	$216 - $244	$337 - $390	$471 - $699	$616 - $737	$933 - $1,190	$1,293 - $1,503	$1,441 - $1,683	$1,920 - $2,360
Fiat	2010 2008	$493 - $404	$642 - $676	$1,128 - $713	$1,725 - $1,615	$2,071 - $1,673	$2,216 - $1,839	$2,484 - $2,920	$2,578 - $2,994	$3,445 - $2,602
Ford	2010 2008	$464 - $167	$501 - $286	$1,399 - $582	$2,029 - $1,737	$2,333 - $2,370	$2,738 - $2,683	$2,919 - $2,690	$2,864 - $2,753	$3,437 - $2,653
Geely	2010 2008	$112 - $289	$457 - $408	$873 - $797	$1,014 - $917	$1,142 - $1,092	$1,281 - $1,222	$1,472 - $1,509	$1,733 - $1,709	$2,402 - $1,817
General Motors	2010 2008	$329 - $318	$668 - $717	$693 - $845	$1,062 - $1,408	$1,260 - $1,909	$1,238 - $1,897	$1,805 - $2,160	$2,124 - $2,520	$2,737 - $2,703
Honda	2010 2008	$503 - $240	$915 - $624	$936 - $616	$923 - $653	$1,092 - $1,290	$1,146 - $1,397	$1,754 - $1,813	$1,855 - $1,919	$1,829 - $2,027
Hyundai	2010 2008	$687 - $518	$720 - $572	$973 - $1,026	$1,011 - $1,086	$1,198 - $1,209	$1,558 - $1,553	$1,576 - $1,582	$2,195 - $2,799	$2,050 - $2,582
Kia	2010 2008	$683 - $476	$691 - $387	$1,164 - $591	$1,416 - $1,503	$1,425 - $1,876	$1,663 - $2,138	$1,665 - $2,440	$1,646 - $2,416	$1,567 - $2,236
Lotus	2010 2008	$281 - $128	$404 - $260	$1,354 - $387	$1,477 - $530	$1,605 - $684	$1,740 - $849	$1,027 - $1,025	$1,202 - $1,206	$1,377 - $1,399
Mazda	2010 2008	$572 - $811	$650 - $1,124	$612 - $1,028	$1,058 - $1,428	$1,044 - $1,395	$1,863 - $2,549	$2,221 - $2,683	$2,266 - $3,059	$2,175 - $3,106

Mitsubishi	2010 2008	$319 - $727	$358 - $888	$323 - $828	$1,849 - $3,824	$2,207 - $4,217	$2,179 - $4,231	$2,142 - $4,246	$2,438 - $4,200	$4,651 - $3,379
Nissan	2010 2008	$541 - $533	$659 - $649	$991 - $1,132	$1,027 - $1,238	$1,036 - $1,311	$1,148 - $1,580	$1,293 - $1,838	$2,161 - $3,028	$2,472 - $2,849
Porsche	2010 2008	$95 - $170	$187 - $407	$367 - $614	$519 - $673	$763 - $818	$1,469 - $883	$1,641 - $1,060	$1,807 - $1,211	$1,807 - $1,407
Spyker	2010 2008	- - $120	- - $302	- - $488	- - $620	- - $778	- - $973	- - $1,528	- - $2,268	- - $2,139
Subaru	2010 2008	$293 - $557	$387 - $642	$1,545 - $890	$2,242 - $1,401	$2,146 - $1,553	$2,100 - $1,632	$2,312 - $1,804	$2,540 - $1,894	$2,887 - $4,439
Suzuki	2010 2008	$486 - $327	$479 - $336	$1,247 - $1,550	$1,606 - $1,611	$1,899 - $2,409	$1,891 - $2,353	$1,858 - $2,321	$1,970 - $2,303	$2,463 - $2,645
Tata	2010 2008	$112 - $369	$225 - $690	$341 - $738	$467 - $878	$559 - $991	$693 - $1,254	$1,091 - $1,536	$1,243 - $1,676	$1,509 - $1,825
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$264 - $259	$358 - $596	$912 - $762	$970 - $966	$1,315 - $1,232	$1,333 - $1,279	$1,310 - $1,262	$1,598 - $1,546	$1,528 - $1,743
Volkswagen	2010 2008	$204 - $136	$562 - $251	$694 - $417	$925 - $937	$1,147 - $1,146	$1,295 - $1,388	$1,473 - $1,613	$1,753 - $1,810	$2,122 - $2,136
Total/Average	2010 2008	$414 - $315	$592 - $550	$944 - $747	$1,208 - $1,196	$1,418 - $1,541	$1,579 - $1,723	$1,832 - $1,927	$2,117 - $2,298	$2,407 - $2,401

Table VII-1j
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
5% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $1	$0 - $1	$0 - $1	$1 - $1	$1 - $1	$1 - $2
BMW	2010 2008	$39 - $46	$112 - $115	$158 - $147	$196 - $214	$281 - $302	$360 - $398	$424 - $461	$752 - $944	$738 - $916
Daimler	2010 2008	$27 - $35	$52 - $67	$83 - $110	$116 - $203	$154 - $221	$234 - $363	$328 - $470	$373 - $559	$502 - $804
Fiat	2010 2008	$360 - $173	$474 - $276	$869 - $287	$1,359 - $688	$1,671 - $722	$1,840 - $800	$2,117 - $1,270	$2,268 - $1,309	$3,106 - $1,165
Ford	2010 2008	$626 - $217	$675 - $376	$1,877 - $776	$2,734 - $2,395	$3,173 - $3,321	$3,773 - $3,798	$4,071 - $3,967	$4,063 - $4,139	$4,955 - $4,087
Geely	2010 2008	$7 - $25	$26 - $36	$53 - $73	$61 - $85	$70 - $101	$80 - $113	$93 - $146	$113 - $169	$158 - $184
General Motors	2010 2008	$544 - $482	$1,079 - $1,104	$1,117 - $1,321	$1,713 - $2,267	$2,047 - $3,110	$2,028 - $3,113	$2,982 - $3,602	$3,562 - $4,281	$4,643 - $4,695
Honda	2010 2008	$565 - $278	$1,043 - $710	$1,073 - $705	$1,077 - $759	$1,298 - $1,546	$1,390 - $1,728	$2,173 - $2,294	$2,352 - $2,510	$2,369 - $2,717
Hyundai	2010 2008	$595 - $307	$612 - $331	$835 - $598	$871 - $650	$1,047 - $741	$1,382 - $975	$1,418 - $1,003	$2,017 - $1,841	$1,918 - $1,749
Kia	2010 2008	$236 - $153	$235 - $121	$383 - $186	$464 - $486	$471 - $622	$559 - $725	$564 - $836	$571 - $850	$550 - $811
Lotus	2010 2008	$0 - $0	$0 - $0	$0 - $0	$1 - $0	$1 - $0	$1 - $0	$0 - $0	$0 - $0	$1 - $0
Mazda	2010 2008	$145 - $190	$162 - $273	$151 - $254	$263 - $354	$260 - $348	$471 - $647	$566 - $718	$588 - $833	$571 - $867

Mitsubishi	2010 2008	$20 - $56	$21 - $67	$19 - $62	$112 - $292	$136 - $325	$138 - $332	$137 - $335	$163 - $345	$316 - $287
Nissan	2010 2008	$481 - $464	$572 - $552	$865 - $968	$898 - $1,093	$911 - $1,197	$1,015 - $1,481	$1,156 - $1,754	$1,962 - $2,976	$2,274 - $2,891
Porsche	2010 2008	$2 - $6	$3 - $14	$6 - $22	$9 - $24	$13 - $30	$25 - $32	$28 - $39	$32 - $48	$32 - $57
Spyker	2010 2008	- - $2	- - $6	- - $10	- - $13	- - $17	- - $21	- - $34	- - $52	- - $49
Subaru	2010 2008	$61 - $125	$80 - $139	$318 - $193	$461 - $313	$444 - $358	$441 - $389	$489 - $436	$547 - $470	$632 - $1,141
Suzuki	2010 2008	$21 - $30	$20 - $30	$54 - $140	$71 - $151	$85 - $231	$87 - $230	$87 - $230	$94 - $231	$120 - $273
Tata	2010 2008	$3 - $21	$6 - $39	$10 - $42	$13 - $51	$16 - $58	$20 - $74	$33 - $93	$38 - $107	$47 - $119
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$404 - $478	$537 - $1,094	$1,376 - $1,399	$1,469 - $1,819	$2,013 - $2,346	$2,064 - $2,541	$2,053 - $2,572	$2,555 - $3,217	$2,480 - $3,674
Volkswagen	2010 2008	$98 - $75	$265 - $136	$322 - $224	$425 - $520	$528 - $671	$602 - $824	$688 - $962	$834 - $1,095	$1,018 - $1,346
Total/Average	2010 2008	$4,233 - $3,163	$5,975 - $5,486	$9,570 - $7,517	$12,313 - $12,379	$14,620 - $16,268	$16,509 - $18,586	$19,407 - $21,227	$22,885 - $25,979	$26,428 - $27,832

Table VII-1k
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
6% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$128 - $145	$271 - $293	$425 - $453	$590 - $623	$761 - $799	$948 - $997	$1,146 - $1,206	$1,355 - $1,432	$1,580 - $1,668
BMW	2010 2008	$120 - $153	$400 - $429	$559 - $541	$712 - $709	$992 - $996	$1,246 - $1,299	$1,458 - $1,521	$2,391 - $2,724	$2,377 - $2,607
Daimler	2010 2008	$128 - $145	$266 - $271	$414 - $421	$581 - $817	$765 - $1,001	$1,120 - $1,377	$1,524 - $1,740	$1,721 - $1,964	$2,255 - $2,701
Fiat	2010 2008	$620 - $473	$805 - $842	$1,263 - $881	$1,896 - $1,855	$2,154 - $2,131	$2,214 - $3,060	$2,450 - $3,514	$4,011 - $4,183	$3,788 - $3,739
Ford	2010 2008	$669 - $523	$735 - $657	$1,569 - $880	$2,258 - $1,635	$2,520 - $2,013	$2,598 - $3,805	$2,871 - $3,768	$5,567 - $5,912	$5,033 - $4,678
Geely	2010 2008	$134 - $327	$521 - $458	$956 - $869	$1,130 - $1,033	$1,296 - $1,246	$1,479 - $1,409	$1,719 - $1,746	$2,025 - $2,000	$2,754 - $2,158
General Motors	2010 2008	$522 - $381	$979 - $933	$1,060 - $1,105	$1,410 - $1,766	$2,425 - $3,449	$2,393 - $3,468	$4,621 - $3,421	$4,733 - $3,556	$4,335 - $4,399
Honda	2010 2008	$221 - $448	$671 - $836	$706 - $823	$687 - $853	$1,356 - $1,492	$1,412 - $1,579	$2,455 - $2,309	$2,609 - $2,428	$2,748 - $3,078
Hyundai	2010 2008	$802 - $670	$832 - $722	$1,204 - $1,348	$1,214 - $1,406	$1,896 - $1,647	$2,413 - $2,253	$2,580 - $2,535	$2,994 - $3,030	$2,980 - $3,055
Kia	2010 2008	$740 - $533	$754 - $443	$1,310 - $711	$1,857 - $1,496	$1,975 - $2,068	$2,774 - $2,242	$2,822 - $2,366	$2,855 - $2,323	$2,588 - $4,029
Lotus	2010 2008	$308 - $156	$459 - $321	$1,442 - $475	$1,598 - $656	$1,765 - $854	$1,949 - $1,063	$1,286 - $1,289	$1,515 - $1,531	$1,746 - $1,784
Mazda	2010 2008	$948 - $884	$1,100 - $1,164	$1,022 - $1,125	$1,973 - $1,454	$2,043 - $1,436	$2,263 - $3,502	$2,554 - $3,527	$2,735 - $3,525	$3,925 - $6,359

Mitsubishi	2010 2008	$881 - $746	$874 - $889	$848 - $828	$1,550 - $3,870	$3,806 - $4,063	$3,759 - $4,096	$3,722 - $4,117	$3,883 - $4,144	$3,742 - $5,516
Nissan	2010 2008	$231 - $816	$374 - $1,078	$1,407 - $1,465	$1,409 - $1,554	$1,431 - $1,581	$1,961 - $2,383	$2,918 - $4,543	$3,304 - $4,753	$3,713 - $4,052
Porsche	2010 2008	$123 - $197	$237 - $467	$449 - $705	$635 - $799	$911 - $988	$1,656 - $1,097	$1,878 - $1,324	$2,093 - $1,535	$2,154 - $1,792
Spyker	2010 2008	- - $148	- - $354	- - $570	- - $735	- - $938	- - $1,177	- - $1,776	- - $2,570	- - $2,502
Subaru	2010 2008	$347 - $554	$459 - $717	$1,607 - $794	$2,440 - $1,573	$2,431 - $1,790	$2,417 - $1,940	$2,779 - $2,161	$3,157 - $2,970	$3,058 - $5,048
Suzuki	2010 2008	$466 - $797	$460 - $797	$1,213 - $1,228	$1,596 - $1,244	$1,992 - $1,414	$2,071 - $1,627	$2,286 - $1,872	$2,471 - $3,655	$3,475 - $3,301
Tata	2010 2008	$134 - $391	$274 - $731	$418 - $818	$577 - $990	$708 - $1,131	$880 - $1,432	$1,322 - $1,761	$1,518 - $1,951	$1,839 - $2,150
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$275 - $317	$428 - $647	$1,020 - $861	$1,126 - $1,223	$1,553 - $1,444	$1,617 - $1,683	$1,589 - $1,667	$2,662 - $2,695	$2,554 - $3,027
Volkswagen	2010 2008	$232 - $164	$613 - $306	$777 - $473	$1,052 - $1,071	$1,306 - $1,328	$1,493 - $1,597	$1,720 - $1,866	$2,050 - $2,112	$2,480 - $2,504
Total/Average	2010 2008	$453 - $453	$676 - $734	$1,108 - $933	$1,405 - $1,381	$1,866 - $1,887	$2,040 - $2,416	$2,700 - $2,761	$3,508 - $3,437	$3,450 - $3,675

Table VII-11
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
6% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $0	$0 - $0	$0 - $1	$0 - $1	$1 - $1	$1 - $1	$1 - $2	$1 - $2
BMW	2010 2008	$39 - $48	$128 - $138	$183 - $187	$234 - $254	$333 - $358	$426 - $468	$506 - $548	$856 - $1,057	$864 - $1,056
Daimler	2010 2008	$32 - $41	$64 - $75	$102 - $118	$143 - $238	$191 - $301	$282 - $420	$387 - $544	$445 - $653	$589 - $920
Fiat	2010 2008	$453 - $203	$594 - $344	$974 - $354	$1,494 - $790	$1,738 - $920	$1,839 - $1,332	$2,088 - $1,529	$3,528 - $1,828	$3,416 - $1,674
Ford	2010 2008	$902 - $680	$990 - $862	$2,105 - $1,172	$3,043 - $2,255	$3,427 - $2,822	$3,580 - $5,385	$4,005 - $5,557	$7,897 - $8,890	$7,254 - $7,205
Geely	2010 2008	$8 - $29	$30 - $41	$58 - $80	$68 - $96	$80 - $115	$92 - $130	$108 - $169	$132 - $198	$181 - $218
General Motors	2010 2008	$863 - $578	$1,582 - $1,437	$1,708 - $1,727	$2,275 - $2,844	$3,940 - $5,618	$3,920 - $5,691	$7,636 - $5,706	$7,935 - $6,042	$7,354 - $7,643
Honda	2010 2008	$249 - $517	$765 - $951	$810 - $942	$802 - $992	$1,610 - $1,789	$1,712 - $1,954	$3,040 - $2,922	$3,308 - $3,176	$3,559 - $4,126
Hyundai	2010 2008	$694 - $396	$707 - $418	$1,032 - $786	$1,045 - $841	$1,656 - $1,010	$2,141 - $1,415	$2,322 - $1,608	$2,752 - $1,993	$2,789 - $2,069
Kia	2010 2008	$256 - $172	$256 - $139	$431 - $224	$609 - $484	$653 - $685	$932 - $760	$956 - $811	$990 - $817	$908 - $1,461
Lotus	2010 2008	$0 - $0	$0 - $0	$1 - $0	$1 - $0	$1 - $0	$1 - $0	$0 - $0	$1 - $0	$1 - $1
Mazda	2010 2008	$241 - $207	$274 - $282	$253 - $278	$490 - $361	$509 - $359	$571 - $889	$651 - $944	$710 - $960	$1,031 - $1,774
Mitsubishi	2010 2008	$54 - $57	$51 - $67	$51 - $62	$94 - $295	$235 - $313	$238 - $321	$238 - $325	$260 - $340	$254 - $468

Nissan	2010 2008	$206 - $711	$324 - $916	$1,229 - $1,252	$1,231 - $1,372	$1,259 - $1,443	$1,735 - $2,234	$2,608 - $4,336	$3,000 - $4,671	$3,416 - $4,112
Porsche	2010 2008	$2 - $7	$4 - $17	$8 - $25	$11 - $29	$16 - $36	$29 - $40	$32 - $49	$37 - $61	$38 - $73
Spyker	2010 2008	- - $3	- - $7	- - $11	- - $15	- - $20	- - $26	- - $40	- - $59	- - $58
Subaru	2010 2008	$73 - $124	$94 - $155	$331 - $172	$502 - $351	$503 - $413	$507 - $463	$588 - $522	$681 - $737	$669 - $1,297
Suzuki	2010 2008	$20 - $72	$20 - $72	$53 - $111	$70 - $116	$89 - $135	$95 - $159	$106 - $186	$118 - $367	$169 - $340
Tata	2010 2008	$4 - $22	$7 - $41	$12 - $47	$16 - $58	$21 - $66	$26 - $85	$40 - $107	$46 - $124	$57 - $141
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$421 - $586	$643 - $1,187	$1,539 - $1,582	$1,706 - $2,303	$2,378 - $2,748	$2,504 - $3,344	$2,490 - $3,395	$4,256 - $5,608	$4,143 - $6,380
Volkswagen	2010 2008	$112 - $90	$289 - $165	$360 - $254	$484 - $594	$602 - $778	$694 - $948	$804 - $1,113	$976 - $1,279	$1,189 - $1,578
Total/Average	2010 2008	$4,627 - $4,544	$6,822 - $7,314	$11,237 - $9,386	$14,319 - $14,289	$19,240 - $19,931	$21,324 - $26,063	$28,606 - $30,412	$37,927 - $38,863	$37,881 - $42,596

Table VII-1m
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
7% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$156 - $167	$326 - $348	$508 - $541	$706 - $750	$920 - $970	$1,157 - $1,212	$1,404 - $1,476	$1,668 - $1,762	$1,965 - $2,070
BMW	2010 2008	$158 - $191	$455 - $470	$647 - $638	$833 - $835	$1,151 - $1,155	$1,455 - $1,508	$1,722 - $1,785	$2,710 - $3,048	$2,768 - $2,997
Daimler	2010 2008	$150 - $170	$321 - $338	$497 - $544	$697 - $932	$919 - $1,155	$1,323 - $1,580	$1,777 - $1,993	$2,029 - $2,277	$2,629 - $3,080
Fiat	2010 2008	$865 - $617	$1,043 - $991	$1,603 - $1,015	$1,782 - $2,106	$2,174 - $2,262	$2,510 - $2,744	$4,755 - $4,449	$4,965 - $5,509	$5,858 - $4,758
Ford	2010 2008	$894 - $760	$1,010 - $1,407	$1,709 - $1,474	$2,270 - $1,898	$2,659 - $2,975	$3,012 - $3,192	$3,240 - $3,390	$4,749 - $5,292	$4,688 - $4,882
Geely	2010 2008	$161 - $359	$571 - $499	$1,044 - $958	$1,251 - $1,148	$1,461 - $1,405	$1,688 - $1,618	$1,983 - $2,004	$2,355 - $2,314	$3,150 - $2,543
General Motors	2010 2008	$849 - $508	$1,315 - $1,070	$2,219 - $1,193	$2,272 - $1,831	$2,978 - $3,696	$3,038 - $3,723	$4,664 - $3,717	$4,913 - $5,944	$4,560 - $5,301
Honda	2010 2008	$460 - $613	$1,277 - $1,060	$1,354 - $1,171	$1,321 - $1,188	$1,903 - $2,162	$2,909 - $2,238	$3,626 - $2,861	$4,345 - $4,069	$3,999 - $3,751
Hyundai	2010 2008	$927 - $778	$993 - $886	$1,242 - $1,485	$1,296 - $1,500	$2,137 - $1,871	$4,328 - $4,284	$4,696 - $4,463	$4,814 - $4,428	$4,148 - $3,640
Kia	2010 2008	$951 - $537	$963 - $447	$1,456 - $817	$1,841 - $1,946	$1,924 - $2,657	$2,719 - $2,812	$3,076 - $3,335	$3,067 - $3,648	$3,035 - $4,530
Lotus	2010 2008	$336 - $183	$514 - $376	$1,530 - $568	$1,724 - $794	$1,941 - $1,036	$2,169 - $1,300	$1,566 - $1,580	$1,856 - $1,888	$2,164 - $2,218
Mazda	2010 2008	$974 - $1,245	$1,148 - $1,488	$1,048 - $1,432	$2,049 - $1,608	$2,202 - $1,581	$2,470 - $7,841	$2,846 - $7,900	$3,098 - $7,864	$4,320 - $6,162
Mitsubishi	2010 2008	$881 - $774	$874 - $905	$983 - $894	$1,676 - $5,197	$2,137 - $5,397	$2,352 - $5,526	$2,588 - $5,674	$2,877 - $6,134	$5,106 - $5,278

Nissan	2010 2008	$587 - $915	$781 - $1,182	$1,355 - $1,635	$1,482 - $1,790	$1,532 - $1,909	$3,798 - $3,889	$4,037 - $4,855	$4,521 - $5,357	$4,107 - $4,710
Porsche	2010 2008	$145 - $225	$286 - $522	$532 - $801	$756 - $937	$1,076 - $1,170	$1,865 - $1,334	$2,136 - $1,615	$2,412 - $1,893	$2,539 - $2,227
Spyker	2010 2008	- - $170	- - $409	- - $658	- - $862	- - $1,108	- - $1,397	- - $2,051	- - $2,911	- - $2,909
Subaru	2010 2008	$508 - $463	$654 - $701	$963 - $2,621	$2,507 - $2,875	$2,626 - $3,033	$2,851 - $3,141	$3,125 - $3,492	$3,286 - $3,721	$7,205 - $5,412
Suzuki	2010 2008	$493 - $797	$487 - $858	$1,079 - $1,375	$1,527 - $1,388	$2,134 - $2,797	$2,389 - $3,081	$2,629 - $3,374	$2,892 - $6,259	$5,044 - $5,206
Tata	2010 2008	$156 - $419	$324 - $781	$500 - $895	$687 - $1,100	$862 - $1,285	$1,078 - $1,630	$1,575 - $2,003	$1,826 - $2,253	$2,213 - $2,518
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$467 - $482	$693 - $974	$1,358 - $1,362	$1,474 - $1,982	$1,929 - $2,299	$3,710 - $3,798	$3,662 - $3,757	$5,135 - $3,738	$4,440 - $3,208
Volkswagen	2010 2008	$254 - $191	$668 - $361	$865 - $591	$1,173 - $1,203	$1,471 - $1,504	$1,708 - $1,817	$1,990 - $2,146	$2,385 - $2,453	$2,881 - $2,917
Total/Average	2010 2008	$664 - $584	$959 - $979	$1,461 - $1,251	$1,688 - $1,712	$2,136 - $2,424	$3,048 - $3,275	$3,705 - $3,606	$4,382 - $4,525	$4,333 - $4,168

Table VII-1n
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
7% Annual Increase
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $0	$0 - $1	$0 - $1	$1 - $1	$1 - $1	$1 - $2	$1 - $2	$1 - $2
BMW	2010 2008	$51 - $60	$145 - $152	$212 - $221	$274 - $299	$387 - $415	$497 - $543	$597 - $644	$970 - $1,183	$1,006 - $1,215
Daimler	2010 2008	$38 - $48	$77 - $93	$122 - $153	$171 - $271	$229 - $347	$333 - $482	$451 - $623	$525 - $757	$687 - $1,050
Fiat	2010 2008	$632 - $265	$769 - $405	$1,236 - $408	$1,405 - $897	$1,754 - $977	$2,084 - $1,194	$4,053 - $1,936	$4,367 - $2,408	$5,282 - $2,130
Ford	2010 2008	$1,205 - $988	$1,361 - $1,845	$2,292 - $1,963	$3,059 - $2,617	$3,616 - $4,170	$4,150 - $4,518	$4,520 - $4,999	$6,736 - $7,957	$6,757 - $7,519
Geely	2010 2008	$10 - $32	$33 - $45	$63 - $88	$75 - $107	$90 - $130	$105 - $150	$125 - $194	$153 - $229	$208 - $257
General Motors	2010 2008	$1,404 - $771	$2,125 - $1,647	$3,576 - $1,865	$3,665 - $2,949	$4,838 - $6,020	$4,977 - $6,110	$7,706 - $6,200	$8,236 - $10,100	$7,737 - $9,209
Honda	2010 2008	$516 - $708	$1,455 - $1,206	$1,553 - $1,341	$1,542 - $1,383	$2,261 - $2,592	$3,528 - $2,769	$4,490 - $3,621	$5,509 - $5,321	$5,180 - $5,028
Hyundai	2010 2008	$802 - $461	$843 - $512	$1,065 - $866	$1,116 - $897	$1,867 - $1,148	$3,839 - $2,690	$4,226 - $2,831	$4,424 - $2,912	$3,881 - $2,465
Kia	2010 2008	$328 - $173	$327 - $140	$479 - $257	$603 - $630	$636 - $880	$913 - $954	$1,042 - $1,143	$1,064 - $1,284	$1,065 - $1,643
Lotus	2010 2008	$0 - $0	$0 - $0	$1 - $0	$1 - $0	$1 - $0	$1 - $0	$1 - $0	$1 - $1	$1 - $1
Mazda	2010 2008	$248 - $292	$286 - $361	$259 - $354	$509 - $399	$549 - $395	$624 - $1,991	$725 - $2,115	$804 - $2,141	$1,135 - $1,719
Mitsubishi	2010 2008	$54 - $60	$51 - $68	$59 - $67	$102 - $396	$132 - $416	$149 - $433	$165 - $448	$193 - $504	$347 - $448

Nissan	2010 2008	$522 - $797	$677 - $1,004	$1,183 - $1,397	$1,296 - $1,580	$1,347 - $1,743	$3,361 - $3,645	$3,608 - $4,633	$4,105 - $5,264	$3,778 - $4,779
Porsche	2010 2008	$3 - $8	$5 - $19	$9 - $29	$13 - $34	$19 - $43	$32 - $49	$37 - $60	$42 - $75	$45 - $91
Spyker	2010 2008	- - $3	- - $8	- - $13	- - $18	- - $24	- - $30	- - $46	- - $66	- - $67
Subaru	2010 2008	$106 - $104	$134 - $152	$198 - $569	$516 - $643	$543 - $700	$598 - $749	$661 - $844	$708 - $924	$1,577 - $1,391
Suzuki	2010 2008	$21 - $72	$21 - $77	$47 - $125	$67 - $130	$96 - $268	$109 - $301	$122 - $335	$138 - $629	$246 - $537
Tata	2010 2008	$4 - $23	$9 - $44	$14 - $51	$20 - $64	$25 - $75	$32 - $97	$47 - $121	$56 - $144	$69 - $165
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$714 - $891	$1,041 - $1,786	$2,049 - $2,501	$2,233 - $3,734	$2,953 - $4,378	$5,744 - $7,543	$5,741 - $7,653	$8,210 - $7,776	$7,202 - $6,764
Volkswagen	2010 2008	$122 - $106	$315 - $195	$401 - $317	$539 - $667	$678 - $881	$794 - $1,078	$930 - $1,281	$1,135 - $1,485	$1,381 - $1,838
Total/Average	2010 2008	$6,780 - $5,862	$9,675 - $9,758	$14,818 - $12,586	$17,205 - $17,714	$22,020 - $25,601	$31,871 - $35,328	$39,248 - $39,727	$47,378 - $51,162	$47,582 - $48,317

Table VII-1o
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Max Net Benefits (3% Discount Rate)
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	\$337 - \$376	\$464 - \$491	\$585 - \$618	\$667 - \$706	\$739 - \$761	\$783 - \$821	\$843 - \$887	\$959 - \$953	\$1,069 - \$1,014
BMW	2010 2008	\$357 - \$397	\$593 - \$620	\$719 - \$713	\$789 - \$796	\$964 - \$952	\$1,075 - \$1,129	\$1,150 - \$1,207	\$1,990 - \$2,256	\$1,860 - \$1,974
Daimler	2010 2008	\$332 - \$363	\$458 - \$486	\$568 - \$631	\$658 - \$894	\$743 - \$963	\$955 - \$1,212	\$1,227 - \$1,432	\$1,331 - \$1,513	\$1,755 - \$2,079
Fiat	2010 2008	\$1,163 - \$1,569	\$1,188 - \$1,706	\$1,556 - \$1,642	\$1,747 - \$1,821	\$1,970 - \$1,875	\$2,116 - \$1,861	\$2,324 - \$2,003	\$2,382 - \$2,088	\$2,423 - \$1,997
Ford	2010 2008	\$835 - \$946	\$894 - \$968	\$2,418 - \$2,473	\$2,456 - \$2,442	\$2,475 - \$2,545	\$2,673 - \$2,596	\$2,669 - \$2,649	\$3,211 - \$2,806	\$2,842 - \$2,336
Geely	2010 2008	\$354 - \$552	\$719 - \$658	\$1,121 - \$1,051	\$1,212 - \$1,126	\$1,274 - \$1,223	\$1,308 - \$1,260	\$1,400 - \$1,453	\$1,618 - \$1,548	\$2,231 - \$1,545
General Motors	2010 2008	\$938 - \$1,016	\$1,182 - \$1,309	\$1,085 - \$1,358	\$1,537 - \$1,671	\$1,620 - \$1,994	\$1,585 - \$1,940	\$1,839 - \$1,954	\$2,123 - \$2,220	\$2,211 - \$2,210
Honda	2010 2008	\$755 - \$1,082	\$947 - \$1,157	\$878 - \$995	\$875 - \$989	\$1,144 - \$1,230	\$1,165 - \$1,254	\$1,400 - \$1,260	\$1,409 - \$1,266	\$1,369 - \$1,290
Hyundai	2010 2008	\$850 - \$859	\$814 - \$867	\$1,120 - \$1,200	\$1,148 - \$1,164	\$1,370 - \$1,257	\$1,583 - \$1,399	\$1,603 - \$1,401	\$1,741 - \$1,694	\$1,649 - \$1,595
Kia	2010 2008	\$1,050 - \$932	\$981 - \$834	\$1,310 - \$873	\$1,346 - \$1,714	\$1,392 - \$1,813	\$1,489 - \$1,796	\$1,494 - \$1,793	\$1,462 - \$1,768	\$1,425 - \$1,662
Lotus	2010 2008	\$534 - \$403	\$668 - \$535	\$1,613 - \$651	\$1,686 - \$750	\$1,737 - \$816	\$1,767 - \$876	\$956 - \$942	\$1,086 - \$1,014	\$1,196 - \$1,085
Mazda	2010 2008	\$950 - \$1,159	\$1,206 - \$1,353	\$1,100 - \$1,243	\$2,003 - \$4,092	\$2,056 - \$4,037	\$2,290 - \$4,034	\$2,268 - \$4,067	\$2,239 - \$3,966	\$3,150 - \$3,205
Mitsubishi	2010 2008	\$885 - \$980	\$859 - \$905	\$885 - \$1,114	\$2,934 - \$3,838	\$2,958 - \$3,778	\$2,915 - \$3,819	\$2,877 - \$3,842	\$2,865 - \$3,812	\$2,428 - \$3,024

Nissan	2010 2008	$673 - $914	$851 - $1,085	$1,181 - $1,332	$1,230 - $1,400	$1,241 - $1,374	$1,422 - $1,446	$1,613 - $1,562	$2,023 - $2,116	$1,922 - $2,008
Porsche	2010 2008	$332 - $445	$429 - $682	$603 - $883	$717 - $893	$889 - $950	$1,491 - $910	$1,570 - $977	$1,697 - $1,018	$1,642 - $1,094
Spyker	2010 2008	- - $379	- - $558	- - $741	- - $823	- - $899	- - $1,001	- - $1,451	- - $2,086	- - $1,842
Subaru	2010 2008	$550 - $614	$759 - $561	$6,106 - $2,206	$5,761 - $2,261	$5,547 - $2,223	$5,400 - $2,260	$5,221 - $2,204	$5,119 - $2,337	$3,913 - $3,456
Suzuki	2010 2008	$529 - $230	$523 - $225	$1,236 - $2,318	$1,582 - $2,329	$1,995 - $2,315	$1,968 - $2,277	$1,936 - $2,241	$2,016 - $2,281	$2,272 - $2,207
Tata	2010 2008	$332 - $606	$461 - $913	$572 - $966	$649 - $1,061	$680 - $1,098	$721 - $1,278	$1,025 - $1,470	$1,133 - $1,511	$1,344 - $1,556
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$620 - $526	$701 - $821	$1,162 - $845	$1,171 - $997	$1,313 - $1,239	$1,325 - $1,226	$1,318 - $1,210	$1,627 - $1,282	$1,547 - $1,217
Volkswagen	2010 2008	$446 - $400	$811 - $510	$942 - $670	$1,134 - $1,159	$1,279 - $1,289	$1,323 - $1,416	$1,401 - $1,541	$1,637 - $1,623	$1,946 - $1,839
Total/Average	2010 2008	$774 - $830	$908 - $981	$1,373 - $1,287	$1,515 - $1,525	$1,634 - $1,680	$1,722 - $1,710	$1,831 - $1,756	$2,083 - $1,941	$2,037 - $1,866

Table VII-1p
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Max Net Benefits (3% Discount Rate)
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $1	$0 - $1	$0 - $1	$0 - $1	$0 - $1	$1 - $1	$1 - $1	$1 - $1
BMW	2010 2008	$114 - $124	$189 - $200	$235 - $247	$260 - $285	$324 - $342	$367 - $406	$399 - $435	$712 - $876	$676 - $800
Daimler	2010 2008	$84 - $103	$110 - $134	$140 - $178	$162 - $260	$185 - $289	$240 - $369	$311 - $448	$344 - $503	$458 - $708
Fiat	2010 2008	$850 - $673	$877 - $697	$1,200 - $661	$1,377 - $775	$1,590 - $809	$1,757 - $810	$1,981 - $871	$2,095 - $913	$2,185 - $894
Ford	2010 2008	$1,126 - $1,230	$1,204 - $1,270	$3,244 - $3,294	$3,310 - $3,367	$3,366 - $3,567	$3,683 - $3,674	$3,723 - $3,906	$4,555 - $4,220	$4,096 - $3,598
Geely	2010 2008	$21 - $49	$41 - $59	$68 - $96	$73 - $105	$78 - $113	$82 - $117	$88 - $141	$105 - $153	$147 - $156
General Motors	2010 2008	$1,550 - $1,541	$1,910 - $2,015	$1,748 - $2,123	$2,478 - $2,691	$2,632 - $3,248	$2,596 - $3,183	$3,039 - $3,259	$3,559 - $3,772	$3,751 - $3,839
Honda	2010 2008	$847 - $1,249	$1,079 - $1,317	$1,007 - $1,139	$1,022 - $1,151	$1,359 - $1,474	$1,412 - $1,552	$1,734 - $1,594	$1,786 - $1,656	$1,774 - $1,729
Hyundai	2010 2008	$735 - $509	$691 - $502	$960 - $700	$989 - $697	$1,197 - $771	$1,404 - $879	$1,442 - $889	$1,600 - $1,114	$1,543 - $1,080
Kia	2010 2008	$363 - $300	$333 - $261	$431 - $275	$441 - $555	$460 - $601	$500 - $609	$506 - $615	$507 - $622	$500 - $603
Lotus	2010 2008	$0 - $0	$0 - $0	$1 - $0	$1 - $0	$1 - $0	$1 - $0	$0 - $0	$0 - $0	$0 - $0
Mazda	2010 2008	$241 - $272	$300 - $328	$272 - $307	$497 - $1,015	$513 - $1,008	$578 - $1,024	$578 - $1,089	$581 - $1,080	$828 - $894
Mitsubishi	2010 2008	$54 - $75	$50 - $68	$53 - $84	$178 - $293	$183 - $291	$185 - $299	$184 - $303	$192 - $313	$165 - $257

Nissan	2010 2008	$598 - $796	$739 - $922	$1,031 - $1,138	$1,075 - $1,236	$1,091 - $1,254	$1,258 - $1,356	$1,442 - $1,490	$1,837 - $2,079	$1,768 - $2,038
Porsche	2010 2008	$6 - $16	$8 - $24	$10 - $32	$12 - $32	$15 - $35	$26 - $33	$27 - $36	$30 - $40	$29 - $45
Spyker	2010 2008	- - $8	- - $11	- - $15	- - $17	- - $19	- - $22	- - $33	- - $48	- - $43
Subaru	2010 2008	$115 - $138	$156 - $121	$1,257 - $479	$1,185 - $505	$1,147 - $513	$1,133 - $539	$1,105 - $532	$1,103 - $580	$857 - $888
Suzuki	2010 2008	$23 - $21	$22 - $20	$54 - $210	$70 - $218	$89 - $222	$90 - $222	$90 - $222	$96 - $229	$111 - $228
Tata	2010 2008	$9 - $34	$13 - $51	$16 - $55	$18 - $62	$20 - $64	$21 - $76	$31 - $89	$35 - $96	$42 - $102
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$947 - $972	$1,053 - $1,506	$1,754 - $1,551	$1,774 - $1,877	$2,010 - $2,358	$2,051 - $2,435	$2,067 - $2,465	$2,601 - $2,667	$2,510 - $2,565
Volkswagen	2010 2008	$215 - $221	$382 - $275	$436 - $360	$522 - $643	$589 - $755	$615 - $840	$655 - $920	$779 - $982	$933 - $1,159
Total/Average	2010 2008	$7,901 - $8,330	$9,158 - $9,782	$13,918 - $12,944	$15,444 - $15,784	$16,850 - $17,736	$18,000 - $18,447	$19,402 - $19,339	$22,519 - $21,945	$22,372 - $21,626

Table VII-1q
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Max Net Benefits (7% Discount Rate)
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$315 - $359	$414 - $469	$519 - $546	$612 - $634	$684 - $673	$722 - $684	$766 - $733	$849 - $794	$926 - $904
BMW	2010 2008	$329 - $380	$543 - $598	$653 - $647	$734 - $725	$909 - $869	$1,020 - $997	$1,073 - $1,059	$1,880 - $2,108	$1,717 - $1,864
Daimler	2010 2008	$310 - $349	$403 - $464	$502 - $565	$603 - $822	$682 - $875	$900 - $1,085	$1,156 - $1,289	$1,226 - $1,364	$1,617 - $1,975
Fiat	2010 2008	$1,141 - $1,569	$1,172 - $1,653	$1,322 - $1,591	$1,689 - $1,661	$1,807 - $1,699	$1,801 - $1,667	$1,977 - $1,751	$2,000 - $1,763	$2,014 - $1,667
Ford	2010 2008	$818 - $922	$852 - $944	$1,590 - $1,834	$1,757 - $2,074	$2,051 - $2,160	$2,076 - $2,152	$2,060 - $2,188	$2,468 - $2,356	$2,166 - $2,012
Geely	2010 2008	$326 - $541	$664 - $636	$1,049 - $985	$1,152 - $1,054	$1,213 - $1,135	$1,248 - $1,133	$1,329 - $1,305	$1,508 - $1,399	$2,083 - $1,435
General Motors	2010 2008	$760 - $965	$983 - $1,163	$902 - $1,121	$1,353 - $1,310	$1,385 - $1,444	$1,356 - $1,413	$1,467 - $1,476	$1,629 - $1,624	$1,759 - $1,842
Honda	2010 2008	$496 - $968	$673 - $999	$612 - $888	$613 - $865	$1,073 - $1,095	$1,063 - $1,112	$1,188 - $1,166	$1,212 - $1,171	$1,192 - $1,179
Hyundai	2010 2008	$830 - $853	$797 - $856	$998 - $1,074	$1,058 - $1,053	$1,264 - $1,101	$1,365 - $1,167	$1,391 - $1,192	$1,601 - $1,232	$1,519 - $1,151
Kia	2010 2008	$987 - $822	$919 - $726	$1,247 - $742	$1,269 - $1,147	$1,250 - $1,261	$1,318 - $1,259	$1,310 - $1,251	$1,294 - $1,237	$1,421 - $1,496
Lotus	2010 2008	$506 - $392	$608 - $502	$1,541 - $574	$1,625 - $667	$1,677 - $717	$1,707 - $733	$873 - $777	$971 - $843	$1,042 - $959
Mazda	2010 2008	$946 - $1,276	$1,206 - $1,573	$1,100 - $1,455	$1,970 - $2,031	$1,986 - $1,974	$2,258 - $2,119	$2,240 - $2,157	$2,218 - $2,129	$2,061 - $2,170
Mitsubishi	2010 2008	$881 - $969	$859 - $905	$794 - $1,015	$2,138 - $3,884	$2,201 - $3,823	$2,159 - $3,865	$2,133 - $3,890	$2,120 - $3,859	$1,972 - $3,057

Nissan	2010 2008	$629 - $846	$773 - $919	$1,055 - $1,134	$1,105 - $1,161	$1,091 - $1,148	$1,226 - $1,262	$1,240 - $1,414	$1,606 - $1,678	$1,554 - $1,650
Porsche	2010 2008	$304 - $434	$374 - $649	$537 - $806	$657 - $810	$829 - $851	$1,436 - $767	$1,498 - $812	$1,587 - $848	$1,499 - $967
Spyker	2010 2008	- - $368	- - $530	- - $669	- - $746	- - $806	- - $863	- - $1,297	- - $1,927	- - $1,726
Subaru	2010 2008	$544 - $611	$760 - $533	$1,344 - $2,131	$4,020 - $2,194	$3,970 - $2,157	$4,008 - $2,134	$4,007 - $2,060	$4,026 - $2,201	$3,202 - $3,456
Suzuki	2010 2008	$529 - $212	$523 - $208	$1,232 - $1,471	$1,578 - $1,554	$2,231 - $1,538	$2,189 - $1,514	$2,154 - $1,491	$2,131 - $1,458	$1,927 - $1,765
Tata	2010 2008	$310 - $589	$412 - $891	$506 - $900	$599 - $995	$625 - $1,015	$660 - $1,152	$953 - $1,327	$1,028 - $1,373	$1,207 - $1,457
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$580 - $526	$661 - $715	$1,092 - $746	$1,104 - $875	$1,156 - $1,116	$1,153 - $1,112	$1,138 - $1,098	$1,278 - $1,208	$1,222 - $1,162
Volkswagen	2010 2008	$424 - $389	$762 - $482	$870 - $599	$1,074 - $1,082	$1,218 - $1,196	$1,262 - $1,278	$1,324 - $1,382	$1,527 - $1,463	$1,798 - $1,723
Total/Average	2010 2008	$696 - $797	$816 - $899	$1,048 - $1,090	$1,281 - $1,265	$1,427 - $1,384	$1,466 - $1,408	$1,522 - $1,462	$1,712 - $1,597	$1,674 - $1,625

Table VII-1r
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Max Net Benefits (7% Discount Rate)
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $0	$0 - $1	$0 - $1	$0 - $1	$0 - $1	$0 - $1	$1 - $1	$1 - $1
BMW	2010 2008	$106 - $119	$173 - $193	$214 - $224	$242 - $259	$305 - $312	$349 - $359	$372 - $382	$673 - $818	$624 - $755
Daimler	2010 2008	$78 - $99	$97 - $128	$123 - $159	$148 - $239	$170 - $263	$226 - $331	$293 - $403	$317 - $453	$422 - $673
Fiat	2010 2008	$834 - $673	$865 - $675	$1,019 - $640	$1,332 - $707	$1,458 - $734	$1,496 - $726	$1,685 - $762	$1,759 - $771	$1,816 - $746
Ford	2010 2008	$1,103 - $1,198	$1,148 - $1,238	$2,133 - $2,443	$2,368 - $2,859	$2,790 - $3,028	$2,861 - $3,045	$2,873 - $3,227	$3,500 - $3,542	$3,121 - $3,098
Geely	2010 2008	$20 - $48	$38 - $57	$63 - $90	$69 - $98	$75 - $105	$78 - $105	$84 - $126	$98 - $139	$137 - $145
General Motors	2010 2008	$1,257 - $1,464	$1,589 - $1,791	$1,454 - $1,752	$2,182 - $2,110	$2,250 - $2,353	$2,221 - $2,319	$2,424 - $2,461	$2,731 - $2,760	$2,985 - $3,200
Honda	2010 2008	$556 - $1,118	$767 - $1,137	$702 - $1,017	$716 - $1,007	$1,274 - $1,313	$1,289 - $1,377	$1,470 - $1,476	$1,537 - $1,532	$1,544 - $1,580
Hyundai	2010 2008	$718 - $505	$677 - $495	$856 - $626	$911 - $630	$1,104 - $675	$1,211 - $733	$1,252 - $756	$1,471 - $810	$1,421 - $779
Kia	2010 2008	$341 - $265	$312 - $227	$410 - $234	$416 - $371	$413 - $418	$442 - $427	$444 - $429	$449 - $435	$498 - $543
Lotus	2010 2008	$0 - $0	$0 - $0	$1 - $0	$1 - $0	$1 - $0	$1 - $0	$0 - $0	$0 - $0	$0 - $0
Mazda	2010 2008	$241 - $300	$300 - $382	$272 - $359	$489 - $503	$495 - $493	$570 - $538	$571 - $577	$575 - $580	$541 - $605
Mitsubishi	2010 2008	$54 - $75	$50 - $68	$48 - $76	$130 - $296	$136 - $294	$137 - $303	$136 - $307	$142 - $317	$134 - $259

Nissan	2010 2008	$559 - $737	$671 - $781	$921 - $969	$966 - $1,025	$959 - $1,048	$1,084 - $1,183	$1,108 - $1,349	$1,458 - $1,649	$1,429 - $1,674
Porsche	2010 2008	$6 - $15	$7 - $23	$9 - $29	$11 - $29	$14 - $31	$25 - $28	$26 - $30	$28 - $33	$26 - $39
Spyker	2010 2008	- - $7	- - $11	- - $13	- - $16	- - $17	- - $19	- - $29	- - $44	- - $40
Subaru	2010 2008	$114 - $137	$156 - $115	$277 - $463	$827 - $490	$821 - $498	$841 - $509	$848 - $498	$868 - $547	$701 - $888
Suzuki	2010 2008	$23 - $19	$22 - $19	$53 - $133	$70 - $145	$100 - $147	$100 - $148	$100 - $148	$102 - $146	$94 - $182
Tata	2010 2008	$9 - $33	$11 - $50	$14 - $52	$17 - $58	$18 - $60	$19 - $68	$28 - $80	$31 - $87	$37 - $95
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$886 - $972	$992 - $1,312	$1,648 - $1,370	$1,672 - $1,649	$1,769 - $2,125	$1,785 - $2,208	$1,784 - $2,236	$2,043 - $2,513	$1,983 - $2,449
Volkswagen	2010 2008	$204 - $215	$359 - $260	$403 - $322	$494 - $600	$561 - $700	$587 - $758	$619 - $824	$727 - $886	$862 - $1,086
Total/Average	2010 2008	$7,108 - $7,999	$8,234 - $8,961	$10,622 - $10,971	$13,060 - $13,094	$14,715 - $14,615	$15,323 - $15,184	$16,119 - $16,101	$18,511 - $18,063	$18,378 - $18,840

Table VII-1s
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Total Cost = Total Benefit (3% Discount Rate)
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$376 - $453	$475 - $563	$585 - $645	$667 - $750	$766 - $805	$854 - $931	$931 - $1,030	$1,085 - $1,135	$1,201 - $1,201
BMW	2010 2008	$398 - $471	$609 - $692	$719 - $746	$789 - $840	$997 - $996	$1,152 - $1,239	$1,244 - $1,350	$2,122 - $2,432	$1,998 - $2,156
Daimler	2010 2008	$370 - $440	$469 - $552	$568 - $658	$658 - $932	$770 - $1,001	$1,032 - $1,316	$1,315 - $1,569	$1,457 - $1,683	$1,887 - $2,255
Fiat	2010 2008	$1,202 - $2,045	$1,188 - $2,145	$1,599 - $2,151	$1,747 - $2,299	$1,977 - $2,401	$2,176 - $2,427	$3,932 - $2,770	$3,903 - $3,389	$3,345 - $2,864
Ford	2010 2008	$817 - $3,310	$842 - $2,948	$2,894 - $3,110	$2,976 - $3,315	$3,002 - $3,341	$3,276 - $3,305	$3,275 - $3,280	$3,848 - $3,300	$3,372 - $2,720
Geely	2010 2008	$392 - $629	$730 - $724	$1,121 - $1,079	$1,212 - $1,170	$1,301 - $1,267	$1,385 - $1,364	$1,494 - $1,591	$1,750 - $1,724	$2,369 - $1,721
General Motors	2010 2008	$1,065 - $1,532	$1,293 - $1,721	$1,197 - $1,770	$1,597 - $2,059	$2,208 - $2,359	$2,160 - $2,320	$3,142 - $2,672	$3,198 - $2,995	$2,737 - $2,826
Honda	2010 2008	$773 - $1,117	$1,058 - $1,202	$981 - $1,050	$977 - $1,047	$1,255 - $1,372	$1,301 - $1,378	$1,637 - $1,527	$1,731 - $1,596	$1,697 - $1,576
Hyundai	2010 2008	$850 - $879	$814 - $901	$1,120 - $1,358	$1,149 - $1,383	$1,372 - $1,515	$1,607 - $1,902	$1,587 - $1,983	$1,882 - $2,514	$1,754 - $2,305
Kia	2010 2008	$1,040 - $1,850	$968 - $1,666	$1,100 - $1,674	$1,395 - $2,087	$1,408 - $2,150	$1,699 - $2,176	$1,713 - $2,210	$1,679 - $2,194	$1,611 - $1,956
Lotus	2010 2008	$572 - $491	$679 - $607	$1,613 - $684	$1,686 - $799	$1,770 - $860	$1,850 - $997	$1,055 - $1,102	$1,224 - $1,206	$1,339 - $1,283
Mazda	2010 2008	$1,133 - $1,443	$1,195 - $1,522	$1,091 - $1,402	$1,584 - $2,051	$1,756 - $2,150	$2,118 - $3,708	$2,273 - $3,674	$2,465 - $3,624	$2,458 - $3,073
Mitsubishi	2010 2008	$923 - $1,063	$859 - $905	$861 - $1,204	$3,831 - $3,838	$3,873 - $4,034	$3,818 - $4,066	$3,782 - $4,084	$3,778 - $4,048	$3,082 - $3,243

Nissan	2010 2008	$725 - $913	$874 - $1,104	$1,352 - $1,514	$1,427 - $1,592	$1,455 - $1,669	$1,602 - $2,175	$1,764 - $2,377	$2,806 - $2,528	$2,590 - $2,341
Porsche	2010 2008	$370 - $533	$440 - $753	$603 - $916	$717 - $942	$917 - $994	$1,568 - $1,031	$1,663 - $1,137	$1,824 - $1,211	$1,774 - $1,292
Spyker	2010 2008	- - $461	- - $629	- - $768	- - $867	- - $943	- - $1,111	- - $1,600	- - $2,273	- - $2,029
Subaru	2010 2008	$587 - $710	$671 - $638	$6,139 - $2,240	$5,415 - $2,303	$5,211 - $2,259	$5,057 - $2,375	$4,876 - $2,365	$4,773 - $2,559	$3,618 - $4,226
Suzuki	2010 2008	$620 - $807	$613 - $790	$1,175 - $1,516	$1,623 - $1,964	$2,043 - $2,002	$2,041 - $2,124	$2,084 - $2,205	$2,219 - $2,294	$2,651 - $2,417
Tata	2010 2008	$370 - $677	$472 - $979	$572 - $994	$649 - $1,105	$713 - $1,136	$792 - $1,377	$1,113 - $1,602	$1,259 - $1,681	$1,476 - $1,726
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$569 - $837	$679 - $1,055	$1,222 - $1,111	$1,266 - $1,283	$1,483 - $1,452	$1,497 - $1,530	$1,492 - $1,517	$1,681 - $1,636	$1,732 - $1,761
Volkswagen	2010 2008	$485 - $483	$828 - $581	$942 - $703	$1,134 - $1,203	$1,312 - $1,333	$1,400 - $1,531	$1,495 - $1,690	$1,775 - $1,810	$2,089 - $2,026
Total/Average	2010 2008	$804 - $1,351	$929 - $1,422	$1,485 - $1,562	$1,626 - $1,775	$1,849 - $1,930	$1,965 - $2,069	$2,325 - $2,199	$2,607 - $2,396	$2,399 - $2,297

Table VII-1t
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Total Cost = Total Benefit (3% Discount Rate)
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $1	$0 - $1	$0 - $1	$0 - $1	$1 - $1	$1 - $1	$1 - $1	$1 - $1
BMW	2010 2008	$128 - $147	$194 - $223	$235 - $258	$260 - $301	$335 - $358	$394 - $446	$431 - $487	$760 - $944	$726 - $874
Daimler	2010 2008	$94 - $125	$113 - $152	$140 - $185	$162 - $271	$192 - $301	$259 - $401	$334 - $490	$377 - $559	$493 - $768
Fiat	2010 2008	$878 - $878	$877 - $876	$1,233 - $866	$1,377 - $979	$1,595 - $1,037	$1,808 - $1,056	$3,351 - $1,205	$3,433 - $1,482	$3,016 - $1,282
Ford	2010 2008	$1,102 - $4,303	$1,135 - $3,866	$3,883 - $4,143	$4,010 - $4,570	$4,083 - $4,683	$4,514 - $4,677	$4,568 - $4,837	$5,459 - $4,963	$4,861 - $4,189
Geely	2010 2008	$24 - $55	$42 - $65	$68 - $99	$73 - $109	$80 - $117	$86 - $126	$94 - $154	$114 - $171	$156 - $174
General Motors	2010 2008	$1,761 - $2,324	$2,090 - $2,649	$1,928 - $2,768	$2,576 - $3,316	$3,587 - $3,843	$3,539 - $3,807	$5,192 - $4,457	$5,362 - $5,088	$4,643 - $4,910
Honda	2010 2008	$868 - $1,290	$1,206 - $1,367	$1,125 - $1,202	$1,141 - $1,218	$1,491 - $1,645	$1,579 - $1,705	$2,027 - $1,932	$2,194 - $2,088	$2,199 - $2,113
Hyundai	2010 2008	$735 - $520	$691 - $521	$961 - $792	$989 - $828	$1,199 - $929	$1,425 - $1,195	$1,428 - $1,258	$1,729 - $1,653	$1,641 - $1,561
Kia	2010 2008	$359 - $596	$328 - $520	$362 - $527	$457 - $675	$465 - $712	$570 - $738	$580 - $757	$582 - $772	$565 - $710
Lotus	2010 2008	$0 - $0	$0 - $0	$1 - $0	$1 - $0	$1 - $0	$1 - $0	$0 - $0	$0 - $0	$1 - $0
Mazda	2010 2008	$288 - $339	$298 - $369	$270 - $346	$393 - $509	$438 - $537	$535 - $942	$579 - $983	$640 - $987	$646 - $857
Mitsubishi	2010 2008	$56 - $82	$50 - $68	$52 - $90	$232 - $293	$239 - $311	$242 - $319	$242 - $322	$253 - $332	$209 - $275

Nissan	2010 2008	$644 - $795	$758 - $938	$1,180 - $1,294	$1,247 - $1,405	$1,280 - $1,523	$1,417 - $2,039	$1,576 - $2,268	$2,547 - $2,484	$2,382 - $2,376
Porsche	2010 2008	$7 - $19	$8 - $27	$10 - $33	$12 - $34	$16 - $36	$27 - $38	$29 - $42	$32 - $48	$31 - $53
Spyker	2010 2008	- - $9	- - $13	- - $15	- - $18	- - $20	- - $24	- - $36	- - $52	- - $47
Subaru	2010 2008	$123 - $159	$138 - $138	$1,264 - $486	$1,114 - $515	$1,078 - $521	$1,061 - $567	$1,032 - $572	$1,029 - $635	$792 - $1,086
Suzuki	2010 2008	$27 - $73	$26 - $71	$51 - $137	$72 - $184	$91 - $192	$93 - $207	$97 - $219	$106 - $230	$129 - $249
Tata	2010 2008	$10 - $38	$13 - $55	$16 - $57	$18 - $64	$21 - $67	$23 - $82	$33 - $97	$38 - $107	$46 - $113
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$870 - $1,547	$1,020 - $1,935	$1,844 - $2,040	$1,918 - $2,417	$2,269 - $2,765	$2,318 - $3,038	$2,338 - $3,090	$2,688 - $3,404	$2,810 - $3,712
Volkswagen	2010 2008	$234 - $266	$390 - $314	$436 - $378	$522 - $667	$604 - $781	$651 - $908	$698 - $1,008	$845 - $1,095	$1,002 - $1,277
Total/Average	2010 2008	$8,207 - $13,567	$9,377 - $14,169	$15,060 - $15,717	$16,574 - $18,374	$19,065 - $20,379	$20,544 - $22,316	$24,632 - $24,218	$28,189 - $27,097	$26,347 - $26,627

Table VII-1u
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Total Cost = Total Benefit (7% Discount Rate)
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$376 - $453	$475 - $563	$585 - $645	$667 - $750	$766 - $805	$854 - $931	$931 - $1,030	$1,085 - $1,135	$1,201 - $1,201
BMW	2010 2008	$398 - $471	$609 - $692	$719 - $746	$789 - $840	$997 - $996	$1,152 - $1,239	$1,244 - $1,350	$2,122 - $2,432	$1,998 - $2,156
Daimler	2010 2008	$370 - $440	$469 - $552	$568 - $658	$658 - $932	$770 - $1,001	$1,032 - $1,316	$1,315 - $1,569	$1,457 - $1,683	$1,887 - $2,255
Fiat	2010 2008	$1,202 - $2,045	$1,188 - $2,145	$1,599 - $2,151	$1,747 - $2,299	$1,977 - $2,401	$2,176 - $2,427	$3,932 - $2,770	$3,903 - $3,389	$3,345 - $2,864
Ford	2010 2008	$817 - $3,310	$842 - $2,948	$2,894 - $3,110	$2,976 - $3,315	$3,002 - $3,341	$3,276 - $3,305	$3,275 - $3,280	$3,848 - $3,300	$3,372 - $2,720
Geely	2010 2008	$392 - $629	$730 - $724	$1,121 - $1,079	$1,212 - $1,170	$1,301 - $1,267	$1,385 - $1,364	$1,494 - $1,591	$1,750 - $1,724	$2,369 - $1,721
General Motors	2010 2008	$1,065 - $1,532	$1,293 - $1,721	$1,197 - $1,770	$1,597 - $2,059	$2,208 - $2,359	$2,160 - $2,320	$3,142 - $2,672	$3,198 - $2,995	$2,737 - $2,826
Honda	2010 2008	$773 - $1,117	$1,058 - $1,202	$981 - $1,050	$977 - $1,047	$1,255 - $1,372	$1,301 - $1,378	$1,637 - $1,527	$1,731 - $1,596	$1,697 - $1,576
Hyundai	2010 2008	$850 - $879	$814 - $901	$1,120 - $1,358	$1,149 - $1,383	$1,372 - $1,515	$1,607 - $1,902	$1,587 - $1,983	$1,882 - $2,514	$1,754 - $2,305
Kia	2010 2008	$1,040 - $1,850	$968 - $1,666	$1,100 - $1,674	$1,395 - $2,087	$1,408 - $2,150	$1,699 - $2,176	$1,713 - $2,210	$1,679 - $2,194	$1,611 - $1,956
Lotus	2010 2008	$572 - $491	$679 - $607	$1,613 - $684	$1,686 - $799	$1,770 - $860	$1,850 - $997	$1,055 - $1,102	$1,224 - $1,206	$1,339 - $1,283
Mazda	2010 2008	$1,133 - $1,443	$1,195 - $1,522	$1,091 - $1,402	$1,584 - $2,051	$1,756 - $2,150	$2,118 - $3,708	$2,273 - $3,674	$2,465 - $3,624	$2,458 - $3,073
Mitsubishi	2010 2008	$923 - $1,063	$859 - $905	$861 - $1,204	$3,831 - $3,838	$3,873 - $4,034	$3,818 - $4,066	$3,782 - $4,084	$3,778 - $4,048	$3,082 - $3,243

Nissan	2010 2008	$725 - $913	$874 - $1,104	$1,352 - $1,514	$1,427 - $1,592	$1,455 - $1,669	$1,602 - $2,175	$1,764 - $2,377	$2,806 - $2,528	$2,590 - $2,341
Porsche	2010 2008	$370 - $533	$440 - $753	$603 - $916	$717 - $942	$917 - $994	$1,568 - $1,031	$1,663 - $1,137	$1,824 - $1,211	$1,774 - $1,292
Spyker	2010 2008	- - $461	- - $629	- - $768	- - $867	- - $943	- - $1,111	- - $1,600	- - $2,273	- - $2,029
Subaru	2010 2008	$587 - $710	$671 - $638	$6,139 - $2,240	$5,415 - $2,303	$5,211 - $2,259	$5,057 - $2,375	$4,876 - $2,365	$4,773 - $2,559	$3,618 - $4,226
Suzuki	2010 2008	$620 - $807	$613 - $790	$1,175 - $1,516	$1,623 - $1,964	$2,043 - $2,002	$2,041 - $2,124	$2,084 - $2,205	$2,219 - $2,294	$2,651 - $2,417
Tata	2010 2008	$370 - $677	$472 - $979	$572 - $994	$649 - $1,105	$713 - $1,136	$792 - $1,377	$1,113 - $1,602	$1,259 - $1,681	$1,476 - $1,726
Tesla	2010 2008	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2	- - $2
Toyota	2010 2008	$569 - $837	$679 - $1,055	$1,222 - $1,111	$1,266 - $1,283	$1,483 - $1,452	$1,497 - $1,530	$1,492 - $1,517	$1,681 - $1,636	$1,732 - $1,761
Volkswagen	2010 2008	$485 - $483	$828 - $581	$942 - $703	$1,134 - $1,203	$1,312 - $1,333	$1,400 - $1,531	$1,495 - $1,690	$1,775 - $1,810	$2,089 - $2,026
Total/Average	2010 2008	$804 - $1,351	$929 - $1,422	$1,485 - $1,562	$1,626 - $1,775	$1,849 - $1,930	$1,965 - $2,069	$2,325 - $2,199	$2,607 - $2,396	$2,399 - $2,297

Table VII-1v
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Total Cost = Total Benefit (7% Discount Rate)
Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	$0 - $0	$0 - $1	$0 - $1	$0 - $1	$0 - $1	$1 - $1	$1 - $1	$1 - $1	$1 - $1
BMW	2010 2008	$128 - $147	$194 - $223	$235 - $258	$260 - $301	$335 - $358	$394 - $446	$431 - $487	$760 - $944	$726 - $874
Daimler	2010 2008	$94 - $125	$113 - $152	$140 - $185	$162 - $271	$192 - $301	$259 - $401	$334 - $490	$377 - $559	$493 - $768
Fiat	2010 2008	$878 - $878	$877 - $876	$1,233 - $866	$1,377 - $979	$1,595 - $1,037	$1,808 - $1,056	$3,351 - $1,205	$3,433 - $1,482	$3,016 - $1,282
Ford	2010 2008	$1,102 - $4,303	$1,135 - $3,866	$3,883 - $4,143	$4,010 - $4,570	$4,083 - $4,683	$4,514 - $4,677	$4,568 - $4,837	$5,459 - $4,963	$4,861 - $4,189
Geely	2010 2008	$24 - $55	$42 - $65	$68 - $99	$73 - $109	$80 - $117	$86 - $126	$94 - $154	$114 - $171	$156 - $174
General Motors	2010 2008	$1,761 - $2,324	$2,090 - $2,649	$1,928 - $2,768	$2,576 - $3,316	$3,587 - $3,843	$3,539 - $3,807	$5,192 - $4,457	$5,362 - $5,088	$4,643 - $4,910
Honda	2010 2008	$868 - $1,290	$1,206 - $1,367	$1,125 - $1,202	$1,141 - $1,218	$1,491 - $1,645	$1,579 - $1,705	$2,027 - $1,932	$2,194 - $2,088	$2,199 - $2,113
Hyundai	2010 2008	$735 - $520	$691 - $521	$961 - $792	$989 - $828	$1,199 - $929	$1,425 - $1,195	$1,428 - $1,258	$1,729 - $1,653	$1,641 - $1,561
Kia	2010 2008	$359 - $596	$328 - $520	$362 - $527	$457 - $675	$465 - $712	$570 - $738	$580 - $757	$582 - $772	$565 - $710
Lotus	2010 2008	$0 - $0	$0 - $0	$1 - $0	$1 - $0	$1 - $0	$1 - $0	$0 - $0	$0 - $0	$1 - $0
Mazda	2010 2008	$288 - $339	$298 - $369	$270 - $346	$393 - $509	$438 - $537	$535 - $942	$579 - $983	$640 - $987	$646 - $857
Mitsubishi	2010 2008	$56 - $82	$50 - $68	$52 - $90	$232 - $293	$239 - $311	$242 - $319	$242 - $322	$253 - $332	$209 - $275

Nissan	2010 2008	$644 - $795	$758 - $938	$1,180 - $1,294	$1,247 - $1,405	$1,280 - $1,523	$1,417 - $2,039	$1,576 - $2,268	$2,547 - $2,484	$2,382 - $2,376
Porsche	2010 2008	$7 - $19	$8 - $27	$10 - $33	$12 - $34	$16 - $36	$27 - $38	$29 - $42	$32 - $48	$31 - $53
Spyker	2010 2008	- - $9	- - $13	- - $15	- - $18	- - $20	- - $24	- - $36	- - $52	- - $47
Subaru	2010 2008	$123 - $159	$138 - $138	$1,264 - $486	$1,114 - $515	$1,078 - $521	$1,061 - $567	$1,032 - $572	$1,029 - $635	$792 - $1,086
Suzuki	2010 2008	$27 - $73	$26 - $71	$51 - $137	$72 - $184	$91 - $192	$93 - $207	$97 - $219	$106 - $230	$129 - $249
Tata	2010 2008	$10 - $38	$13 - $55	$16 - $57	$18 - $64	$21 - $67	$23 - $82	$33 - $97	$38 - $107	$46 - $113
Tesla	2010 2008	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0	- - $0
Toyota	2010 2008	$870 - $1,547	$1,020 - $1,935	$1,844 - $2,040	$1,918 - $2,417	$2,269 - $2,765	$2,318 - $3,038	$2,338 - $3,090	$2,688 - $3,404	$2,810 - $3,712
Volkswagen	2010 2008	$234 - $266	$390 - $314	$436 - $378	$522 - $667	$604 - $781	$651 - $908	$698 - $1,008	$845 - $1,095	$1,002 - $1,277
Total/Average	2010 2008	$8,207 - $13,567	$9,377 - $14,169	$15,060 - $15,717	$16,574 - $18,374	$19,065 - $20,379	$20,544 - $22,316	$24,632 - $24,218	$28,189 - $27,097	$26,347 - $26,627

Table VII-2a
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Preferred Alternative
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$275 - $607	$291 - $607	$264 - $590	$259 - $582	$438 - $903	$741 - $1,337	$718 - $1,319	$724 - $1,339	$882 - $1,307
Daimler	2010 2008	$253 - $240	$346 - $247	$326 - $237	$320 - $317	$417 - $309	$805 - $1,311	$877 - $1,306	$855 - $1,285	$963 - $1,208
Fiat	2010 2008	$474 - $52	$472 - $60	$541 - $111	$949 - $745	$1,269 - $836	$1,245 - $839	$1,727 - $1,222	$1,699 - $1,243	$1,585 - $1,622
Ford	2010 2008	$131 - $81	$149 - $101	$216 - $116	$258 - $261	$997 - $765	$988 - $832	$982 - $838	$981 - $855	$957 - $805
Geely	2010 2008	$12 - $104	$445 - $340	$439 - $368	$430 - $362	$425 - $352	$510 - $889	$1,266 - $1,251	$1,275 - $1,234	$1,271 - $1,141
General Motors	2010 2008	$46 - ($7)	$62 - $97	$587 - $335	$995 - $550	$984 - $550	$959 - $547	$958 - $625	$1,020 - $631	$986 - $1,093
Honda	2010 2008	($4) - $288	$48 - $300	$313 - $375	$320 - $329	$782 - $630	$1,026 - $868	$1,045 - $859	$1,068 - $903	$1,018 - $862
Hyundai	2010 2008	$293 - $54	$211 - $68	$967 - $233	$964 - $252	$950 - $245	$1,248 - $572	$1,270 - $565	$1,484 - $820	$1,465 - $791
Kia	2010 2008	$209 - $237	$218 - $284	$476 - $465	$473 - $544	$791 - $1,108	$777 - $1,088	$832 - $1,128	$855 - $1,164	$855 - $1,114
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$15 - $2	$683 - $859	$594 - $771	$570 - $823	$593 - $740	$583 - $743	$749 - $730	$912 - $719	$849 - $702
Mitsubishi	2010 2008	$302 - $69	$444 - $82	$406 - $57	$402 - $58	$1,161 - $1,837	$1,128 - $1,785	$1,113 - $1,741	$1,099 - $1,717	$1,071 - $1,601

Nissan	2010 2008	$5 - $178	$18 - $185	$414 - $366	$540 - $440	$660 - $675	$729 - $1,033	$729 - $1,008	$712 - $1,153	$682 - $1,353
Porsche	2010 2008	$1 - $1	$41 - $13	$528 - $453	$516 - $447	$502 - $440	$528 - $483	$1,255 - $1,279	$1,319 - $1,342	$1,306 - $1,340
Spyker	2010 2008	- - $257	- - $294	- - $287	- - $283	- - $633	- - $650	- - $658	- - $803	- - $865
Subaru	2010 2008	$731 - $1	$755 - $104	$971 - $613	$958 - $572	$940 - $582	$911 - $582	$899 - $574	$1,442 - $568	$1,368 - $543
Suzuki	2010 2008	($13) - $4	$0 - $16	($3) - $582	($2) - $574	$900 - $662	$854 - $651	$844 - $643	$835 - $635	$781 - $611
Tata	2010 2008	$7 - $9	$68 - $62	$101 - $112	$150 - $151	$599 - $636	$740 - $714	$837 - $804	$933 - $905	$1,016 - $963
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$132 - $25	$160 - $230	$258 - $400	$314 - $482	$463 - $626	$522 - $648	$581 - $659	$904 - $886	$886 - $958
Volkswagen	2010 2008	$202 - $1	$309 - $102	$576 - $658	$1,037 - $667	$1,022 - $822	$1,007 - $829	$1,136 - $1,051	$1,155 - $1,088	$1,144 - $1,005
Total/Average	2010 2008	$158 - $87	$187 - $179	$416 - $331	$596 - $470	$863 - $648	$911 - $752	$1,000 - $808	$1,081 - $888	$1,047 - $1,040

Table VII-2b
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Preferred Alternative
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$29 - $84	$30 - $80	$28 - $78	$26 - $75	$44 - $116	$74 - $84	$71 - $80	$73 - $83	$89 - $93
Daimler	2010 2008	$25 - $21	$38 - $21	$35 - $21	$35 - $29	$46 - $31	$90 - $21	$100 - $21	$100 - $22	$115 - $32
Fiat	2010 2008	$367 - $21	$351 - $23	$405 - $40	$703 - $266	$930 - $288	$917 - $21	$1,263 - $23	$1,227 - $40	$1,152 - $266
Ford	2010 2008	$136 - $62	$153 - $75	$219 - $84	$257 - $187	$987 - $546	$979 - $62	$968 - $75	$973 - $84	$955 - $187
Geely	2010 2008	$0 - $4	$14 - $14	$15 - $16	$14 - $15	$14 - $15	$16 - $4	$39 - $14	$41 - $16	$40 - $15
General Motors	2010 2008	$55 - ($9)	$74 - $133	$714 - $481	$1,205 - $805	$1,199 - $807	$1,176 - ($9)	$1,181 - $133	$1,268 - $481	$1,243 - $805
Honda	2010 2008	($2) - $172	$25 - $163	$165 - $198	$166 - $173	$401 - $338	$529 - $172	$533 - $163	$540 - $198	$513 - $173
Hyundai	2010 2008	$39 - $8	$27 - $10	$118 - $36	$114 - $39	$112 - $38	$145 - $8	$146 - $10	$173 - $36	$172 - $39
Kia	2010 2008	$9 - $23	$9 - $28	$20 - $47	$19 - $53	$31 - $106	$30 - $23	$32 - $28	$33 - $47	$32 - $53
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$1 - $0	$40 - $67	$33 - $60	$30 - $66	$31 - $62	$31 - $0	$39 - $67	$48 - $60	$45 - $66
Mitsubishi	2010 2008	$4 - $2	$6 - $2	$6 - $1	$6 - $1	$17 - $44	$17 - $2	$17 - $2	$17 - $1	$17 - $1

Nissan	2010 2008	$2 - $79	$6 - $76	$128 - $146	$164 - $175	$201 - $275	$222 - $79	$222 - $76	$220 - $146	$213 - $175
Porsche	2010 2008	$0 - $0	$1 - $0	$10 - $5	$10 - $5	$9 - $5	$10 - $0	$23 - $1	$25 - $7	$25 - $8
Spyker	2010 2008	- - $1	- - $1	- - $1	- - $1	- - $2	- - $1	- - $1	- - $2	- - $2
Subaru	2010 2008	$71 - $0	$71 - $8	$90 - $45	$87 - $41	$86 - $42	$84 - $0	$83 - $8	$136 - $45	$132 - $41
Suzuki	2010 2008	($0) - $0	$0 - $0	($0) - $12	($0) - $12	$3 - $14	$3 - $0	$3 - $0	$3 - $12	$3 - $12
Tata	2010 2008	$0 - $1	$4 - $4	$5 - $6	$8 - $8	$31 - $37	$38 - $10	$42 - $16	$47 - $22	$51 - $28
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$127 - $33	$153 - $282	$245 - $456	$293 - $556	$429 - $761	$483 - $33	$534 - $282	$830 - $456	$816 - $556
Volkswagen	2010 2008	$21 - $0	$31 - $15	$59 - $97	$105 - $98	$104 - $122	$103 - $0	$115 - $15	$121 - $97	$120 - $98
Total/Average	2010 2008	$885 - $501	$1,034 - $1,003	$2,295 - $1,829	$3,241 - $2,606	$4,675 - $3,650	$4,946 - $501	$5,411 - $1,003	$5,875 - $1,829	$5,734 - $2,606

Table VII-2c
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
2% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$383 - $318	$400 - $322	$362 - $310	$355 - $350	$490 - $539	$517 - $1,070	$510 - $1,054	$487 - $1,033	$506 - $960
Daimler	2010 2008	$385 - $78	$490 - $101	$464 - $106	$473 - $172	$460 - $149	$746 - $1,040	$775 - $1,035	$748 - $1,001	$728 - $956
Fiat	2010 2008	$587 - $149	$584 - $161	$701 - $169	$933 - $677	$1,181 - $699	$1,170 - $689	$1,304 - $792	$1,279 - $810	$1,176 - $781
Ford	2010 2008	$552 - $63	$568 - $74	$599 - $86	$583 - $159	$415 - $475	$414 - $513	$407 - $500	$422 - $492	$417 - $472
Geely	2010 2008	$73 - $222	$285 - $474	$294 - $463	$287 - $456	$302 - $445	$377 - $648	$608 - $669	$569 - $656	$530 - $604
General Motors	2010 2008	$433 - $52	$442 - $142	$529 - $303	$607 - $420	$595 - $396	$601 - $389	$604 - $423	$590 - $432	$572 - $511
Honda	2010 2008	$216 - $266	$253 - $279	$265 - $209	$274 - $217	$335 - $332	$399 - $469	$486 - $434	$582 - $471	$569 - $451
Hyundai	2010 2008	$297 - $196	$218 - $208	$838 - $452	$846 - $461	$834 - $449	$896 - $599	$884 - $591	$945 - $579	$905 - $550
Kia	2010 2008	$513 - $386	$518 - $435	$493 - $487	$488 - $531	$678 - $521	$669 - $511	$707 - $539	$673 - $628	$656 - $610
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$150 - $7	$434 - $603	$416 - $570	$404 - $651	$423 - $721	$413 - $709	$570 - $910	$624 - $973	$602 - $938
Mitsubishi	2010 2008	$302 - $69	$603 - $82	$557 - $57	$550 - $58	$961 - $882	$932 - $837	$919 - $819	$907 - $809	$886 - $765

Nissan	2010 2008	$33 - $197	$45 - $205	$227 - $321	$267 - $438	$261 - $525	$450 - $616	$467 - $602	$477 - $743	$467 - $683
Porsche	2010 2008	$56 - $1	$96 - $61	$675 - $453	$664 - $447	$651 - $413	$677 - $472	$1,104 - $985	$1,091 - $966	$970 - $876
Spyker	2010 2008	- - $308	- - $369	- - $412	- - $447	- - $611	- - $590	- - $584	- - $622	- - $529
Subaru	2010 2008	($7) - $42	$14 - $162	$503 - $446	$476 - $439	$463 - $400	$560 - $403	$552 - $398	$642 - $394	$609 - $373
Suzuki	2010 2008	($67) - $4	($52) - $16	($47) - $305	($45) - $303	$520 - $340	$511 - $336	$485 - $333	$478 - $330	$461 - $578
Tata	2010 2008	$67 - $59	$123 - $123	$161 - $172	$210 - $217	$571 - $595	$652 - $557	$694 - $657	$729 - $696	$747 - $678
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$252 - $150	$183 - $280	$182 - $315	$181 - $357	$367 - $405	$414 - $437	$437 - $425	$639 - $525	$672 - $503
Volkswagen	2010 2008	$252 - $69	$267 - $303	$409 - $681	$570 - $674	$556 - $678	$566 - $669	$576 - $662	$616 - $645	$590 - $610
Total/Average	2010 2008	$376 - $133	$379 - $205	$457 - $280	$509 - $376	$555 - $449	$590 - $512	$626 - $524	$667 - $564	$649 - $562

Table VII-2d
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
2% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$41 - $44	$42 - $43	$38 - $41	$36 - $45	$50 - $69	$52 - $44	$51 - $43	$49 - $41	$51 - $45
Daimler	2010 2008	$38 - $7	$53 - $8	$50 - $9	$51 - $16	$51 - $15	$84 - $7	$88 - $8	$87 - $9	$87 - $16
Fiat	2010 2008	$455 - $60	$434 - $62	$525 - $61	$691 - $242	$866 - $241	$861 - $60	$953 - $62	$924 - $61	$855 - $242
Ford	2010 2008	$571 - $48	$582 - $56	$609 - $62	$580 - $114	$411 - $339	$410 - $48	$401 - $56	$419 - $62	$416 - $114
Geely	2010 2008	$3 - $9	$9 - $20	$10 - $20	$9 - $19	$10 - $19	$12 - $9	$19 - $20	$18 - $20	$17 - $19
General Motors	2010 2008	$526 - $67	$531 - $195	$644 - $435	$736 - $615	$725 - $580	$737 - $67	$745 - $195	$734 - $435	$722 - $615
Honda	2010 2008	$116 - $159	$133 - $152	$140 - $110	$141 - $114	$172 - $178	$206 - $159	$248 - $152	$294 - $110	$287 - $114
Hyundai	2010 2008	$39 - $30	$28 - $32	$102 - $70	$100 - $71	$98 - $70	$104 - $30	$102 - $32	$110 - $70	$106 - $71
Kia	2010 2008	$22 - $38	$22 - $43	$21 - $49	$20 - $51	$27 - $50	$26 - $38	$27 - $43	$26 - $49	$25 - $51
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$9 - $0	$26 - $47	$23 - $44	$22 - $52	$22 - $61	$22 - $0	$30 - $47	$33 - $44	$32 - $52
Mitsubishi	2010 2008	$4 - $2	$8 - $2	$8 - $1	$8 - $1	$14 - $21	$14 - $2	$14 - $2	$14 - $1	$14 - $1

Nissan	2010 2008	$10 - $88	$14 - $85	$70 - $128	$81 - $174	$79 - $214	$137 - $88	$142 - $85	$147 - $128	$146 - $174
Porsche	2010 2008	$1 - $0	$2 - $1	$13 - $5	$13 - $5	$12 - $5	$13 - $0	$20 - $1	$21 - $5	$19 - $5
Spyker	2010 2008	- - $1	- - $1	- - $2	- - $2	- - $2	- - $1	- - $1	- - $2	- - $1
Subaru	2010 2008	($1) - $3	$1 - $12	$46 - $33	$43 - $32	$42 - $29	$51 - $3	$51 - $12	$61 - $33	$59 - $32
Suzuki	2010 2008	($0) - $0	($0) - $0	($0) - $6	($0) - $6	$2 - $7	$2 - $0	$2 - $0	$2 - $6	$2 - $6
Tata	2010 2008	$4 - $3	$7 - $7	$8 - $10	$11 - $12	$29 - $35	$33 - $1	$35 - $8	$37 - $10	$38 - $12
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$243 - $200	$175 - $343	$173 - $360	$168 - $412	$340 - $492	$383 - $200	$402 - $343	$586 - $360	$619 - $412
Volkswagen	2010 2008	$26 - $9	$27 - $44	$42 - $100	$58 - $99	$56 - $101	$58 - $9	$59 - $44	$65 - $100	$62 - $99
Total/Average	2010 2008	$2,107 - $769	$2,093 - $1,152	$2,523 - $1,547	$2,768 - $2,084	$3,006 - $2,527	$3,203 - $769	$3,387 - $1,152	$3,626 - $1,547	$3,555 - $2,084

Table VII-2e
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
3% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$422 - $556	$441 - $557	$439 - $522	$471 - $615	$682 - $941	$934 - $1,519	$914 - $1,483	$912 - $1,458	$868 - $1,399
Daimler	2010 2008	$511 - $736	$622 - $744	$591 - $690	$600 - $692	$584 - $697	$1,001 - $1,207	$1,017 - $1,199	$1,045 - $1,170	$1,017 - $1,087
Fiat	2010 2008	$624 - $150	$621 - $163	$793 - $180	$1,027 - $1,003	$1,313 - $1,064	$1,346 - $1,060	$1,696 - $1,269	$1,676 - $1,284	$1,565 - $1,240
Ford	2010 2008	$549 - $125	$587 - $153	$588 - $164	$583 - $320	$954 - $712	$948 - $799	$943 - $785	$936 - $796	$1,183 - $1,133
Geely	2010 2008	$84 - $183	$593 - $815	$595 - $829	$581 - $798	$570 - $828	$669 - $1,055	$1,281 - $1,041	$1,257 - $1,023	$1,131 - $1,057
General Motors	2010 2008	$463 - $52	$478 - $162	$693 - $555	$1,182 - $788	$1,162 - $761	$1,124 - $748	$1,105 - $784	$1,121 - $824	$1,080 - $799
Honda	2010 2008	$196 - $293	$232 - $307	$353 - $300	$370 - $310	$492 - $509	$662 - $757	$640 - $766	$667 - $734	$637 - $832
Hyundai	2010 2008	$262 - $470	$180 - $485	$829 - $628	$903 - $619	$893 - $608	$1,051 - $792	$1,044 - $783	$1,200 - $1,003	$1,202 - $957
Kia	2010 2008	$513 - $251	$518 - $261	$544 - $616	$540 - $685	$1,001 - $863	$956 - $850	$1,076 - $875	$1,063 - $869	$1,039 - $856
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$150 - $16	$492 - $792	$426 - $705	$408 - $790	$400 - $702	$391 - $688	$762 - $1,175	$976 - $1,166	$886 - $1,130
Mitsubishi	2010 2008	$228 - $196	$372 - $206	$322 - $182	$320 - $180	$1,277 - $1,499	$1,232 - $1,418	$1,215 - $1,397	$1,199 - $1,379	$1,173 - $1,285

Nissan	2010 2008	$125 - $237	$137 - $246	$263 - $421	$387 - $464	$411 - $759	$794 - $931	$786 - $968	$895 - $1,159	$924 - $1,208
Porsche	2010 2008	$73 - $1	$134 - $152	$1,050 - $453	$1,033 - $502	$1,015 - $517	$1,068 - $604	$1,061 - $1,296	$1,075 - $1,325	$1,132 - $1,291
Spyker	2010 2008	- - $358	- - $419	- - $403	- - $496	- - $763	- - $767	- - $825	- - $889	- - $901
Subaru	2010 2008	$755 - ($28)	$769 - $73	$1,073 - $561	$1,058 - $556	$1,039 - $578	$1,008 - $536	$993 - $530	$1,128 - $766	$1,092 - $730
Suzuki	2010 2008	$4 - $51	$18 - $62	($1) - $521	$1 - $513	$868 - $631	$832 - $696	$823 - $687	$814 - $678	$761 - $653
Tata	2010 2008	$84 - $95	$167 - $155	$227 - $238	$293 - $305	$676 - $713	$784 - $742	$853 - $820	$916 - $888	$961 - $908
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$417 - $164	$330 - $297	$376 - $341	$459 - $484	$509 - $572	$514 - $570	$618 - $617	$761 - $720	$788 - $735
Volkswagen	2010 2008	$278 - $85	$422 - $432	$723 - $727	$882 - $706	$860 - $683	$900 - $665	$1,022 - $641	$1,158 - $1,394	$1,352 - $1,284
Total/Average	2010 2008	$435 - $172	$445 - $258	$570 - $409	$739 - $583	$876 - $706	$928 - $777	$996 - $820	$1,039 - $898	$1,065 - $935

Table VII-2f
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
3% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$45 - $77	$46 - $73	$46 - $69	$48 - $79	$69 - $121	$94 - $77	$91 - $73	$92 - $69	$88 - $89
Daimler	2010 2008	$51 - $64	$68 - $62	$64 - $61	$65 - $64	$64 - $69	$112 - $64	$115 - $62	$122 - $62	$121 - $66
Fiat	2010 2008	$483 - $61	$462 - $62	$594 - $65	$761 - $358	$962 - $367	$991 - $61	$1,240 - $62	$1,210 - $65	$1,137 - $358
Ford	2010 2008	$568 - $95	$601 - $115	$598 - $117	$580 - $230	$944 - $509	$939 - $95	$929 - $115	$928 - $117	$1,180 - $230
Geely	2010 2008	$3 - $8	$19 - $34	$20 - $36	$19 - $34	$18 - $35	$21 - $8	$40 - $34	$40 - $36	$36 - $39
General Motors	2010 2008	$561 - $67	$574 - $223	$844 - $797	$1,432 - $1,154	$1,416 - $1,115	$1,378 - $67	$1,362 - $223	$1,395 - $797	$1,363 - $1,154
Honda	2010 2008	$105 - $175	$122 - $167	$186 - $158	$191 - $163	$252 - $273	$341 - $175	$326 - $167	$337 - $158	$321 - $163
Hyundai	2010 2008	$35 - $72	$23 - $74	$101 - $98	$107 - $95	$105 - $95	$122 - $72	$120 - $74	$140 - $98	$141 - $95
Kia	2010 2008	$22 - $25	$22 - $26	$23 - $62	$22 - $66	$39 - $82	$37 - $25	$41 - $26	$40 - $62	$39 - $66
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$9 - $1	$29 - $61	$23 - $55	$22 - $63	$21 - $59	$21 - $1	$40 - $61	$52 - $55	$47 - $63
Mitsubishi	2010 2008	$3 - $5	$5 - $5	$5 - $4	$5 - $4	$18 - $36	$18 - $5	$18 - $5	$18 - $4	$18 - $4

Nissan	2010 2008	$38 - $106	$42 - $101	$81 - $168	$118 - $185	$125 - $310	$242 - $106	$239 - $101	$276 - $168	$288 - $185
Porsche	2010 2008	$1 - $0	$3 - $2	$21 - $5	$19 - $6	$19 - $6	$20 - $2	$20 - $2	$20 - $7	$22 - $7
Spyker	2010 2008	- - $1	- - $2	- - $2	- - $2	- - $3	- - $1	- - $2	- - $2	- - $2
Subaru	2010 2008	$73 - ($2)	$73 - $5	$99 - $41	$96 - $40	$95 - $42	$93 - ($2)	$92 - $5	$106 - $41	$105 - $40
Suzuki	2010 2008	$0 - $1	$0 - $1	($0) - $11	$0 - $11	$3 - $13	$3 - $1	$3 - $1	$3 - $11	$3 - $11
Tata	2010 2008	$5 - $5	$9 - $9	$12 - $14	$15 - $17	$34 - $41	$40 - $11	$43 - $17	$46 - $21	$48 - $25
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$403 - $218	$315 - $363	$358 - $389	$428 - $558	$472 - $695	$476 - $218	$568 - $363	$699 - $389	$726 - $558
Volkswagen	2010 2008	$29 - $11	$42 - $63	$74 - $107	$89 - $104	$87 - $102	$92 - $9	$104 - $62	$121 - $107	$142 - $105
Total/Average	2010 2008	$2,434 - $989	$2,455 - $1,449	$3,149 - $2,258	$4,016 - $3,233	$4,747 - $3,973	$5,039 - $989	$5,391 - $1,449	$5,648 - $2,258	$5,827 - $3,233

Table VII-2g
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
4% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$630 - $795	$650 - $791	$624 - $797	$612 - $844	$759 - $974	$1,134 - $1,409	$1,168 - $1,460	$1,245 - $1,543	$1,309 - $1,536
Daimler	2010 2008	$511 - $1,034	$622 - $1,041	$630 - $979	$670 - $976	$634 - $990	$1,111 - $1,188	$1,160 - $1,262	$1,232 - $1,331	$1,265 - $1,349
Fiat	2010 2008	$706 - $498	$701 - $489	$899 - $503	$1,295 - $1,723	$1,543 - $1,822	$1,629 - $1,869	$2,097 - $2,022	$2,132 - $2,148	$2,772 - $2,019
Ford	2010 2008	$619 - $62	$693 - $150	$645 - $155	$731 - $335	$1,102 - $1,200	$1,109 - $1,320	$1,106 - $1,397	$1,215 - $1,386	$1,427 - $1,961
Geely	2010 2008	$100 - $204	$791 - $837	$791 - $851	$775 - $819	$829 - $953	$885 - $1,087	$1,476 - $1,203	$1,538 - $1,288	$1,518 - $1,324
General Motors	2010 2008	$463 - $109	$484 - $284	$715 - $900	$1,363 - $1,248	$1,340 - $1,197	$1,307 - $1,168	$1,315 - $1,188	$1,336 - $1,163	$1,434 - $1,125
Honda	2010 2008	$214 - $653	$255 - $659	$404 - $602	$450 - $603	$709 - $946	$1,077 - $1,271	$1,060 - $1,240	$1,241 - $1,342	$1,151 - $1,283
Hyundai	2010 2008	$326 - $670	$297 - $680	$1,011 - $795	$1,067 - $783	$1,052 - $770	$1,602 - $1,134	$1,594 - $1,122	$1,820 - $1,841	$1,745 - $1,703
Kia	2010 2008	$486 - $373	$492 - $383	$559 - $692	$555 - $798	$1,064 - $1,410	$1,018 - $1,360	$1,088 - $1,341	$1,074 - $1,324	$1,036 - $1,256
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$408 - $16	$1,217 - $1,064	$1,112 - $971	$1,124 - $1,039	$1,102 - $961	$1,141 - $947	$1,350 - $1,412	$1,531 - $1,429	$1,400 - $1,351
Mitsubishi	2010 2008	$1,357 - $342	$1,347 - $349	$1,233 - $326	$1,293 - $320	$2,013 - $2,577	$1,980 - $2,476	$1,924 - $2,436	$1,895 - $2,400	$1,803 - $2,227

Nissan	2010 2008	$126 - $478	$140 - $474	$654 - $850	$800 - $954	$925 - $1,512	$1,171 - $1,665	$1,168 - $1,672	$1,380 - $1,950	$1,469 - $2,201
Porsche	2010 2008	$95 - $1	$173 - $190	$1,084 - $453	$1,067 - $590	$1,048 - $621	$1,184 - $741	$1,273 - $1,461	$1,358 - $1,523	$1,361 - $1,516
Spyker	2010 2008	- - $358	- - $419	- - $451	- - $584	- - $873	- - $905	- - $996	- - $1,093	- - $1,138
Subaru	2010 2008	$812 - ($30)	$855 - $207	$1,219 - $698	$1,203 - $689	$1,184 - $708	$1,298 - $665	$1,228 - $658	$1,737 - $1,528	$1,652 - $1,388
Suzuki	2010 2008	$860 - $20	$858 - $32	$802 - $1,255	$789 - $1,234	$1,869 - $1,613	$1,839 - $1,586	$1,787 - $1,562	$1,760 - $1,538	$1,693 - $1,422
Tata	2010 2008	$106 - $111	$206 - $172	$288 - $299	$381 - $395	$791 - $837	$927 - $908	$1,024 - $997	$1,120 - $1,098	$1,198 - $1,151
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$383 - $184	$472 - $357	$544 - $466	$565 - $574	$651 - $672	$670 - $689	$734 - $924	$1,020 - $1,061	$1,071 - $1,079
Volkswagen	2010 2008	$294 - $102	$495 - $470	$767 - $829	$1,034 - $811	$1,009 - $751	$1,088 - $850	$1,207 - $1,002	$1,504 - $1,590	$1,858 - $1,561
Total/Average	2010 2008	$468 - $280	$526 - $399	$679 - $635	$917 - $864	$1,071 - $1,083	$1,163 - $1,166	$1,247 - $1,255	$1,378 - $1,369	$1,534 - $1,426

Table VII-2h
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
4% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$67 - $110	$68 - $104	$66 - $105	$62 - $108	$77 - $125	$114 - $112	$116 - $119	$126 - $137	$132 - $156
Daimler	2010 2008	$51 - $90	$68 - $87	$68 - $86	$73 - $91	$70 - $98	$125 - $90	$132 - $96	$144 - $107	$151 - $119
Fiat	2010 2008	$546 - $202	$521 - $188	$673 - $182	$959 - $615	$1,131 - $629	$1,199 - $202	$1,533 - $188	$1,540 - $182	$2,013 - $615
Ford	2010 2008	$641 - $47	$710 - $113	$656 - $112	$728 - $241	$1,091 - $857	$1,099 - $47	$1,090 - $113	$1,205 - $112	$1,423 - $241
Geely	2010 2008	$4 - $9	$26 - $35	$26 - $37	$25 - $35	$27 - $40	$28 - $9	$46 - $42	$49 - $47	$48 - $50
General Motors	2010 2008	$561 - $142	$581 - $389	$870 - $1,292	$1,651 - $1,829	$1,632 - $1,755	$1,602 - $142	$1,621 - $389	$1,662 - $1,292	$1,809 - $1,829
Honda	2010 2008	$115 - $389	$134 - $359	$213 - $317	$233 - $317	$363 - $507	$555 - $389	$540 - $359	$627 - $317	$580 - $317
Hyundai	2010 2008	$43 - $102	$38 - $103	$123 - $124	$126 - $121	$124 - $120	$186 - $102	$184 - $103	$212 - $124	$205 - $121
Kia	2010 2008	$21 - $37	$21 - $38	$23 - $70	$22 - $77	$42 - $135	$40 - $37	$42 - $38	$41 - $70	$39 - $77
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$24 - $1	$72 - $82	$61 - $75	$60 - $83	$58 - $81	$60 - $1	$70 - $82	$81 - $75	$74 - $83
Mitsubishi	2010 2008	$19 - $9	$19 - $9	$18 - $8	$18 - $8	$29 - $62	$29 - $9	$29 - $9	$29 - $8	$28 - $8

Nissan	2010 2008	$39 - $213	$43 - $195	$202 - $339	$243 - $380	$281 - $617	$356 - $213	$356 - $195	$426 - $339	$458 - $380
Porsche	2010 2008	$2 - $0	$3 - $2	$21 - $5	$20 - $7	$20 - $7	$22 - $3	$24 - $4	$26 - $9	$26 - $10
Spyker	2010 2008	- - $1	- - $2	- - $2	- - $2	- - $3	- - $2	- - $3	- - $3	- - $3
Subaru	2010 2008	$79 - ($2)	$81 - $16	$112 - $51	$109 - $50	$109 - $52	$119 - ($2)	$113 - $16	$164 - $51	$159 - $50
Suzuki	2010 2008	$3 - $0	$3 - $1	$3 - $26	$3 - $26	$7 - $34	$7 - $0	$7 - $1	$7 - $26	$7 - $26
Tata	2010 2008	$6 - $6	$11 - $10	$15 - $17	$20 - $22	$40 - $49	$47 - $21	$51 - $28	$56 - $34	$60 - $39
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$370 - $245	$451 - $436	$518 - $532	$527 - $663	$604 - $817	$620 - $245	$674 - $436	$937 - $532	$987 - $663
Volkswagen	2010 2008	$30 - $13	$50 - $68	$79 - $122	$104 - $119	$102 - $112	$111 - $26	$123 - $92	$157 - $140	$195 - $152
Total/Average	2010 2008	$2,620 - $1,614	$2,899 - $2,237	$3,749 - $3,502	$4,984 - $4,792	$5,806 - $6,098	$6,319 - $1,614	$6,750 - $2,237	$7,489 - $3,502	$8,396 - $4,792

Table VII-2i
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
5% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$543 - $943	$584 - $938	$542 - $894	$747 - $1,049	$977 - $1,080	$1,354 - $1,541	$1,463 - $1,621	$1,583 - $1,763	$1,664 - $1,789
Daimler	2010 2008	$511 - $955	$622 - $961	$690 - $900	$758 - $1,020	$807 - $1,001	$1,254 - $1,378	$1,336 - $1,509	$1,446 - $1,609	$1,518 - $1,653
Fiat	2010 2008	$706 - $566	$701 - $551	$946 - $585	$1,419 - $2,227	$1,667 - $2,441	$1,760 - $2,520	$2,598 - $2,772	$2,702 - $2,961	$2,798 - $2,743
Ford	2010 2008	$570 - $197	$648 - $366	$744 - $358	$1,214 - $1,328	$2,358 - $2,038	$2,371 - $2,344	$2,385 - $2,430	$2,564 - $2,489	$2,350 - $3,074
Geely	2010 2008	$122 - $321	$885 - $696	$882 - $714	$935 - $747	$1,016 - $890	$1,157 - $1,385	$1,636 - $1,668	$1,755 - $1,786	$1,780 - $1,821
General Motors	2010 2008	$463 - $177	$575 - $430	$1,103 - $1,296	$2,338 - $1,817	$2,274 - $1,774	$2,228 - $1,739	$2,312 - $1,869	$2,348 - $1,833	$2,707 - $1,728
Honda	2010 2008	$287 - $840	$334 - $842	$718 - $823	$744 - $796	$1,246 - $1,469	$2,072 - $2,452	$2,154 - $2,467	$2,337 - $2,750	$2,343 - $2,782
Hyundai	2010 2008	$611 - $639	$669 - $650	$1,240 - $885	$1,228 - $916	$1,208 - $880	$1,590 - $1,829	$1,552 - $1,795	$2,319 - $3,251	$2,210 - $2,961
Kia	2010 2008	$427 - $531	$433 - $544	$980 - $721	$974 - $825	$1,511 - $1,829	$1,487 - $1,744	$1,739 - $1,966	$1,815 - $1,945	$1,708 - $1,829
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$416 - $16	$1,227 - $1,243	$1,121 - $1,147	$1,128 - $1,212	$1,104 - $1,126	$1,296 - $1,130	$1,773 - $2,186	$2,600 - $2,691	$2,416 - $2,708
Mitsubishi	2010 2008	$1,343 - $342	$1,423 - $349	$1,309 - $326	$1,474 - $349	$2,013 - $2,757	$1,980 - $2,653	$1,924 - $2,608	$2,135 - $2,647	$2,048 - $2,420

Nissan	2010 2008	$290 - $668	$313 - $639	$769 - $1,040	$990 - $1,525	$1,104 - $1,984	$1,443 - $2,427	$1,414 - $2,335	$2,413 - $2,841	$2,558 - $2,545
Porsche	2010 2008	$111 - $1	$211 - $234	$1,084 - $498	$1,138 - $672	$1,189 - $769	$1,332 - $915	$1,455 - $1,642	$1,578 - $1,738	$1,614 - $1,775
Spyker	2010 2008	- - $358	- - $477	- - $571	- - $719	- - $994	- - $1,059	- - $1,183	- - $1,313	- - $1,402
Subaru	2010 2008	$901 - $126	$1,045 - $399	$2,289 - $1,382	$2,252 - $1,362	$2,219 - $1,369	$2,113 - $1,304	$2,102 - $1,284	$2,049 - $2,353	$1,951 - $2,134
Suzuki	2010 2008	$1,120 - $139	$1,114 - $150	$1,175 - $1,369	$1,157 - $1,346	$2,200 - $1,976	$2,165 - $1,924	$2,117 - $1,911	$2,338 - $1,877	$2,116 - $2,604
Tata	2010 2008	$122 - $133	$250 - $247	$354 - $370	$474 - $489	$912 - $964	$1,081 - $1,062	$1,211 - $1,190	$1,345 - $1,324	$1,467 - $1,426
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$426 - $196	$464 - $477	$624 - $582	$696 - $758	$883 - $999	$1,001 - $1,064	$1,163 - $1,193	$1,877 - $1,787	$1,872 - $1,893
Volkswagen	2010 2008	$316 - $124	$671 - $509	$955 - $1,086	$1,169 - $1,063	$1,222 - $1,026	$1,330 - $1,217	$1,466 - $1,398	$1,720 - $1,799	$2,116 - $1,809
Total/Average	2010 2008	$489 - $363	$568 - $534	$870 - $851	$1,334 - $1,301	$1,667 - $1,567	$1,819 - $1,792	$2,004 - $1,906	$2,289 - $2,190	$2,358 - $2,216

Table VII-2j
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
5% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$58 - $130	$61 - $124	$57 - $117	$76 - $135	$99 - $139	$136 - $153	$145 - $162	$160 - $182	$168 - $212
Daimler	2010 2008	$51 - $83	$68 - $80	$75 - $79	$82 - $95	$89 - $100	$141 - $92	$152 - $108	$169 - $120	$181 - $145
Fiat	2010 2008	$546 - $230	$521 - $212	$709 - $212	$1,051 - $795	$1,222 - $842	$1,295 - $230	$1,900 - $212	$1,952 - $213	$2,032 - $795
Ford	2010 2008	$590 - $151	$663 - $274	$756 - $257	$1,209 - $952	$2,335 - $1,455	$2,349 - $151	$2,351 - $274	$2,543 - $257	$2,345 - $952
Geely	2010 2008	$4 - $13	$29 - $29	$29 - $31	$30 - $32	$32 - $37	$37 - $21	$51 - $40	$56 - $47	$56 - $52
General Motors	2010 2008	$561 - $231	$690 - $591	$1,343 - $1,861	$2,832 - $2,662	$2,770 - $2,600	$2,733 - $231	$2,849 - $591	$2,922 - $1,861	$3,415 - $2,662
Honda	2010 2008	$154 - $501	$176 - $458	$379 - $434	$385 - $418	$639 - $787	$1,069 - $501	$1,098 - $458	$1,181 - $434	$1,181 - $418
Hyundai	2010 2008	$81 - $98	$85 - $98	$151 - $138	$145 - $141	$142 - $138	$185 - $98	$179 - $98	$270 - $138	$260 - $141
Kia	2010 2008	$19 - $52	$19 - $53	$41 - $73	$39 - $80	$59 - $175	$58 - $52	$66 - $53	$69 - $73	$65 - $80
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$25 - $1	$73 - $96	$62 - $89	$60 - $97	$58 - $95	$68 - $1	$92 - $96	$138 - $89	$128 - $97
Mitsubishi	2010 2008	$18 - $9	$20 - $9	$19 - $8	$21 - $8	$29 - $67	$29 - $9	$29 - $9	$33 - $10	$32 - $10

Nissan	2010 2008	$89 - $297	$96 - $264	$238 - $415	$301 - $607	$335 - $810	$439 - $297	$431 - $264	$744 - $427	$798 - $607
Porsche	2010 2008	$2 - $0	$4 - $3	$21 - $6	$21 - $7	$22 - $9	$25 - $5	$27 - $6	$30 - $12	$31 - $13
Spyker	2010 2008	- - $1	- - $2	- - $2	- - $3	- - $4	- - $2	- - $3	- - $4	- - $4
Subaru	2010 2008	$87 - $10	$99 - $30	$211 - $101	$204 - $99	$203 - $100	$194 - $10	$194 - $30	$193 - $101	$188 - $99
Suzuki	2010 2008	$4 - $3	$4 - $3	$4 - $28	$4 - $28	$8 - $41	$8 - $3	$8 - $4	$10 - $29	$9 - $28
Tata	2010 2008	$7 - $8	$13 - $14	$19 - $21	$24 - $27	$47 - $56	$55 - $30	$61 - $39	$68 - $47	$74 - $55
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$412 - $261	$444 - $583	$594 - $665	$649 - $875	$819 - $1,214	$926 - $261	$1,068 - $583	$1,724 - $665	$1,724 - $875
Volkswagen	2010 2008	$33 - $16	$67 - $74	$98 - $159	$118 - $156	$124 - $153	$136 - $39	$149 - $109	$180 - $210	$222 - $227
Total/Average	2010 2008	$2,740 - $2,095	$3,131 - $2,998	$4,807 - $4,695	$7,253 - $7,216	$9,033 - $8,819	$9,883 - $2,095	$10,850 - $2,998	$12,441 - $4,695	$12,909 - $7,216

Table VII-2k
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
6% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$543 - $988	$628 - $984	$679 - $982	$846 - $1,089	$1,103 - $1,293	$1,519 - $1,793	$1,667 - $1,922	$1,830 - $2,075	$1,956 - $2,151
Daimler	2010 2008	$511 - $1,019	$650 - $1,014	$756 - $961	$852 - $1,122	$959 - $1,077	$1,414 - $1,572	$1,528 - $1,698	$1,683 - $1,836	$1,798 - $1,923
Fiat	2010 2008	$699 - $775	$689 - $757	$982 - $837	$1,516 - $2,608	$1,789 - $2,850	$1,944 - $3,493	$2,808 - $3,594	$2,944 - $3,870	$3,177 - $3,834
Ford	2010 2008	$695 - $601	$825 - $772	$829 - $720	$1,321 - $3,105	$2,808 - $3,431	$2,800 - $3,474	$2,784 - $3,634	$3,065 - $3,748	$3,739 - $3,513
Geely	2010 2008	$139 - $222	$885 - $605	$926 - $678	$1,062 - $899	$1,148 - $1,044	$1,351 - $1,545	$1,845 - $1,861	$2,003 - $2,034	$2,077 - $2,118
General Motors	2010 2008	$463 - $260	$577 - $536	$1,116 - $1,341	$2,364 - $2,087	$2,313 - $2,056	$2,258 - $2,022	$2,459 - $2,304	$2,589 - $2,481	$3,392 - $3,429
Honda	2010 2008	$509 - $829	$557 - $831	$873 - $1,013	$927 - $1,000	$1,669 - $1,707	$2,314 - $2,976	$2,441 - $2,895	$2,934 - $3,027	$2,869 - $3,172
Hyundai	2010 2008	$524 - $729	$442 - $737	$1,762 - $1,532	$1,708 - $1,556	$1,681 - $1,506	$2,271 - $2,576	$2,317 - $2,546	$3,464 - $3,164	$3,228 - $3,189
Kia	2010 2008	$618 - $584	$622 - $597	$1,106 - $722	$1,098 - $1,029	$2,033 - $2,736	$1,998 - $2,689	$3,036 - $2,884	$3,014 - $2,836	$2,775 - $2,607
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$519 - $43	$1,232 - $2,249	$1,126 - $2,101	$1,457 - $2,154	$1,386 - $2,066	$1,732 - $2,094	$3,340 - $3,536	$3,501 - $3,586	$3,323 - $3,607
Mitsubishi	2010 2008	$1,357 - $1,271	$1,347 - $1,263	$1,300 - $1,171	$1,213 - $1,341	$3,464 - $2,458	$3,381 - $2,529	$3,331 - $2,615	$3,312 - $2,862	$3,023 - $2,907

Nissan	2010 2008	$323 - $801	$342 - $761	$1,222 - $1,324	$1,622 - $1,765	$1,791 - $2,417	$2,207 - $2,755	$2,182 - $2,672	$3,129 - $2,929	$3,102 - $2,959
Porsche	2010 2008	$128 - $5	$255 - $273	$1,110 - $652	$1,236 - $893	$1,365 - $1,020	$1,501 - $1,196	$1,653 - $1,835	$1,815 - $1,974	$1,900 - $2,061
Spyker	2010 2008	- - $369	- - $511	- - $645	- - $813	- - $1,126	- - $1,224	- - $1,386	- - $1,560	- - $1,699
Subaru	2010 2008	$921 - $141	$977 - $1,087	$2,210 - $2,216	$2,174 - $2,170	$2,082 - $2,173	$2,031 - $2,094	$2,286 - $2,168	$3,727 - $3,112	$3,424 - $2,960
Suzuki	2010 2008	$638 - $705	$639 - $706	$848 - $1,272	$954 - $1,251	$2,018 - $5,648	$2,072 - $5,584	$2,192 - $5,567	$2,405 - $5,578	$2,344 - $5,012
Tata	2010 2008	$144 - $155	$288 - $294	$425 - $436	$568 - $588	$1,044 - $1,096	$1,246 - $1,232	$1,420 - $1,399	$1,593 - $1,582	$1,764 - $1,728
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$464 - $344	$575 - $624	$978 - $787	$1,043 - $997	$1,331 - $1,302	$1,574 - $1,457	$1,733 - $1,538	$3,365 - $3,018	$3,001 - $2,746
Volkswagen	2010 2008	$333 - $140	$712 - $553	$1,027 - $1,086	$1,355 - $1,129	$1,454 - $1,230	$1,584 - $1,371	$1,774 - $1,585	$2,076 - $2,030	$2,429 - $2,084
Total/Average	2010 2008	$542 - $506	$639 - $704	$1,012 - $1,057	$1,507 - $1,770	$1,960 - $2,046	$2,132 - $2,320	$2,371 - $2,462	$2,910 - $2,937	$3,179 - $3,108

Table VII-2l
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
6% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$58 - $136	$66 - $130	$71 - $129	$86 - $140	$112 - $166	$152 - $176	$165 - $191	$185 - $225	$198 - $254
Daimler	2010 2008	$51 - $89	$71 - $85	$82 - $85	$93 - $104	$106 - $107	$159 - $117	$174 - $132	$197 - $150	$214 - $175
Fiat	2010 2008	$541 - $315	$512 - $290	$736 - $304	$1,123 - $931	$1,312 - $983	$1,431 - $315	$2,054 - $290	$2,126 - $364	$2,308 - $1,004
Ford	2010 2008	$720 - $459	$845 - $578	$842 - $517	$1,315 - $2,226	$2,781 - $2,450	$2,774 - $459	$2,745 - $578	$3,039 - $517	$3,731 - $2,416
Geely	2010 2008	$5 - $9	$29 - $26	$31 - $29	$34 - $38	$37 - $44	$43 - $24	$57 - $44	$64 - $56	$65 - $64
General Motors	2010 2008	$561 - $340	$693 - $736	$1,359 - $1,925	$2,864 - $3,058	$2,818 - $3,013	$2,769 - $340	$3,031 - $736	$3,221 - $1,925	$4,279 - $3,297
Honda	2010 2008	$273 - $495	$293 - $453	$461 - $535	$480 - $525	$856 - $915	$1,193 - $495	$1,244 - $453	$1,483 - $535	$1,446 - $608
Hyundai	2010 2008	$69 - $111	$56 - $112	$215 - $238	$202 - $240	$198 - $236	$264 - $111	$267 - $117	$403 - $238	$380 - $289
Kia	2010 2008	$27 - $58	$27 - $59	$46 - $73	$44 - $99	$80 - $261	$78 - $58	$116 - $59	$115 - $73	$105 - $99
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$31 - $3	$73 - $174	$62 - $163	$78 - $173	$73 - $174	$91 - $3	$174 - $174	$186 - $163	$177 - $175
Mitsubishi	2010 2008	$19 - $33	$19 - $31	$19 - $28	$17 - $32	$50 - $59	$50 - $35	$49 - $38	$50 - $42	$47 - $52

Nissan	2010 2008	$99 - $356	$105 - $314	$378 - $528	$493 - $702	$544 - $986	$672 - $356	$665 - $314	$965 - $643	$968 - $866
Porsche	2010 2008	$3 - $0	$5 - $3	$22 - $7	$23 - $10	$26 - $11	$28 - $6	$31 - $8	$34 - $16	$36 - $17
Spyker	2010 2008	- - $1	- - $2	- - $2	- - $3	- - $4	- - $3	- - $4	- - $5	- - $5
Subaru	2010 2008	$89 - $11	$92 - $82	$204 - $161	$197 - $157	$191 - $158	$187 - $11	$211 - $89	$351 - $161	$330 - $169
Suzuki	2010 2008	$2 - $16	$2 - $15	$3 - $26	$4 - $26	$8 - $117	$8 - $16	$9 - $15	$10 - $27	$10 - $26
Tata	2010 2008	$8 - $9	$15 - $17	$22 - $25	$29 - $33	$53 - $64	$63 - $40	$71 - $51	$80 - $62	$89 - $72
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$448 - $457	$549 - $764	$931 - $899	$973 - $1,151	$1,234 - $1,583	$1,456 - $457	$1,592 - $764	$3,091 - $899	$2,765 - $1,151
Volkswagen	2010 2008	$34 - $18	$72 - $80	$106 - $159	$137 - $166	$147 - $183	$162 - $57	$180 - $134	$217 - $247	$255 - $270
Total/Average	2010 2008	$3,037 - $2,916	$3,523 - $3,949	$5,589 - $5,834	$8,191 - $9,815	$10,624 - $11,515	$11,579 - $2,916	$12,834 - $3,949	$15,818 - $5,834	$17,402 - $9,815

Table VII-2m
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
7% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$543 - $968	$667 - $963	$750 - $920	$945 - $1,236	$1,241 - $1,474	$1,695 - $1,950	$1,887 - $2,122	$2,105 - $2,344	$2,286 - $2,470
Daimler	2010 2008	$511 - $1,021	$688 - $1,016	$822 - $963	$951 - $1,215	$1,111 - $1,199	$1,579 - $1,737	$1,743 - $1,901	$1,947 - $2,084	$2,112 - $2,225
Fiat	2010 2008	$721 - $779	$724 - $778	$1,048 - $919	$1,627 - $2,362	$1,930 - $2,728	$2,109 - $3,493	$3,017 - $3,934	$3,202 - $4,174	$3,485 - $4,340
Ford	2010 2008	$887 - $557	$1,027 - $793	$1,123 - $751	$2,251 - $2,011	$3,108 - $3,083	$3,115 - $3,271	$3,103 - $4,160	$3,442 - $4,437	$3,722 - $6,108
Geely	2010 2008	$161 - $104	$885 - $785	$997 - $978	$1,166 - $1,142	$1,285 - $1,307	$1,578 - $1,838	$2,065 - $2,017	$2,278 - $2,230	$2,412 - $2,385
General Motors	2010 2008	$605 - $352	$744 - $710	$1,330 - $1,541	$2,444 - $2,696	$2,431 - $2,682	$2,444 - $2,649	$2,677 - $3,094	$2,852 - $3,455	$3,579 - $3,772
Honda	2010 2008	$869 - $844	$1,006 - $846	$1,313 - $1,218	$1,440 - $1,251	$1,635 - $2,218	$2,296 - $3,435	$2,362 - $3,424	$3,013 - $3,535	$3,107 - $4,054
Hyundai	2010 2008	$884 - $938	$885 - $949	$1,819 - $1,592	$1,808 - $1,595	$1,778 - $1,537	$2,299 - $4,536	$2,265 - $4,480	$5,644 - $5,085	$4,538 - $4,549
Kia	2010 2008	$519 - $888	$525 - $903	$1,265 - $1,091	$1,256 - $1,385	$2,155 - $2,816	$2,121 - $2,768	$5,554 - $4,913	$5,580 - $4,939	$4,238 - $3,981
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$538 - $43	$1,478 - $1,911	$1,367 - $1,792	$1,646 - $1,831	$1,709 - $1,735	$1,732 - $1,716	$3,554 - $3,948	$3,792 - $3,930	$3,669 - $3,904
Mitsubishi	2010 2008	$1,357 - $1,366	$1,347 - $1,357	$1,417 - $1,261	$1,255 - $1,448	$3,464 - $2,189	$3,381 - $2,548	$3,331 - $2,717	$3,514 - $2,934	$3,683 - $3,043

Nissan	2010 2008	$561 - $999	$586 - $953	$1,314 - $1,425	$1,971 - $1,831	$2,127 - $2,504	$2,564 - $2,650	$2,735 - $2,852	$3,148 - $3,569	$3,199 - $3,519
Porsche	2010 2008	$150 - $21	$299 - $317	$1,176 - $720	$1,335 - $992	$1,497 - $1,152	$1,672 - $1,367	$1,867 - $2,049	$2,079 - $2,244	$2,224 - $2,380
Spyker	2010 2008	- - $391	- - $555	- - $717	- - $917	- - $1,264	- - $1,400	- - $1,606	- - $1,835	- - $2,029
Subaru	2010 2008	$921 - $141	$969 - $1,128	$2,202 - $2,255	$2,166 - $2,208	$2,152 - $2,122	$2,064 - $2,094	$2,521 - $2,416	$5,059 - $4,182	$4,325 - $3,828
Suzuki	2010 2008	$638 - $747	$639 - $840	$1,018 - $1,256	$1,037 - $1,236	$2,090 - $5,608	$2,264 - $5,570	$2,477 - $5,740	$2,702 - $5,965	$2,707 - $6,344
Tata	2010 2008	$166 - $172	$338 - $338	$497 - $513	$672 - $692	$1,182 - $1,239	$1,427 - $1,414	$1,645 - $1,630	$1,873 - $1,863	$2,100 - $2,075
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$476 - $284	$624 - $736	$1,042 - $1,210	$1,125 - $1,433	$1,821 - $1,852	$2,007 - $2,047	$2,151 - $2,510	$3,436 - $2,934	$3,278 - $3,189
Volkswagen	2010 2008	$355 - $157	$756 - $591	$1,093 - $1,086	$1,454 - $1,222	$1,586 - $1,362	$1,755 - $1,536	$1,994 - $1,794	$2,345 - $2,283	$2,753 - $2,392
Total/Average	2010 2008	$670 - $535	$797 - $801	$1,191 - $1,240	$1,805 - $1,907	$2,178 - $2,339	$2,361 - $2,685	$2,641 - $3,144	$3,207 - $3,504	$3,419 - $3,878

Table VII-2n
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
7% Annual Increase
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$58 - $134	$70 - $127	$79 - $121	$96 - $159	$126 - $190	$170 - $197	$187 - $217	$213 - $256	$231 - $296
Daimler	2010 2008	$51 - $89	$75 - $85	$89 - $85	$103 - $113	$122 - $119	$177 - $134	$198 - $153	$228 - $176	$251 - $206
Fiat	2010 2008	$558 - $316	$538 - $299	$785 - $333	$1,205 - $843	$1,416 - $941	$1,552 - $376	$2,207 - $373	$2,313 - $474	$2,531 - $1,022
Ford	2010 2008	$919 - $426	$1,052 - $593	$1,141 - $539	$2,241 - $1,442	$3,077 - $2,202	$3,087 - $481	$3,059 - $699	$3,414 - $804	$3,713 - $1,619
Geely	2010 2008	$6 - $4	$29 - $33	$33 - $42	$37 - $49	$41 - $55	$50 - $25	$64 - $63	$72 - $76	$76 - $86
General Motors	2010 2008	$734 - $461	$894 - $975	$1,618 - $2,212	$2,960 - $3,951	$2,962 - $3,931	$2,997 - $461	$3,299 - $1,326	$3,549 - $2,746	$4,515 - $4,722
Honda	2010 2008	$467 - $504	$529 - $461	$693 - $643	$745 - $657	$838 - $1,188	$1,184 - $504	$1,204 - $484	$1,523 - $669	$1,566 - $866
Hyundai	2010 2008	$117 - $143	$113 - $144	$222 - $248	$214 - $246	$209 - $240	$267 - $143	$261 - $145	$657 - $248	$534 - $291
Kia	2010 2008	$23 - $88	$23 - $89	$53 - $110	$51 - $134	$85 - $269	$82 - $88	$212 - $89	$212 - $110	$161 - $134
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$32 - $3	$87 - $148	$75 - $139	$88 - $147	$90 - $146	$91 - $3	$185 - $152	$201 - $147	$195 - $182
Mitsubishi	2010 2008	$19 - $35	$19 - $34	$20 - $30	$18 - $35	$50 - $53	$50 - $45	$49 - $50	$54 - $53	$57 - $61

Nissan	2010 2008	$172 - $444	$180 - $393	$406 - $568	$600 - $729	$646 - $1,022	$780 - $466	$833 - $528	$971 - $775	$998 - $1,038
Porsche	2010 2008	$3 - $0	$6 - $4	$23 - $8	$25 - $11	$28 - $13	$31 - $8	$35 - $11	$39 - $19	$42 - $21
Spyker	2010 2008	- - $1	- - $2	- - $3	- - $3	- - $4	- - $3	- - $5	- - $6	- - $6
Subaru	2010 2008	$89 - $11	$92 - $85	$203 - $164	$197 - $160	$197 - $154	$190 - $11	$233 - $110	$477 - $164	$417 - $178
Suzuki	2010 2008	$2 - $17	$2 - $18	$4 - $26	$4 - $26	$8 - $116	$9 - $17	$10 - $20	$11 - $35	$11 - $26
Tata	2010 2008	$9 - $10	$18 - $19	$26 - $30	$35 - $39	$60 - $72	$72 - $51	$83 - $65	$94 - $78	$106 - $92
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$460 - $378	$596 - $900	$992 - $1,381	$1,048 - $1,654	$1,689 - $2,252	$1,857 - $378	$1,976 - $900	$3,156 - $1,381	$3,020 - $2,070
Volkswagen	2010 2008	$37 - $20	$76 - $86	$112 - $159	$147 - $179	$161 - $203	$179 - $81	$202 - $166	$245 - $286	$289 - $317
Total/Average	2010 2008	$3,752 - $3,083	$4,397 - $4,494	$6,576 - $6,841	$9,814 - $10,576	$11,805 - $13,170	$12,827 - $3,083	$14,298 - $4,494	$17,429 - $6,841	$18,713 - $10,576

Table VII-2o
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Max Net Benefits (3% Discount Rate)
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$543 - $1,249	$628 - $1,309	$712 - $1,370	$851 - $1,480	$1,169 - $1,669	$1,464 - $1,759	$1,496 - $1,759	$1,528 - $1,811	$1,532 - $1,788
Daimler	2010 2008	$555 - $1,093	$650 - $1,122	$762 - $1,130	$857 - $1,284	$1,044 - $1,335	$1,359 - $1,572	$1,363 - $1,566	$1,397 - $1,589	$1,391 - $1,587
Fiat	2010 2008	$783 - $1,418	$701 - $1,308	$1,024 - $1,301	$1,526 - $1,956	$1,868 - $2,336	$1,886 - $2,337	$2,648 - $2,757	$2,663 - $2,910	$2,772 - $2,988
Ford	2010 2008	$998 - $973	$1,026 - $1,135	$1,512 - $1,308	$1,650 - $3,183	$2,417 - $3,402	$2,395 - $3,362	$2,361 - $3,370	$2,375 - $3,459	$2,254 - $2,770
Geely	2010 2008	$216 - $525	$885 - $746	$931 - $969	$1,073 - $1,069	$1,214 - $1,132	$1,296 - $1,544	$1,669 - $1,723	$1,700 - $1,759	$1,648 - $1,750
General Motors	2010 2008	$967 - $1,478	$1,022 - $1,538	$1,283 - $1,840	$2,230 - $2,325	$2,221 - $2,329	$2,129 - $2,278	$2,235 - $2,450	$2,370 - $2,716	$2,630 - $2,814
Honda	2010 2008	$482 - $954	$523 - $939	$926 - $981	$974 - $1,011	$1,367 - $1,611	$1,948 - $2,190	$1,967 - $2,161	$2,207 - $2,339	$2,065 - $2,198
Hyundai	2010 2008	$1,013 - $964	$922 - $971	$1,578 - $1,675	$1,553 - $1,630	$1,528 - $1,597	$1,796 - $1,977	$1,770 - $1,935	$2,002 - $2,525	$1,886 - $2,327
Kia	2010 2008	$647 - $729	$651 - $738	$854 - $617	$847 - $729	$1,617 - $1,606	$1,540 - $1,531	$1,943 - $1,704	$1,906 - $1,683	$1,806 - $1,587
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$1,048 - $1,304	$1,334 - $1,722	$1,220 - $1,573	$1,359 - $1,745	$1,315 - $1,629	$1,293 - $1,693	$1,758 - $2,152	$1,967 - $2,214	$1,775 - $2,050
Mitsubishi	2010 2008	$1,357 - $1,508	$1,347 - $1,382	$1,233 - $1,287	$1,433 - $1,341	$2,485 - $2,760	$2,415 - $2,653	$2,378 - $2,608	$2,342 - $2,619	$2,213 - $2,577

Nissan	2010 2008	$471 - $1,909	$492 - $1,828	$1,185 - $1,890	$1,506 - $4,260	$1,580 - $4,234	$1,893 - $4,185	$1,873 - $4,104	$1,981 - $4,091	$2,030 - $3,306
Porsche	2010 2008	$199 - $263	$255 - $504	$1,116 - $846	$1,242 - $1,052	$1,426 - $1,108	$1,446 - $1,196	$1,482 - $1,697	$1,523 - $1,710	$1,487 - $1,703
Spyker	2010 2008	- - $639	- - $753	- - $849	- - $978	- - $1,214	- - $1,218	- - $1,238	- - $1,285	- - $1,325
Subaru	2010 2008	$921 - $196	$977 - $471	$2,130 - $1,895	$2,095 - $1,801	$2,005 - $1,763	$1,956 - $1,742	$1,926 - $1,713	$1,918 - $1,973	$1,839 - $1,828
Suzuki	2010 2008	$821 - $503	$820 - $504	$848 - $2,872	$955 - $2,803	$5,928 - $2,790	$5,864 - $2,748	$5,826 - $2,699	$5,790 - $2,821	$4,606 - $3,244
Tata	2010 2008	$216 - $430	$294 - $541	$431 - $651	$573 - $758	$1,110 - $1,189	$1,191 - $1,232	$1,244 - $1,250	$1,290 - $1,296	$1,330 - $1,349
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$521 - $568	$605 - $766	$702 - $888	$758 - $989	$1,005 - $1,263	$1,072 - $1,306	$1,178 - $1,326	$1,355 - $1,569	$1,332 - $1,617
Volkswagen	2010 2008	$404 - $393	$712 - $773	$1,032 - $1,207	$1,361 - $1,283	$1,515 - $1,318	$1,529 - $1,371	$1,603 - $1,453	$1,779 - $1,772	$2,005 - $1,737
Total/Average	2010 2008	$756 - $1,070	$798 - $1,167	$1,130 - $1,370	$1,481 - $1,990	$1,780 - $2,175	$1,860 - $2,237	$2,011 - $2,315	$2,116 - $2,502	$2,151 - $2,375

Table VII-2p
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Max Net Benefits (3% Discount Rate)
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$58 - $172	$66 - $173	$75 - $180	$87 - $190	$118 - $215	$147 - $213	$148 - $205	$155 - $215	$155 - $227
Daimler	2010 2008	$55 - $95	$71 - $94	$83 - $100	$93 - $119	$115 - $133	$152 - $124	$155 - $123	$163 - $129	$166 - $142
Fiat	2010 2008	$606 - $575	$521 - $502	$767 - $472	$1,130 - $698	$1,370 - $806	$1,388 - $612	$1,936 - $506	$1,923 - $481	$2,014 - $698
Ford	2010 2008	$1,033 - $743	$1,051 - $850	$1,536 - $939	$1,643 - $2,282	$2,393 - $2,430	$2,373 - $743	$2,327 - $850	$2,356 - $845	$2,249 - $2,282
Geely	2010 2008	$8 - $22	$29 - $31	$31 - $42	$34 - $46	$39 - $47	$41 - $28	$52 - $42	$54 - $44	$52 - $48
General Motors	2010 2008	$1,173 - $1,934	$1,228 - $2,111	$1,561 - $2,641	$2,701 - $3,406	$2,706 - $3,412	$2,611 - $1,829	$2,755 - $2,111	$2,949 - $2,649	$3,318 - $3,406
Honda	2010 2008	$259 - $569	$275 - $511	$489 - $518	$504 - $531	$701 - $864	$1,004 - $569	$1,002 - $511	$1,116 - $518	$1,041 - $531
Hyundai	2010 2008	$134 - $147	$117 - $147	$193 - $261	$184 - $251	$180 - $250	$209 - $147	$204 - $147	$233 - $261	$222 - $251
Kia	2010 2008	$28 - $72	$28 - $73	$36 - $62	$34 - $70	$63 - $153	$60 - $72	$74 - $73	$72 - $62	$69 - $70
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$63 - $92	$79 - $133	$67 - $122	$72 - $140	$70 - $137	$68 - $95	$92 - $133	$104 - $122	$94 - $140
Mitsubishi	2010 2008	$19 - $39	$19 - $34	$18 - $31	$20 - $32	$36 - $67	$36 - $36	$35 - $34	$36 - $32	$34 - $38

Nissan	2010 2008	$144 - $850	$151 - $754	$366 - $753	$458 - $1,695	$480 - $1,728	$576 - $850	$571 - $754	$611 - $753	$633 - $1,695
Porsche	2010 2008	$4 - $3	$5 - $6	$22 - $10	$23 - $12	$27 - $12	$27 - $6	$28 - $7	$29 - $13	$28 - $13
Spyker	2010 2008	- - $2	- - $3	- - $3	- - $3	- - $4	- - $3	- - $4	- - $4	- - $4
Subaru	2010 2008	$89 - $15	$92 - $35	$196 - $138	$190 - $131	$184 - $128	$180 - $15	$178 - $35	$181 - $138	$177 - $131
Suzuki	2010 2008	$3 - $11	$3 - $11	$3 - $59	$4 - $58	$22 - $58	$23 - $11	$23 - $11	$24 - $62	$19 - $58
Tata	2010 2008	$12 - $25	$16 - $31	$23 - $38	$30 - $43	$57 - $69	$60 - $40	$63 - $43	$65 - $45	$67 - $50
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$503 - $756	$578 - $938	$668 - $1,014	$707 - $1,142	$932 - $1,535	$992 - $756	$1,082 - $938	$1,244 - $1,014	$1,227 - $1,142
Volkswagen	2010 2008	$42 - $51	$72 - $112	$106 - $177	$137 - $188	$154 - $196	$156 - $57	$163 - $114	$186 - $206	$211 - $216
Total/Average	2010 2008	$4,231 - $6,173	$4,400 - $6,549	$6,239 - $7,559	$8,052 - $11,037	$9,645 - $12,244	$10,102 - $6,173	$10,887 - $6,549	$11,501 - $7,559	$11,776 - $11,037

Table VII-2q
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Max Net Benefits (7% Discount Rate)
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$543 - $1,249	$628 - $1,265	$701 - $1,297	$840 - $1,447	$1,131 - $1,636	$1,426 - $1,682	$1,452 - $1,671	$1,500 - $1,717	$1,543 - $1,695
Daimler	2010 2008	$555 - $1,093	$650 - $1,084	$756 - $1,064	$846 - $1,246	$1,011 - $1,302	$1,320 - $1,500	$1,325 - $1,483	$1,369 - $1,501	$1,402 - $1,494
Fiat	2010 2008	$783 - $1,370	$701 - $1,308	$1,010 - $1,283	$1,515 - $1,862	$1,827 - $2,324	$1,854 - $2,277	$2,610 - $2,555	$2,637 - $2,650	$2,762 - $2,725
Ford	2010 2008	$998 - $915	$1,026 - $1,077	$1,522 - $1,309	$1,542 - $1,728	$2,201 - $2,399	$2,172 - $2,355	$2,135 - $2,352	$2,102 - $2,340	$2,543 - $2,131
Geely	2010 2008	$216 - $481	$885 - $702	$920 - $936	$1,056 - $1,031	$1,175 - $1,093	$1,258 - $1,467	$1,630 - $1,630	$1,673 - $1,665	$1,659 - $1,651
General Motors	2010 2008	$967 - $1,440	$1,022 - $1,494	$1,286 - $1,743	$2,212 - $2,015	$2,170 - $2,005	$2,112 - $1,959	$2,104 - $1,971	$2,329 - $2,109	$2,604 - $2,217
Honda	2010 2008	$486 - $928	$528 - $925	$912 - $1,042	$979 - $1,066	$1,563 - $1,391	$2,167 - $1,826	$2,222 - $1,798	$2,320 - $1,961	$2,169 - $1,873
Hyundai	2010 2008	$1,005 - $873	$913 - $878	$1,472 - $1,490	$1,478 - $1,461	$1,455 - $1,432	$1,677 - $1,668	$1,653 - $1,644	$2,346 - $1,785	$2,201 - $1,664
Kia	2010 2008	$619 - $635	$624 - $647	$827 - $637	$821 - $749	$1,468 - $1,658	$1,443 - $1,577	$1,570 - $1,636	$1,612 - $1,614	$1,513 - $1,573
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$1,048 - $1,122	$1,221 - $1,636	$1,110 - $1,493	$1,096 - $2,424	$1,094 - $2,230	$1,071 - $2,264	$1,600 - $2,560	$1,725 - $2,672	$1,612 - $2,320
Mitsubishi	2010 2008	$1,357 - $1,464	$1,347 - $1,382	$1,233 - $1,287	$1,441 - $1,341	$2,374 - $2,577	$2,308 - $2,474	$2,274 - $2,430	$2,240 - $2,395	$2,111 - $2,306

Nissan	2010 2008	$434 - $1,778	$455 - $1,697	$973 - $1,834	$1,319 - $4,272	$1,464 - $4,137	$1,581 - $4,091	$1,550 - $4,011	$2,035 - $3,988	$2,121 - $3,207
Porsche	2010 2008	$199 - $225	$255 - $460	$1,110 - $813	$1,231 - $1,014	$1,393 - $1,069	$1,408 - $1,119	$1,444 - $1,604	$1,496 - $1,622	$1,504 - $1,604
Spyker	2010 2008	- - $595	- - $709	- - $816	- - $945	- - $1,176	- - $1,141	- - $1,144	- - $1,192	- - $1,226
Subaru	2010 2008	$921 - $146	$977 - $325	$1,987 - $1,311	$1,954 - $1,229	$1,867 - $1,200	$1,819 - $1,193	$1,791 - $1,176	$2,064 - $1,711	$1,967 - $1,579
Suzuki	2010 2008	$742 - $92	$741 - $99	$848 - $1,639	$863 - $1,561	$2,018 - $1,779	$1,973 - $1,748	$1,991 - $1,716	$1,915 - $1,690	$1,888 - $1,870
Tata	2010 2008	$216 - $386	$294 - $492	$420 - $612	$562 - $720	$1,072 - $1,151	$1,152 - $1,150	$1,200 - $1,151	$1,263 - $1,197	$1,346 - $1,244
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$529 - $533	$571 - $748	$677 - $876	$756 - $903	$1,025 - $1,023	$1,133 - $1,077	$1,255 - $1,035	$1,400 - $1,233	$1,400 - $1,330
Volkswagen	2010 2008	$404 - $349	$712 - $734	$1,021 - $1,174	$1,350 - $1,244	$1,482 - $1,279	$1,491 - $1,294	$1,565 - $1,365	$1,751 - $1,684	$2,022 - $1,644
Total/Average	2010 2008	$755 - $1,019	$788 - $1,121	$1,106 - $1,320	$1,438 - $1,692	$1,726 - $1,873	$1,811 - $1,915	$1,939 - $1,927	$2,074 - $2,046	$2,227 - $1,994

Table VII-2r
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Max Net Benefits (7% Discount Rate)
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$58 - $172	$66 - $167	$74 - $170	$86 - $186	$114 - $211	$143 - $203	$144 - $193	$152 - $202	$156 - $213
Daimler	2010 2008	$55 - $95	$71 - $91	$82 - $94	$92 - $116	$111 - $130	$148 - $117	$150 - $115	$160 - $119	$167 - $133
Fiat	2010 2008	$606 - $556	$521 - $502	$757 - $465	$1,122 - $665	$1,339 - $802	$1,364 - $593	$1,909 - $502	$1,904 - $465	$2,006 - $665
Ford	2010 2008	$1,033 - $698	$1,051 - $806	$1,547 - $940	$1,535 - $1,239	$2,180 - $1,713	$2,152 - $698	$2,105 - $806	$2,085 - $804	$2,537 - $1,239
Geely	2010 2008	$8 - $20	$29 - $30	$31 - $40	$34 - $44	$38 - $46	$40 - $25	$51 - $38	$53 - $40	$52 - $43
General Motors	2010 2008	$1,173 - $1,883	$1,228 - $2,051	$1,565 - $2,502	$2,680 - $2,953	$2,644 - $2,938	$2,590 - $1,829	$2,594 - $2,051	$2,897 - $2,502	$3,285 - $2,953
Honda	2010 2008	$261 - $553	$277 - $504	$481 - $550	$506 - $560	$802 - $745	$1,117 - $553	$1,132 - $504	$1,173 - $550	$1,093 - $560
Hyundai	2010 2008	$133 - $133	$116 - $133	$180 - $232	$175 - $225	$171 - $224	$195 - $133	$191 - $133	$273 - $232	$259 - $225
Kia	2010 2008	$27 - $63	$27 - $64	$34 - $64	$33 - $72	$58 - $158	$56 - $63	$60 - $64	$61 - $64	$57 - $72
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$63 - $79	$72 - $127	$61 - $116	$58 - $195	$58 - $188	$56 - $82	$83 - $127	$91 - $116	$86 - $195
Mitsubishi	2010 2008	$19 - $38	$19 - $34	$18 - $31	$21 - $32	$34 - $62	$34 - $36	$34 - $34	$34 - $31	$33 - $35

Nissan	2010 2008	$133 - $791	$140 - $700	$301 - $731	$401 - $1,700	$445 - $1,688	$481 - $791	$472 - $700	$628 - $731	$662 - $1,700
Porsche	2010 2008	$4 - $3	$5 - $6	$22 - $9	$23 - $11	$26 - $12	$26 - $6	$27 - $6	$28 - $12	$29 - $12
Spyker	2010 2008	- - $2	- - $3	- - $3	- - $3	- - $4	- - $3	- - $3	- - $4	- - $4
Subaru	2010 2008	$89 - $11	$92 - $24	$183 - $95	$177 - $89	$171 - $87	$167 - $11	$165 - $24	$195 - $95	$189 - $89
Suzuki	2010 2008	$3 - $2	$2 - $2	$3 - $34	$3 - $32	$8 - $37	$8 - $2	$8 - $2	$8 - $34	$8 - $32
Tata	2010 2008	$12 - $22	$16 - $28	$22 - $35	$29 - $40	$55 - $67	$58 - $35	$60 - $37	$64 - $39	$68 - $44
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$511 - $709	$545 - $915	$644 - $1,001	$705 - $1,042	$950 - $1,244	$1,048 - $709	$1,153 - $915	$1,285 - $1,001	$1,289 - $1,042
Volkswagen	2010 2008	$42 - $45	$72 - $107	$105 - $172	$136 - $183	$150 - $190	$152 - $46	$159 - $100	$183 - $192	$212 - $202
Total/Average	2010 2008	$4,227 - $5,876	$4,348 - $6,291	$6,110 - $7,285	$7,817 - $9,387	$9,354 - $10,546	$9,837 - $5,876	$10,497 - $6,291	$11,275 - $7,285	$12,189 - $9,387

Table VII-2s
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Total Cost = Total Benefit (3% Discount Rate)
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010	- -	- -	- -	- -	- -	- -	- -	- -	- -
	2008	- -	- -	- -	- -	- -	- -	- -	- -	- -
BMW	2010	$548 -	$650 -	$712 -	$851 -	$1,180 -	$1,481 -	$1,507 -	$1,528 -	$1,543 -
	2008	$1,249	$1,320	$1,390	$1,508	$1,697	$1,748	$1,776	$1,849	$1,805
Daimler	2010	$571 -	$672 -	$762 -	$857 -	$1,061 -	$1,370 -	$1,374 -	$1,397 -	$1,402 -
	2008	$1,093	$1,133	$1,162	$1,306	$1,363	$1,561	$1,577	$1,627	$1,598
Fiat	2010	$800 -	$702 -	$1,006 -	$1,538 -	$1,881 -	$1,906 -	$2,660 -	$2,630 -	$2,725 -
	2008	$1,448	$1,320	$1,311	$1,955	$2,305	$2,302	$2,718	$2,885	$3,142
Ford	2010	$862 -	$893 -	$1,123 -	$1,880 -	$2,533 -	$2,504 -	$2,457 -	$2,449 -	$2,712 -
	2008	$1,155	$1,281	$1,457	$3,185	$3,505	$3,471	$3,555	$3,599	$3,035
Geely	2010	$232 -	$885 -	$931 -	$1,073 -	$1,225 -	$1,335 -	$1,680 -	$1,700 -	$1,659 -
	2008	$547	$757	$980	$1,097	$1,159	$1,533	$1,734	$1,797	$1,761
General Motors	2010	$984 -	$1,022 -	$1,283 -	$2,230 -	$2,228 -	$2,129 -	$2,236 -	$2,348 -	$2,502 -
	2008	$1,502	$1,538	$1,841	$2,522	$2,540	$2,487	$2,707	$2,937	$2,949
Honda	2010	$834 -	$910 -	$1,057 -	$1,140 -	$1,367 -	$1,980 -	$1,943 -	$2,194 -	$2,009 -
	2008	$1,163	$1,138	$1,303	$1,320	$1,767	$2,439	$2,403	$2,520	$2,367
Hyundai	2010	$966 -	$876 -	$1,591 -	$1,563 -	$1,536 -	$1,796 -	$1,770 -	$1,997 -	$1,886 -
	2008	$1,083	$1,091	$1,823	$1,773	$1,740	$2,531	$2,485	$3,035	$2,773
Kia	2010	$647 -	$651 -	$919 -	$911 -	$1,616 -	$1,589 -	$1,756 -	$1,718 -	$1,633 -
	2008	$851	$853	$723	$872	$1,716	$1,637	$1,663	$1,638	$1,671
Lotus	2010	- -	- -	- -	- -	- -	- -	- -	- -	- -
	2008	- -	- -	- -	- -	- -	- -	- -	- -	- -
Mazda	2010	$1,064 -	$1,334 -	$1,220 -	$1,497 -	$1,492 -	$1,472 -	$2,131 -	$2,251 -	$2,032 -
	2008	$1,552	$1,860	$1,715	$2,293	$2,115	$2,045	$2,329	$2,462	$2,160
Mitsubishi	2010	$1,357 -	$1,347 -	$1,233 -	$1,433 -	$2,485 -	$2,415 -	$2,378 -	$2,342 -	$2,213 -
	2008	$1,530	$1,382	$1,287	$1,397	$2,760	$2,653	$2,683	$2,663	$2,620

Nissan	2010 2008	$511 - $1,919	$534 - $1,837	$1,228 - $1,843	$1,863 - $4,208	$2,008 - $4,175	$2,015 - $4,128	$1,985 - $4,053	$2,247 - $4,040	$2,139 - $3,261
Porsche	2010 2008	$221 - $285	$277 - $520	$1,116 - $857	$1,242 - $1,074	$1,442 - $1,135	$1,457 - $1,185	$1,499 - $1,708	$1,523 - $1,754	$1,504 - $1,714
Spyker	2010 2008	- - $661	- - $764	- - $865	- - $1,005	- - $1,242	- - $1,207	- - $1,254	- - $1,329	- - $1,341
Subaru	2010 2008	$921 - $245	$977 - $497	$1,987 - $1,871	$1,954 - $1,778	$1,867 - $1,739	$1,819 - $1,719	$1,791 - $1,690	$2,064 - $2,032	$1,967 - $1,888
Suzuki	2010 2008	$860 - $525	$858 - $526	$786 - $2,115	$913 - $2,057	$2,991 - $2,475	$2,913 - $2,495	$2,862 - $2,514	$2,813 - $2,561	$2,519 - $2,966
Tata	2010 2008	$238 - $452	$316 - $552	$431 - $662	$573 - $786	$1,121 - $1,217	$1,207 - $1,216	$1,255 - $1,261	$1,290 - $1,340	$1,346 - $1,360
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$626 - $608	$688 - $787	$770 - $901	$837 - $960	$1,168 - $1,258	$1,164 - $1,294	$1,300 - $1,366	$1,496 - $1,606	$1,449 - $1,623
Volkswagen	2010 2008	$426 - $415	$734 - $784	$1,032 - $1,218	$1,361 - $1,305	$1,531 - $1,340	$1,540 - $1,354	$1,620 - $1,464	$1,779 - $1,810	$2,022 - $1,748
Total/Average	2010 2008	$791 - $1,144	$827 - $1,221	$1,081 - $1,427	$1,574 - $2,076	$1,855 - $2,265	$1,907 - $2,338	$2,054 - $2,447	$2,159 - $2,617	$2,223 - $2,484

Table VII-2t
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Total Cost = Total Benefit (3% Discount Rate)
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$58 - $172	$68 - $174	$75 - $183	$87 - $193	$119 - $218	$149 - $211	$149 - $207	$155 - $221	$156 - $229
Daimler	2010 2008	$57 - $95	$73 - $95	$83 - $103	$93 - $121	$117 - $136	$154 - $123	$156 - $124	$163 - $133	$167 - $143
Fiat	2010 2008	$619 - $588	$522 - $507	$754 - $475	$1,139 - $698	$1,380 - $795	$1,402 - $610	$1,945 - $511	$1,900 - $492	$1,979 - $698
Ford	2010 2008	$893 - $882	$915 - $959	$1,142 - $1,046	$1,871 - $2,284	$2,508 - $2,504	$2,481 - $882	$2,422 - $959	$2,429 - $946	$2,706 - $2,284
Geely	2010 2008	$8 - $23	$29 - $32	$31 - $42	$34 - $47	$39 - $48	$42 - $28	$52 - $43	$54 - $46	$52 - $48
General Motors	2010 2008	$1,194 - $1,965	$1,228 - $2,112	$1,561 - $2,643	$2,701 - $3,696	$2,715 - $3,723	$2,611 - $1,829	$2,756 - $2,112	$2,921 - $2,674	$3,157 - $3,696
Honda	2010 2008	$448 - $694	$478 - $620	$558 - $687	$590 - $693	$701 - $947	$1,021 - $694	$990 - $620	$1,109 - $687	$1,012 - $693
Hyundai	2010 2008	$127 - $166	$112 - $165	$194 - $284	$185 - $273	$181 - $272	$209 - $166	$204 - $165	$232 - $284	$222 - $273
Kia	2010 2008	$28 - $84	$28 - $84	$38 - $73	$37 - $84	$63 - $164	$62 - $84	$67 - $84	$65 - $73	$62 - $84
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$64 - $109	$79 - $144	$67 - $133	$80 - $184	$79 - $178	$78 - $108	$111 - $144	$119 - $133	$108 - $184
Mitsubishi	2010 2008	$19 - $39	$19 - $34	$18 - $31	$20 - $34	$36 - $67	$36 - $36	$35 - $36	$36 - $33	$34 - $39

Nissan	2010 2008	$156 - $854	$164 - $758	$380 - $735	$567 - $1,674	$610 - $1,703	$613 - $854	$605 - $758	$693 - $735	$667 - $1,674
Porsche	2010 2008	$4 - $4	$5 - $6	$22 - $10	$23 - $12	$27 - $13	$27 - $6	$28 - $7	$29 - $14	$29 - $14
Spyker	2010 2008	- - $2	- - $3	- - $3	- - $4	- - $4	- - $3	- - $4	- - $4	- - $4
Subaru	2010 2008	$89 - $19	$92 - $37	$183 - $136	$177 - $129	$171 - $127	$167 - $19	$165 - $37	$195 - $136	$189 - $129
Suzuki	2010 2008	$3 - $12	$3 - $11	$3 - $44	$3 - $43	$11 - $51	$11 - $13	$11 - $14	$11 - $48	$11 - $43
Tata	2010 2008	$13 - $26	$17 - $31	$23 - $38	$30 - $44	$57 - $71	$61 - $39	$63 - $43	$65 - $48	$68 - $51
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$605 - $809	$658 - $963	$733 - $1,029	$780 - $1,108	$1,083 - $1,529	$1,077 - $809	$1,194 - $963	$1,374 - $1,029	$1,335 - $1,108
Volkswagen	2010 2008	$44 - $53	$74 - $114	$106 - $179	$137 - $191	$155 - $199	$157 - $55	$165 - $115	$186 - $212	$212 - $218
Total/Average	2010 2008	$4,429 - $6,596	$4,562 - $6,849	$5,971 - $7,872	$8,555 - $11,512	$10,052 - $12,749	$10,358 - $6,596	$11,120 - $6,849	$11,737 - $7,872	$12,167 - $11,512

Table VII-2u
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2010 Dollars)
Total Cost = Total Benefit (7% Discount Rate)
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$548 - $1,249	$650 - $1,320	$712 - $1,390	$851 - $1,508	$1,180 - $1,697	$1,481 - $1,748	$1,507 - $1,776	$1,528 - $1,849	$1,543 - $1,805
Daimler	2010 2008	$571 - $1,093	$672 - $1,133	$762 - $1,162	$857 - $1,306	$1,061 - $1,363	$1,370 - $1,561	$1,374 - $1,577	$1,397 - $1,627	$1,402 - $1,598
Fiat	2010 2008	$800 - $1,448	$702 - $1,320	$1,006 - $1,311	$1,538 - $1,955	$1,881 - $2,305	$1,906 - $2,302	$2,660 - $2,718	$2,630 - $2,885	$2,725 - $3,142
Ford	2010 2008	$862 - $1,155	$893 - $1,281	$1,123 - $1,457	$1,880 - $3,185	$2,533 - $3,505	$2,504 - $3,471	$2,457 - $3,555	$2,449 - $3,599	$2,712 - $3,035
Geely	2010 2008	$232 - $547	$885 - $757	$931 - $980	$1,073 - $1,097	$1,225 - $1,159	$1,335 - $1,533	$1,680 - $1,734	$1,700 - $1,797	$1,659 - $1,761
General Motors	2010 2008	$984 - $1,502	$1,022 - $1,538	$1,283 - $1,841	$2,230 - $2,522	$2,228 - $2,540	$2,129 - $2,487	$2,236 - $2,707	$2,348 - $2,937	$2,502 - $2,949
Honda	2010 2008	$834 - $1,163	$910 - $1,138	$1,057 - $1,303	$1,140 - $1,320	$1,367 - $1,767	$1,980 - $2,439	$1,943 - $2,403	$2,194 - $2,520	$2,009 - $2,367
Hyundai	2010 2008	$966 - $1,083	$876 - $1,091	$1,591 - $1,823	$1,563 - $1,773	$1,536 - $1,740	$1,796 - $2,531	$1,770 - $2,485	$1,997 - $3,035	$1,886 - $2,773
Kia	2010 2008	$647 - $851	$651 - $853	$919 - $723	$911 - $872	$1,616 - $1,716	$1,589 - $1,637	$1,756 - $1,663	$1,718 - $1,638	$1,633 - $1,671
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$1,064 - $1,552	$1,334 - $1,860	$1,220 - $1,715	$1,497 - $2,293	$1,492 - $2,115	$1,472 - $2,045	$2,131 - $2,329	$2,251 - $2,462	$2,032 - $2,160
Mitsubishi	2010 2008	$1,357 - $1,530	$1,347 - $1,382	$1,233 - $1,287	$1,433 - $1,397	$2,485 - $2,760	$2,415 - $2,653	$2,378 - $2,683	$2,342 - $2,663	$2,213 - $2,620

Nissan	2010 2008	$511 - $1,919	$534 - $1,837	$1,228 - $1,843	$1,863 - $4,208	$2,008 - $4,175	$2,015 - $4,128	$1,985 - $4,053	$2,247 - $4,040	$2,139 - $3,261
Porsche	2010 2008	$221 - $285	$277 - $520	$1,116 - $857	$1,242 - $1,074	$1,442 - $1,135	$1,457 - $1,185	$1,499 - $1,708	$1,523 - $1,754	$1,504 - $1,714
Spyker	2010 2008	- - $661	- - $764	- - $865	- - $1,005	- - $1,242	- - $1,207	- - $1,254	- - $1,329	- - $1,341
Subaru	2010 2008	$921 - $245	$977 - $497	$1,987 - $1,871	$1,954 - $1,778	$1,867 - $1,739	$1,819 - $1,719	$1,791 - $1,690	$2,064 - $2,032	$1,967 - $1,888
Suzuki	2010 2008	$860 - $525	$858 - $526	$786 - $2,115	$913 - $2,057	$2,991 - $2,475	$2,913 - $2,495	$2,862 - $2,514	$2,813 - $2,561	$2,519 - $2,966
Tata	2010 2008	$238 - $452	$316 - $552	$431 - $662	$573 - $786	$1,121 - $1,217	$1,207 - $1,216	$1,255 - $1,261	$1,290 - $1,340	$1,346 - $1,360
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$626 - $608	$688 - $787	$770 - $901	$837 - $960	$1,168 - $1,258	$1,164 - $1,294	$1,300 - $1,366	$1,496 - $1,606	$1,449 - $1,623
Volkswagen	2010 2008	$426 - $415	$734 - $784	$1,032 - $1,218	$1,361 - $1,305	$1,531 - $1,340	$1,540 - $1,354	$1,620 - $1,464	$1,779 - $1,810	$2,022 - $1,748
Total/Average	2010 2008	$791 - $1,144	$827 - $1,221	$1,081 - $1,427	$1,574 - $2,076	$1,855 - $2,265	$1,907 - $2,338	$2,054 - $2,447	$2,159 - $2,617	$2,223 - $2,484

Table VII-2v
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2010 Dollars)
Total Cost = Total Benefit (7% Discount Rate)
Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
BMW	2010 2008	$58 - $172	$68 - $174	$75 - $183	$87 - $193	$119 - $218	$149 - $211	$149 - $207	$155 - $221	$156 - $229
Daimler	2010 2008	$57 - $95	$73 - $95	$83 - $103	$93 - $121	$117 - $136	$154 - $123	$156 - $124	$163 - $133	$167 - $143
Fiat	2010 2008	$619 - $588	$522 - $507	$754 - $475	$1,139 - $698	$1,380 - $795	$1,402 - $610	$1,945 - $511	$1,900 - $492	$1,979 - $698
Ford	2010 2008	$893 - $882	$915 - $959	$1,142 - $1,046	$1,871 - $2,284	$2,508 - $2,504	$2,481 - $882	$2,422 - $959	$2,429 - $946	$2,706 - $2,284
Geely	2010 2008	$8 - $23	$29 - $32	$31 - $42	$34 - $47	$39 - $48	$42 - $28	$52 - $43	$54 - $46	$52 - $48
General Motors	2010 2008	$1,194 - $1,965	$1,228 - $2,112	$1,561 - $2,643	$2,701 - $3,696	$2,715 - $3,723	$2,611 - $1,829	$2,756 - $2,112	$2,921 - $2,674	$3,157 - $3,696
Honda	2010 2008	$448 - $694	$478 - $620	$558 - $687	$590 - $693	$701 - $947	$1,021 - $694	$990 - $620	$1,109 - $687	$1,012 - $693
Hyundai	2010 2008	$127 - $166	$112 - $165	$194 - $284	$185 - $273	$181 - $272	$209 - $166	$204 - $165	$232 - $284	$222 - $273
Kia	2010 2008	$28 - $84	$28 - $84	$38 - $73	$37 - $84	$63 - $164	$62 - $84	$67 - $84	$65 - $73	$62 - $84
Lotus	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Mazda	2010 2008	$64 - $109	$79 - $144	$67 - $133	$80 - $184	$79 - $178	$78 - $108	$111 - $144	$119 - $133	$108 - $184
Mitsubishi	2010 2008	$19 - $39	$19 - $34	$18 - $31	$20 - $34	$36 - $67	$36 - $36	$35 - $36	$36 - $33	$34 - $39

Nissan	2010 2008	$156 - $854	$164 - $758	$380 - $735	$567 - $1,674	$610 - $1,703	$613 - $854	$605 - $758	$693 - $735	$667 - $1,674
Porsche	2010 2008	$4 - $4	$5 - $6	$22 - $10	$23 - $12	$27 - $13	$27 - $6	$28 - $7	$29 - $14	$29 - $14
Spyker	2010 2008	- - $2	- - $3	- - $3	- - $4	- - $4	- - $3	- - $4	- - $4	- - $4
Subaru	2010 2008	$89 - $19	$92 - $37	$183 - $136	$177 - $129	$171 - $127	$167 - $19	$165 - $37	$195 - $136	$189 - $129
Suzuki	2010 2008	$3 - $12	$3 - $11	$3 - $44	$3 - $43	$11 - $51	$11 - $13	$11 - $14	$11 - $48	$11 - $43
Tata	2010 2008	$13 - $26	$17 - $31	$23 - $38	$30 - $44	$57 - $71	$61 - $39	$63 - $43	$65 - $48	$68 - $51
Tesla	2010 2008	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -	- - - -
Toyota	2010 2008	$605 - $809	$658 - $963	$733 - $1,029	$780 - $1,108	$1,083 - $1,529	$1,077 - $809	$1,194 - $963	$1,374 - $1,029	$1,335 - $1,108
Volkswagen	2010 2008	$44 - $53	$74 - $114	$106 - $179	$137 - $191	$155 - $199	$157 - $55	$165 - $115	$186 - $212	$212 - $218
Total/Average	2010 2008	$4,429 - $6,596	$4,562 - $6,849	$5,971 - $7,872	$8,555 - $11,512	$10,052 - $12,749	$10,358 - $6,596	$11,120 - $6,849	$11,737 - $7,872	$12,167 - $11,512

Indirect Costs

Indirect Cost Multiplier Changes

As discussed in greater detail below, for the NPRM, the agencies revised the markups used to estimate indirect costs. The first change was to adjust ICM values based on a change in the retail price equivalent (RPE) value to which they are normalized. Previously, the ICM values were normalized to a single year value of 1.46, which was recommended in a study conducted by RTI.[351] The agencies have revised the normalization to 1.50, which represents the historical average retail price equivalent (RPE). This was done by applying a factor of .50/.46 to all indirect cost elements. The second change was to re-consider the markup factors and the data used to generate them. The ICM values for low and medium complexity technologies are now based solely on modified Delphi estimates. The final change is the way in which the ICM factors are applied. In previous analyses ICMs were applied to the learned value of direct costs. However, since learning influences direct costs only, the agencies have reconsidered this approach and are no longer applying learning to ICMs, except the warranty component, which are influenced by the learned value of direct costs. Indirect costs are thus now established based on the initial value of direct costs and held constant until the long-term ICM is applied. The collective effect of these changes is to increase the ICM factors applied to technologies.

Cost markups to account for indirect costs

To produce a unit of output, auto manufacturers incur direct and indirect costs. Direct costs include the cost of materials and labor costs. Indirect costs may be related to production (such as research and development [R&D]), corporate operations (such as salaries, pensions, and health care costs for corporate staff), or selling (such as transportation, dealer support, and marketing). Indirect costs are generally recovered by allocating a share of the costs to each unit of goods sold. Although it is possible to account for direct costs allocated to each unit of goods sold, it is more challenging to account for indirect costs allocated to a unit of goods sold. To make a cost analysis process more feasible, markup factors, which relate total indirect costs to total direct costs, have been developed. These factors are often referred to as retail price equivalent (RPE) multipliers.

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[351] RTI International. Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers. February 2009. http://www.epa.gov/otaq/ld-hwy/420r09003.pdf (last accessed August 3, 2012); Rogozhin, A.,et al., “Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry,” International Journal of Production Economics (2009), doi:10.1016/j.ijpe.2009.11.031. The peer review for the RTI report is at http://www.epa.gov/otaq/ld-hwy/420r09004.pdf (last accessed August 3, 2012).

Cost analysts and regulatory agencies including EPA and NHTSA have frequently used these multipliers to estimate the resultant impact on costs associated with manufacturers' responses to regulatory requirements. The best approach to determining the impact of changes in direct manufacturing costs on a manufacturer's indirect costs would be to actually estimate the cost impact on each indirect cost element. However, doing this within the constraints of an agency's time or budget is not always feasible, and the technical, financial, and accounting information to carry out such an analysis may simply be unavailable.

RPE multipliers provide, at an aggregate level, the relative shares of revenues (Revenue = Direct Costs + Indirect Costs + Net Income) to direct manufacturing costs. Using RPE multipliers implicitly assumes that incremental changes in direct manufacturing costs produce common incremental changes in all indirect cost contributors as well as net income. A concern in using the RPE multiplier in cost analysis for new technologies added in response to regulatory requirements is that the indirect costs of vehicle modifications are not likely to be the same for different technologies. For example, less complex technologies could require fewer R&D efforts or less warranty coverage than more complex technologies. In addition, some simple technological adjustments may, for example, have no effect on the number of corporate personnel and the indirect costs attributable to those personnel. The use of RPEs, with their assumption that all technologies have the same proportion of indirect costs, is likely to overestimate the costs of less complex technologies and underestimate the costs of more complex technologies.

To address this concern, the agencies have developed modified multipliers. These multipliers are referred to as indirect cost multipliers (ICMs). In contrast to RPE multipliers, ICMs assign unique incremental changes to each indirect cost contributor.

$$\text{ICM} = (\text{direct cost} + \text{adjusted indirect cost} + \text{profit})/(\text{direct cost})$$

To develop the ICMs from the RPE multipliers adjustment factors were developed based on the complexity of the technology and the time frame under consideration. This methodology was used in the cost estimation for the MYs 2012-2016 final rule. The ICMs were developed in a peer-reviewed report from RTI International and were subsequently discussed in a peer-reviewed journal article.[352] Note that the cost of capital (reflected in profit) is included because of the assumption implicit in ICMs (and RPEs) that capital costs are proportional to direct costs, and

[352] RTI International. Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers. February 2009. http://www.epa.gov/otaq/ld-hwy/420r09003.pdf (last accessed August 3, 2012); Rogozhin, A.,et al., "Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry," International Journal of Production Economics (2009), doi:10.1016/j.ijpe.2009.11.031. The peer review for the RTI report is at http://www.epa.gov/otaq/ld-hwy/420r09004.pdf (last accessed August 3, 2012).

businesses need to be able to earn returns on their investments. The capital costs are those associated with the incremental costs of the new technologies.

As noted above, for the analysis supporting this proposed rulemaking, the agencies are again using the ICM approach but have made some changes to both the ICM factors and to the method of applying those factors to arrive at a final cost estimate. The first of these changes was done in response to further analysis by the EPA-NHTSA team related to the derivation of the ICM values. The second change was implemented in response to both further consideration by the agencies and public feedback that learning effects should not be applied to indirect costs through the multiplicative approach that was being used.

Regarding the first change, in the original work done under contract to EPA by RTI International,[353] the EPA panel used a consensus approach to determine the impact of three new technologies on the indirect costs of manufacturers. Subsequent to that work, the EPA panel used a somewhat different approach to estimate the costs for three different technologies using a blind survey to make this determination on a different set of technology changes. This subsequent effort, referred to by EPA as a modified-Delphi approach, resulted in different ICM aggregate and individual element values. This effort is detailed in a memorandum contained in the docket for this rule.[354] For the MY 2012-2016 GHG/CAFE rulemaking, the original RTI values were averaged with the modified-Delphi values to arrive at the final ICMs for low and medium complexity technologies, RTI values were used for high complexity level 1 technologies, and modified-Delphi values were used for high complexity level 2 technologies.

Recently, EPA and NHTSA have examined the elements of the ICMs more closely and determined that the technologies that were analyzed in the original RTI study are not as representative of the broad array of low and medium complexity technologies as the technologies that were examined in the modified-Delphi study, and that the values in the Delphi study better estimate the markup cost elements for low and medium complexity technologies. The original light-duty RTI study used low rolling resistance tires as a low complexity technology example and a dual clutch transmission as a medium complexity technology. In comparison, the modified-Delphi study used passive aerodynamic improvements as the representative low complexity technology and turbocharging with downsizing as the representative medium complexity technology. Consequently, the modified-Delphi values are being used alone as the basis for ICMs for low and medium complexity technologies. NHTSA and EPA technical staffs have also re-examined the selection of technology complexity category for each of the

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[353] Rogozhin, A.,et al., "Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry," International Journal of Production Economics (2009), doi:10.1016/j.ijpe.2009.11.031.
[354] Helfand, Gloria, and Todd Sherwood, "Documentation of the Development of Indirect Cost Multipliers for Three Automotive Technologies," August 2009. EPA-HQ-OAR-2010-0799.

technologies to better align the unexamined technologies to the reference technologies for which ICM values were estimated. The resulting designations together with the associated reference technologies are shown in Table VII-3.

Table VII-3
Technology Designations by ICM Category, with Reference Technology

Low Technology ***Passive Aerodynamic Improvements.***	**Medium Technology** ***Engine Turbo Downsizing***	**High Tech 1** ***Hybrid Electric Vehicle***	**High Tech 2** ***Plug-in Hybrid Electric Vehicle***
Passive Aerodynamic Improv.	6-speed DCTs	Strong Hybrids	PHEV battery packs
Lubricant improvements	Mass Reduction 15-20%	PHEV and EV chargers	All Electric vehicles
Mass Reductions 3-10%	Turbocharging	PHEV non battery components	
Aggressive Shift Logic	Cylinder deactivation		
Engine Friction Reduction	VVT-dual cam phasing & Discrete variable valve lift		
Engine Downsizing	8-speed auto and DCT transmissions		
6 speed auto transmissions	12 volt start-stop systems		
Low Drag Brakes	Active aerodynamic improvements		
Electro-hydraulic power steering	Converting OHV/SOHC to DOHC		
Electric power steering	Gasoline direct injection		
WT intake or coupled	Turbo downsizing		
Improved accessories	Turbo downsizing +EGR		
	Advanced Diesel		

Many of the basic technologies listed in Table VII-3 have variations that share the same complexity designation and ICM estimate. Table VII-4 lists each of the technologies used in the VOLPE model together with both their ICM category and the year through which the short term ICM will be applied. Note that the number behind each ICM Category designation refers to the source of the ICM estimate, with 1 indicating the consensus panel and 2 indicating the modified Delphi panel.

Table VII-4
ICM categories and Short Term ICM Schedules for CAFE Technologies

Technology	ICM Category	Short Term Through
Low Friction Lubricants - Level 1	Low2	2018
Engine Friction Reduction - Level 1	Low2	2018
Low Friction Lubricants and Engine Friction Reduction - Level 2	Low2	2024
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	Low2	2018
Discrete Variable Valve Lift (DVVL) on SOHC	Medium2	2018
Cylinder Deactivation on SOHC	Medium2	2018
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	Low2	2018
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	Medium2	2018
Discrete Variable Valve Lift (DVVL) on DOHC	Medium2	2018
Continuously Variable Valve Lift (CVVL)	Medium2	2018
Cylinder Deactivation on DOHC	Medium2	2018
Stoichiometric Gasoline Direct Injection (GDI)	Medium2	2018
Cylinder Deactivation on OHV	Medium2	2018
Variable Valve Actuation - CCP and DVVL on OHV	Medium2	2018
Stoichiometric Gasoline Direct Injection (GDI) on OHV	Medium2	2018
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement - Turbo	Medium2	2018
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement - Downsize	Medium2	2018
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement -Turbo	Medium2	2018
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement - Downsize	Medium2	2018
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement - Turbo	Medium2	2018
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement - Downsize	Medium2	2018
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement - Turbo	Medium2	2024
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement - Downsize	Medium2	2018

Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement - Turbo	Medium2	2024
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement - Downsize	Medium2	2018
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement - Turbo	Medium2	2024
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement - Downsize	Medium2	2018
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement - Turbo	Medium2	2024
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement - Downsize	Medium2	2018
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement - Turbo	Medium2	2024
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement - Downsize	Medium2	2018
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement - Turbo	Medium2	2024
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement - Downsize	Medium2	2018
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement - Turbo	Medium2	2024
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement - Downsize	Medium2	2018
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement - Turbo	Medium2	2024
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement - Downsize	Medium2	2018
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement - Turbo	Medium2	2024
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement - Downsize	Medium2	2018
Advanced Diesel - Small Displacement	Medium2	2024
Advanced Diesel - Medium Displacement	Medium2	2024
Advanced Diesel - Large Displacement	Medium2	2024
6-Speed Manual/Improved Internals	Low2	2018
Improved Auto. Trans. Controls/Externals	Low2	2018
6-Speed Trans with Improved Internals (Auto)	Low2	2018
6-speed DCT	Medium2	2018
8-Speed Trans (Auto or DCT)	Medium2	2018
High Efficiency Gearbox w/ dry sump (Auto or DCT)	Low2	2024
Shift Optimizer	Low2	2024
Electric Power Steering	Low2	2018

Improved Accessories - Level 1	Low2	2018
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	Low2	2024
12V Micro-Hybrid (Stop-Start)	Medium2	2018
Integrated Starter Generator	High1	2018
Strong Hybrid (Powersplit or 2-Mode) - Level 1 – Battery	High1	2024
Strong Hybrid (Powersplit or 2-Mode) - Level 1 - Non-Battery	High1	2018
Conversion from SHEV1 to SHEV2	HIgh1	2018
Strong Hybrid (P2 Parallel or 2-Mode) - Level 2 – Battery	High1	2024
Strong Hybrid (P2 Parallel or 2-Mode) - Level 2 - Non-Battery	High1	2018
Plug-in Hybrid - 20 mi range – Battery	High2	2024
Plug-in Hybrid - 20 mi range - Non-Battery	High1	2018
Plug-in Hybrid - 40 mi range – Battery	High2	2024
Plug-in Hybrid - 40 mi range - Non-Battery	High1	2018
Electric Vehicle (Early Adopter) - 75 mile range – Battery	High2	2024
Electric Vehicle (Early Adopter) - 75 mile range - Non-Battery	High2	2024
Electric Vehicle (Early Adopter) - 100 mile range – Battery	High2	2024
Electric Vehicle (Early Adopter) - 100 mile range - Non-Battery	High2	2024
Electric Vehicle (Early Adopter) - 150 mile range – Battery	High2	2024
Electric Vehicle (Early Adopter) - 150 mile range - Non-Battery	High2	2024
Electric Vehicle (Broad Market) - 150 mile range – Battery	High2	2024
Electric Vehicle (Broad Market) - 150 mile range - Non-Battery	High2	2024
Fuel Cell Vehicle	High2	2024
Charger-PHEV20	High1	2024
Charger-PHEV40	High1	2024
Charger-EV	High1	2024
Charger Labor	None	2024
Mass Reduction - Level 1	Low2	2018

Mass Reduction - Level 2	Low2	2018
Mass Reduction - Level 3	Low2	2018
Mass Reduction - Level 4	Low2	2018
Mass Reduction - Level 5	Low2	2018
Low Rolling Resistance Tires - Level 1	Low2	2018
Low Rolling Resistance Tires - Level 2	Low2	2024
Low Rolling Resistance Tires - Level 3	Low2	2024
Low Drag Brakes	Low2	2018
Secondary Axle Disconnect	Low2	2018
Aero Drag Reduction, Level 1	Low2	2018
Aero Drag Reduction, Level 2	Medium2	2024

A secondary-level change was also made as part of this ICM recalculation to the light-duty ICMs. That change was to revise upward the RPE level reported in the original RTI report from an original value of 1.46 to 1.50 to better reflect the long term average RPE. The original RTI study was based on 2007 data. However, an analysis of historical RPE data indicates that, although there is year to year variation, the average RPE has remained at approximately 1.50. The agencies believe that using the historical average value would result in ICMs that better estimate the future values. Therefore, ICMs in this proposed rulemaking were adjusted to reflect this average level. As a result, the ICM values for the High 1 and High 2 complexity technologies have also changed.

Table VII-5 shows both the ICM values used in the MYs 2012-2016 final rule and the new ICM values used for the analysis supporting these proposed rules. Near term values account for differences in the levels of R&D, tooling, and other indirect costs that will be incurred. Once the program has been fully implemented, some of the indirect costs will no longer be attributable to the standards and, as such, a lower ICM factor, the long term ICM is applied to direct costs.

Table VII-5
Indirect Cost Multipliers Used in this Analysis[a]

	2012-2016 Rule		This Proposal	
Complexity	Near term	Long term	Near term	Long term
Low	1.17	1.13	1.24	1.19
Medium	1.31	1.19	1.39	1.29
High1	1.51	1.32	1.56	1.35
High2	1.70	1.45	1.77	1.50

[a] Rogozhin, A., et. al., "Using indirect cost multipliers to estimate the total cost of adding new technology in the automobile industry," International Journal of Production Economics (2009); "Documentation of the Development of Indirect Cost Multipliers for Three Automotive Technologies," Helfand, G., and Sherwood, T., Memorandum dated August 2009; "Heavy Duty Truck Retail Price Equivalent and Indirect Cost Multipliers," Draft Report prepared by RTI International and Transportation Research Institute, University of Michigan, July 2010

The second change made to the ICMs has to do with the way in which they are applied. In the past, ICMs have been applied as pure multiplicative factors. This way, a direct manufacturing cost of, say, $100 would be multiplied by an ICM of 1.24 to arrive at a marked up technology cost of $124. However, as learning effects (discussed below) are applied to the direct manufacturing cost, the indirect costs are also reduced accordingly. Therefore, in year two the $100 direct manufacturing cost might reduce to $97 because of learning, and the marked up cost would become $120 ($97 x 1.24). As a result, indirect costs would be reduced from $24 to $20. Given that indirect costs are composed of a number of costs, such as facility-related costs, electricity, etc., that are not affected by learning, the agencies do not believe ICMs should be applied to the learned direct costs, at least not for those indirect cost elements unlikely to change with learning. The EPA-NHTSA team believes that it is appropriate to allow only warranty costs to decrease with learning, since warranty costs are tied to direct manufacturing costs (since warranty typically involves replacement of actual parts which should be less costly with learning). The remaining elements of the indirect costs should remain constant year-over-year, at least until some of those indirect costs are no longer attributable to the rulemaking effort that imposed them (such as R&D).

As a result, the ICM calculation has been modified for this proposal and is more complex. First the year in which the direct manufacturing costs are considered "valid" is established. For example, a cost estimate might be considered valid today, or perhaps not until high volume production is reached—which will not occur until MY 2015 or later. That year is known as the base year for the estimated cost. The costs in that year are used to determine the "non-warranty" portion of the indirect costs. For example, the non-warranty portion of the medium complexity ICM in the short-term is 0.343 (the warranty versus non-warranty portions of the ICMs are shown in Table VII-6.). For the dual cam phasing (DCP) technology on an I4 engine we have estimated a direct manufacturing cost of $70 in MY 2015. So the non-warranty portion of the indirect costs would be $24.01 ($70 x 0.343). This value would be added to the learned direct manufacturing cost for each year through 2018, the last year of short term indirect costs.

Beginning in 2019, when long-term indirect costs begin, the additive factor would become \$18.13 (\$70 x 0.259). Additionally, the \$70 cost in 2015 would become \$67.90 in MY 2016 due to learning (\$70 x (1-3%)). So, while the warranty portion of the indirect costs would be \$3.15 (\$70 x 0.045) in 2015, indirect costs would decrease to \$3.06 (\$67.90 x 0.045) in 2016 as warranty costs decrease with learning. The resultant indirect costs for the DCP-I4 technology would be \$27.16 (\$24.01+\$3.15) in MY 2015 and \$27.07 (\$24.01+\$3.06) in MY2016, and so on for subsequent years.

Table VII-6
Warranty and Non-Warranty Portions of ICMs

	Near term		Long term	
Complexity	Warranty	Non-warranty	Warranty	Non-warranty
Low	0.012	0.230	0.005	0.187
Medium	0.045	0.343	0.031	0.259
High1	0.065	0.499	0.032	0.314
High2	0.074	0.696	0.049	0.448

The impact of learning on direct costs, together with the eventual application of long-term ICMs, causes the effective ICM based markup to differ from the initial ICM on a year-by-year basis. An example of how this occurs is provided in Table VII-7[355]. This table traces the impact of learning on direct costs and its implications for both total costs and the derived ICM based markup. Direct costs are assigned a value of 1 to simplify the illustrative analysis and to use the same basis as for ICMs (in an ICM markup factor, the value of direct costs is represented by 1 while the value of indirect costs is represent by the fraction of 1 to the right of the decimal.) The table examines the impacts of these factors on Turbo downsized engines, one of the more prevalent CAFE technologies.

[355] The table illustrates the learning process from the base year consistent with the direct cost estimate obtained by the agencies. It is a mature technology well into the flat portion of the learning curve. Note however, that the costs actually applied in this rulemaking will begin with the 2017 model year.

Table VII-7
Derived Annual ICMs for Turbo Downsized Engines

Year	Learning Schedule #11	Direct Costs	Other Indirect Costs	Warranty	Total Costs	Effective ICM Based Markup Factor
2010	0.03					
2011	0.03					
2012	0.03	1	0.3427	0.0446	1.3872	1.387
2013	0.03	0.97	0.3427	0.0432451	1.3559	1.398
2014	0.03	0.9409	0.3427	0.0419478	1.3255	1.409
2015	0.03	0.912673	0.3427	0.0406893	1.2960	1.420
2016	0.03	0.8852928	0.3427	0.0394687	1.2674	1.432
2017	0.02	0.867587	0.3427	0.0386793	1.2489	1.440
2018	0.02	0.8502352	0.3427	0.0379057	1.2308	1.448
2019	0.02	0.8332305	0.2587	0.0310	1.1229	1.348
2020	0.02	0.8165659	0.2587	0.0303882	1.1056	1.354
2021	0.02	0.8002346	0.2587	0.0297805	1.0887	1.360
2022	0.02	0.7842299	0.2587	0.0291849	1.0721	1.367
2023	0.02	0.7685453	0.2587	0.0286012	1.0558	1.374
2024	0.02	0.7531744	0.2587	0.0280291	1.0399	1.381
2025	0.02	0.7381109	0.2587	0.0274686	1.0243	1.388
2026	0.01	0.7307298	0.2587	0.0271939	1.0166	1.391
2027	0.01	0.7234225	0.2587	0.0269219	1.0090	1.395
2028	0.01	0.7161883	0.2587	0.0266527	1.0015	1.398
2029	0.01	0.7090264	0.2587	0.0263862	0.9941	1.402
2030	0.01	0.7019361	0.2587	0.0261223	0.9867	1.406
Average ICM 2017 through 2030 =						1.389

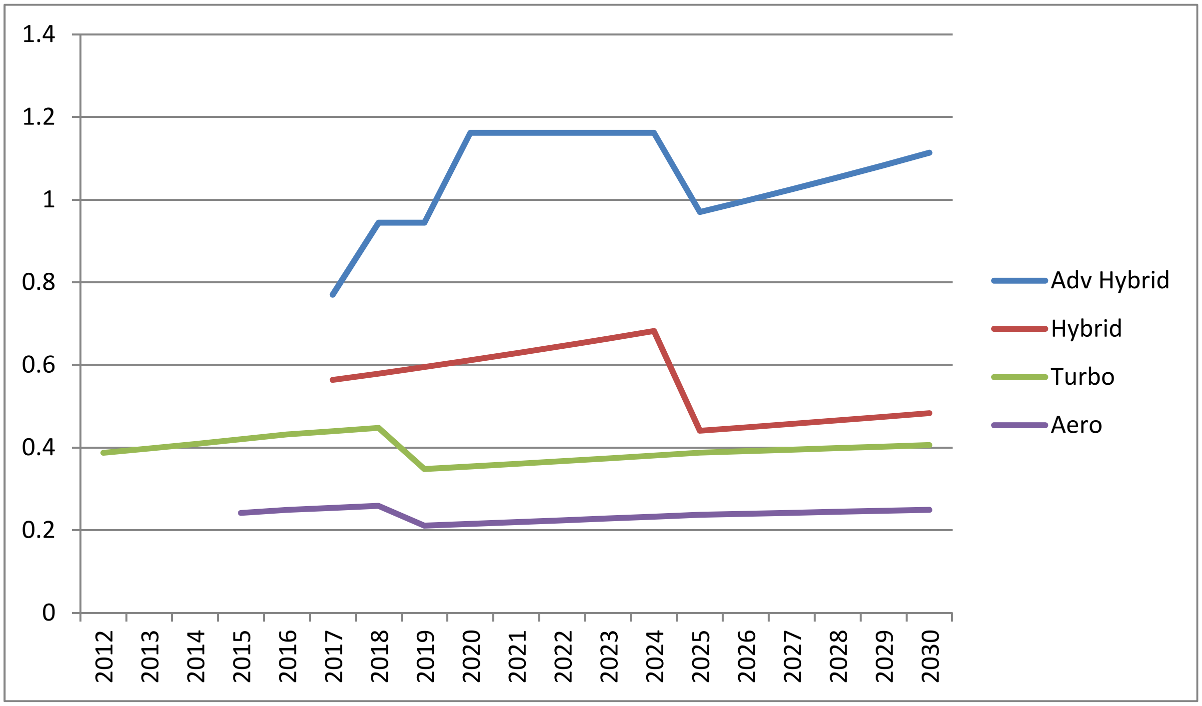
The second column of Table VII-7 lists the learning schedule that is applied to turbocharging and downsizing. Turbocharging and downsizing is a mature technology so the learning schedule captures the relatively flat portion of the learning curve that occurs after the larger decreases have already reduced direct costs. The cost basis for Turbocharging and downsizing in the analysis was effective in 2012, so this is the base year for this calculation when direct costs are set to 1. The third column shows the progressive decline in direct costs as the learning schedule in column 2 is applied to direct costs. Column 4 contains the value of all indirect costs except warranty. Turbocharging and downsizing are a medium complexity technology so this value is taken from the Medium row of Table VII-6. The initial value in 2012 is the near term value, which is used through 2018. During this time, these indirect costs are not impacted by learning and they remain constant. Beginning in 2019, the long-term ICM from Table VII-6 is applied. The fifth column contains warranty costs. As previously mentioned, these costs are considered to be impacted by learning like direct costs, so they decline steadily until the long-term ICM is applied in 2019, at which point they drop before continuing their gradual decline. In the sixth column, direct and indirect costs are totaled. The results show an overall decline in total costs of roughly 30% during this 14 year period. The last column shows the effective ICM based markup, which is derived by dividing total costs by direct costs. Over this period, the derived ICM based markup rose from the initial short term ICM level of 1.39 to 1.45 in 2018. It then declined to 1.35 in 2019 when the long-term ICM was applied to the learned down direct cost. Over the remaining years, the ICM based markup gradually rises back up to 1.41 as learning continues to decrease direct costs.

There are thus two somewhat offsetting processes that impact the effective ICM based markup. The first is the learning curve which reduces direct costs, which raises the derived ICM based markup. As noted previously learning reflects learned efficiencies in assembly methods as well as reduced parts and materials costs. The second is the application of a long-term ICM, which reduces the derived ICM based markup. This represents the reduced burden needed to maintain new technologies once they are fully developed. In this case, the two processes largely offset one another and produce an average ICM based markup over this 14 year period that roughly equals the original short term ICM.

Figure VII-1 illustrates this process for each of the 4 representative technologies that are used to estimate ICM values for each of the complexity categories. As with the turbocharging and downsizing, aerodynamic improvements and strong hybrid vehicles show a gradual increase in the effective ICM based markup through the point where the long-term ICM is applied. At that time, the effective markup declines, and then begins a gradual rise. The advanced hybrid ICM behaves somewhat differently because the technology is not as mature and, as a result, experiences a greater change in the learning value that influences the effective markup value. This produces a step-up in markup values concurrent with each learning step, followed by a decline when the long-term ICM is applied. After that, the effective markup value begins a gradual rise as more moderate learning is applied to reflect its shift to a mature technology. Note that, as with the turbocharging and downsizing example above, for the aerodynamic improvements and mild hybrid technologies the offsetting processes of learning and long-term ICMs result in an average effective ICM based markup over the full time frame that is roughly equal to the initial short-term ICM. However, the advanced hybrid markup rose to a level that is significantly higher than the initial ICM. This is a direct function of the rapid learning schedule applied in the early years to this developing technology. Brand new technologies might thus be expected to have lifetime effective ICM based markups that exceed their initial ICMs, while more mature technologies are more likely to experience markups over their remaining life span that more closely approximate their initial ICMs.

Figure VII-1

Derived ICM Based Markups for Advanced Hybrid Technologies (PHEV Battery Packs and EVs), Hybrids, Turbocharging and Downsizing, and Passive Aerodynamic Improvements



ICMs for these 4 technologies determine the indirect cost markup rate for all technologies used in the CAFE model analysis that supports this proposal. However, the overall impact on costs is also a function of the relative incidence of each of the 88 technologies shown in Table V11-4, which are estimated to have ICMs similar to one of these 4 technologies. The net impact on costs of these ICMs is also influenced by the learning curve that is appropriate to each technology, creating numerous different and unique ICM based markup paths. The average effective markup applied by the CAFE model is also a function of each technologies direct cost - since ICMs are applied to direct costs, the measured indirect cost is proportionately higher for any given ICM when direct costs are higher. The average ICM based markup applied to the fleet for any given model year is calculated as follows:

$$\sum_{1}^{88} \frac{D_n A_n}{\sum_1^{88} D_n A_n} * ICM_n$$

Where: D = learned direct cost of each technology

A = application rate for each technology

ICM = average ICM applied to each technology

n=1,88

The VOLPE model predicts technology application rates assuming that manufacturers will apply technologies to meet standards in a logical fashion based on estimated costs and benefits. The application rates will thus be different for each model year and for each alternative scenario that is examined. To illustrate the overall impact of ICMs on total technology costs, NHTSA has calculated the weighted average ICM based markup across all technologies for the Preferred Alternative.[356] This was done separately for each vehicle type and then aggregated based on the predicted sales of each vehicle type used in the model. The results are shown in Table VII-8.

Table VII-8
Average ICM Based Markup Applied in Preferred Alternative Scenario

Model Year	**Passenger Cars**	**Light Trucks**	**All Vehicles**
2017	0.393	0.370	0.383
2018	0.400	0.377	0.390
2019	0.315	0.308	0.312
2020	0.322	0.317	0.320
2021	0.330	0.323	0.327
2022	0.336	0.329	0.333
2023	0.344	0.337	0.341
2024	0.357	0.343	0.351
2025	0.340	0.319	0.331
All Years	0.348	0.336	0.343

[356] For each alternative, this rulemaking examined numerous scenarios based on different assumptions and these assumptions could have some influence on the relative frequency of selection of different technologies, which in turn could affect the average ICM. The scenario examined here uses the 2010 as the base year, assumes a 3% discount rate, a 1 year payback period, real world application of expected fines, and reflects expected voluntary over-compliance by manufacturers.

The effective ICM based markups in table VII-8 are derived in a manner consistent with the way that the RPE is measured, that is, they reflect the combined influences of direct cost learning and changes in indirect cost requirements weighted by both the incidence of each technologies adaptation and the relative direct cost of each technology.   The results indicate slightly higher ICMs for passenger cars than for light trucks. This is a function of the technologies that are estimated to be adopted for each respective vehicle type, especially in the later years when hybrids and electric vehicles become more prevalent in the passenger car fleet. The influence of these advanced vehicles is driven primarily by their direct costs, which greatly outweigh the costs of other technologies. This results in the application of much more weight to their higher ICMs. This is most notable in 2024 and 2025 for passenger cars, when electric vehicles begin to enter the fleet in larger numbers. The average ICM increases 0.013 in 2024 primarily due to these vehicles. It immediately drops 0.017 in 2025 because both an additional application of 20% learning to the direct cost of these vehicles (which reduces their relative weight), and the long term ICM becomes effective in that year (which decreases the absolute ICM factor). Both influences occur one year after these vehicles begin to enter the fleet due to CAFE requirements.

The ICM based markups also change over time, again, reflecting the different mix of technologies that are present during the earlier years, but that are often replaced with more expensive technologies in the later years. Across all model years, the wide ranging application of diverse technologies required to meet CAFE standards produces an average ICM of approximately 1.34.

There is some level of uncertainty surrounding both the ICM and RPE markup factors. The ICM estimates used in this proposal group all technologies into four broad categories (low, medium, and two levels of high complexity) and applies a single ICM factor to all of the individual technologies within each of the categories. This simplification assumes that the 4 technologies for which ICM values were estimated are representative of the other technologies which were not examined (see table VII-4 above). The accuracy of the estimates is affected by how appropriately each technology is categorized with the representative technology, and if the ICMs for that representative technology are near the midpoint of the real ICMs of all the technologies that they represent. It is likely that the direct cost for some technologies within a category will be higher and some lower than the estimate for the category in general.   Additionally, there is uncertainty because the ICM estimates were developed using panel estimates rather than empirical data, and they have not been validated through a direct accounting of actual indirect costs for individual technologies. RPEs themselves are also inherently difficult to estimate because the accounting statements of manufacturers do not neatly categorize all cost elements as either direct or indirect costs. Hence, each researcher developing an RPE estimate must apply a certain amount of judgment to the allocation of the costs. Since empirical estimates of ICMs are ultimately derived from the same data used to measure RPEs, this affects both measures. However, the value of RPE has not been measured for specific technologies, or for groups of specific technologies. Thus applying a single average RPE to any given technology by definition overstates costs for simple technologies, or understates them for advanced technologies.

Recognizing this uncertainty, NHTSA has conducted a sensitivity analysis substituting the RPE for the ICMs used in the central analysis to mark up direct manufacturing costs. This serves as a measure of the potential impact on total costs of using ICMs compared to the RPE. As noted previously, the RPE is the ratio of aggregate retail prices to aggregate direct manufacturing costs. The ratio already reflects the mixture of learned costs of technologies at various stages of maturity. Therefore, the RPE is applied directly to the learned direct cost for each technology in each year. This was done for the same Preferred Alternative scenario used in the above analysis of average ICMs (see footnote 6). The results are shown in Tables VII-9a and VII-9b for the 2010 and 2008 baselines respectively.

Table VII-9a
Relative Impacts of Applying ICMs vs. RPE to Determine Indirect Costs
2010 Baseline

Model Year	Incremental Technology Costs (Millions$)		Ratios		
	ICM	**1.5 RPE**	**RPE/ICM**	**ICM/RPE**	**RPE-ICM /RPE**
2017	$3,722	$3,749	1.01	0.99	0.01
2018	$5,227	$5,522	1.06	0.95	0.05
2019	$8,256	$9,604	1.16	0.86	0.14
2020	$10,809	$12,451	1.15	0.87	0.13
2021	$14,033	$16,214	1.16	0.87	0.13
2022	$15,262	$18,079	1.18	0.84	0.16
2023	$16,883	$20,806	1.23	0.81	0.19
2024	$19,727	$24,691	1.25	0.80	0.20
2025	$20,015	$27,244	1.36	0.73	0.27
Total	$113,935	$138,361	1.21	0.82	0.18

Table VII-9b
Relative Impacts of Applying ICMs vs. RPE to Determine Indirect Costs
2008 Baseline

Model Year	Incremental Technology Costs (Millions$)		Ratios		
	ICM	1.5 RPE	RPE/ICM	ICM/RPE	RPE-ICM /RPE
2017	$2,499	$3,242	1.30	0.77	0.23
2018	$4,589	$5,909	1.29	0.78	0.22
2019	$7,349	$10,238	1.39	0.72	0.28
2020	$11,059	$14,392	1.30	0.77	0.23
2021	$14,236	$18,465	1.30	0.77	0.23
2022	$16,447	$20,802	1.26	0.79	0.21
2023	$17,767	$23,433	1.32	0.76	0.24
2024	$20,552	$26,526	1.29	0.77	0.23
2025	$23,289	$30,694	1.32	0.76	0.24
Total	$117,787	$153,702	1.30	0.77	0.23

Application of an RPE instead of ICMs would result in technology cost increases averaging roughly 21 -30%- higher (depending on baseline year) over the MY2012-MY2025 timeframe that is represented in these cost estimates. The difference is generally higher in earlier model years because in those years the more cost effective technologies are incorporated into the fleet. These tend to be low complexity technologies with lower ICMs. In later years, the more expensive technologies are applied, including more hybrid and electric vehicles. These tend to be more complex technologies, and the average ICM based markup thus increases to a level closer to the average RPE. Note that there are two different reasons for these differences. The first is the direct impact of applying a higher retail markup. The second is an indirect effect resulting from the impact that these differing markups have on the order of the selection of technologies, which can change as different direct cost levels interact with altered retail markups, shifting their relative overall effectiveness. This has a very pronounced impact under the 2010 baseline. The inclusion of additional technologies in the 2010 baseline fleet results in a different profile of available unused technologies. The shift to an RPE basis makes some of these technologies relatively more expensive and this shifts the pattern of technology adoption predicted by the VOLPE model. For example, fewer advanced engine and electric vehicles were applied under the RPE scenario. In addition, two technologies with negative costs, NAUTO and DCT, are applied more frequently under the RPE scenario, which also lowers the average cost.

In some cases, manufacturers may choose to pay fines under the higher cost RPE scenario. The net result is a predicted reduction in the relative costs of the RPE scenario, especially in the earlier years. By comparison, these factors are mitigated under the 2008 baseline, when more alternative technologies are available for selection in the future vehicles.

The relative impacts of ICMs may vary somewhat by scenario, but in this case, the application of ICMs produces total technology cost estimates that are roughly 18-23% lower than those that would result from applying a single RPE factor to all technologies. The impacts of applying an RPE to other scenarios can be found in the Sensitivity Analysis Chapter.

NPRM Comments on Indirect Cost Markups:

In response to the NPRM, comments on the issue of applying ICMs or RPEs to estimate indirect costs were provided by the National Automobile Dealers Association (NADA) and the International Council on Clean Transportation (ICCT). NADA disagreed with the application of ICMs, stating that they were untested opinions and understated the true costs of CAFE regulations. ICCT supported the use of ICMs and advocated removing the sensitivity analysis that demonstrated the impact of using RPEs and how costs would differ under the two approaches.

<u>NADA Comments on Indirect Costs</u>

NADA argued that the ICM approach is not valid and should be replaced with an RPE approach. Further, it argued that the RPE factor should be 2x rather than the 1.5x approach that is supported by filings to the Securities and Exchange Commission. We have conducted a thorough analysis of the NADA comments on the RPE vs. ICM approach. We disagree with NADA's arguments for both using the RPE approach and a 2x RPE factor, for the following reasons.

NADA's objections to the ICM approach include:

1. There is no evidence that the RPE method is flawed.
2. The ICMs do not include the total costs of complying with the standards, because it does not include all the costs included in the RPE.
3. The ICMs use a subjective judgment to adjust indirect costs for different technologies, while the RPE uses one value for all components and does not rely on "nearly perfect foreknowledge."
4. The ICMs do not incorporate dealer and OEM profits.

NADA's arguments for the RPE of 2x include:

5. Several scholarly papers support the use of RPEs in the 2.0 range.
6. A case study comparison of the added content of a 1971 Chevrolet Vega and 2011 Cruze shows that an RPE of 2.0 accounts for the change in retail price.

The discussion above provides background on the issue of RPEs and ICMs, and on the agencies' decision to use ICMs to estimate indirect costs for this rulemaking. Our responses here address the specific points raised by NADA.

First, the RPE approach applies the same average indirect cost markup across all technologies in the redesigned vehicle fleet, regardless of the source of the direct cost (i.e. whether a technology is simple or complex; whether the source of the additional cost is a new or a mature technology). The RPE methodology also assumes that an indirect cost is associated with the rule, even if no relation is apparent. For instance, the RPEs (until recent union contract changes) would have included the costs to the domestic auto companies of the health insurance for retired auto workers. Because the rulemaking would not affect the current retiree health care costs (which account for about 1.5% of the RPE), they are irrelevant to the rulemaking. The ICM approach differs in that it allows indirect costs to vary with the complexity of the technology and the time frame.[357] It is a reasonable assumption that simple technologies are expected to have fewer indirect costs per dollar than complex technologies. For instance, the use of low-rolling-resistance tires, considered by the EPA/NHTSA team to be a low-complexity technology, adds costs, but, because they require significantly less vehicle integration effort than for example, adding a hybrid powertrain would, the additional indirect costs per dollar of direct manufacturing costs may be very low. In contrast, converting a conventional vehicle to a hybrid-electric is a far more complex activity, involving increases in indirect costs such as research and development disproportionate to its direct costs. Shortly after product introduction, indirect costs for components such as warranty and research may be relatively high, but auto makers are expected to be able to reduce the costs of any specific technology over time, as they gain experience with them and, thus, redirect those expenditures to other areas of their choosing.

Second, the ICM approach excludes some costs included in the RPE when those costs are expected not to be affected by the standards. The ICM approach, as discussed above, begins with the RPE and includes all the relevant cost categories. ICMs reflect the indirect costs judged by the EPA panel (see above for further explanation) to be incurred for each technology in response to regulatory imposed changes. Any "omissions", or instances where the ICM carries no costs for a given technology, are cases where the indirect costs are considered by the EPA

[357] Rogozhin, A., Gallaher, M., McManus, W., February 2009. Automobile industry retail price equivalent and indirect cost multipliers. EPA-420-R-09-003. Available at: /http://www.epa.gov/otaq/ld-hwy/420r09003.pdf (last accessed August 3, 2012)

panel not to be impacted by regulatory imposed changes for that technology. For instance, the costs of switching from a standard tire to a low-rolling-resistance tire (the example of a low-complexity technology in Rogozhin et al. (2009)) are not expected to lead to an increase in transportation costs (i.e., costs for transporting finished vehicles from production site to retail site) because it is not expected to be any more expensive to ship a new vehicle with the new tires than with the old tires.[358]

Third, the RPE approach relies on the assumption that applying the average RPE for the vehicle fleet as a whole will produce a reasonable average indirect cost for all technologies in the redesigned vehicle fleet resulting from these standards. The agencies believe that using the professional judgment and expertise of EPA staff with extensive experience in the auto industry provides useful insight into how a given regulation will impact indirect costs and is an improvement over ignoring differences among technologies. The agencies have therefore based their central analyses on the ICM method.

Fourth, it is incorrect that the ICMs do not include profit. Although the initial ICM report reviewed by NRC did not include OEM profit, the ICM approach applied in this rulemaking does incorporate an allowance for profit, at the average corporate profit rate of 6% of sales. The inclusion of profit for the Joint NPRM is discussed in the draft Technical Support Document, and the agencies have included profit as an element of the indirect costs for the final rulemaking as well.[359]

Fifth, the papers cited to support the use of an RPE of 2x are only a subset of the literature. The National Research Council (NRC)[360] discusses the four studies that NADA's Exhibit A cites in its support of an RPE of 2.0. The NRC also notes that NHTSA used an RPE of 1.5 for its MY 2011 fuel economy rule; the NRC in 2002 used an RPE of 1.4, as did the California Air Resources Board; and EPA has used a markup factor of 1.3. The NRC report then discusses work done for the committee itself, doing a detailed analysis of a Honda Accord and a Ford F-150 truck; the former had an RPE of "1.39 to market transaction price and 1.49 to MSRP," and

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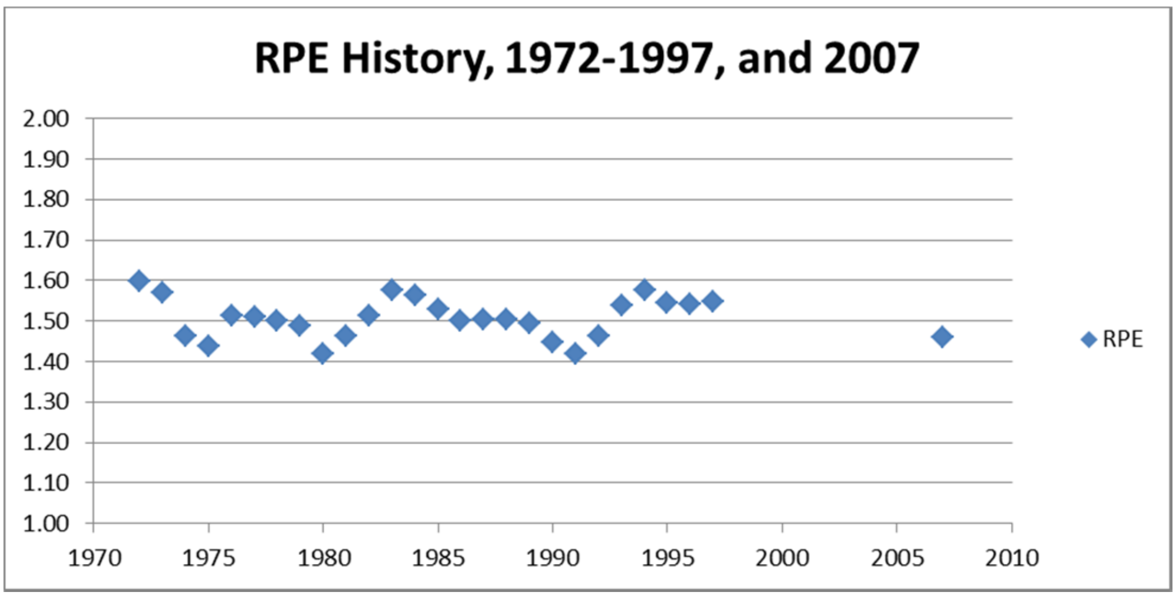
358 Rogozhin, A., Gallaher, M., McManus, W., February 2009. Automobile industry retail price equivalent and indirect cost multipliers. EPA-420-R-09-003, Table 4-3.

359 U.S. Environmental Protection Agency and National Highway Traffic Safety Administration (November 2011). *Draft Joint Technical Support Document: Proposed Rulemaking for 2017-2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards.*" EPA-420-D-11_901, available at http://www.epa.gov/otaq/climate/documents/420d11901.pdf, p. 3-12.

360 National Research Council. Assessment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, D.C.: National Academies Press, 2010.

the latter had an RPE of "1.52 for market price and 1.54 for MSRP." Most significantly, the NRC does not recommend an RPE of 2.0. Rather, the NRC recommends, for technologies where the primary manufacturer of the technology is the automotive supply base, an RPE of 1.5, except for hybrid powertrain components from the automotive supply base, where it recommends an RPE of 1.3 due to the inclusion of several indirect costs in their base estimate.[361] Only in the case of technologies where an automotive OEM is the primary manufacturer does the NRC recommend an RPE of 2.0.[362]

Further support for an average RPE lower than 2.0 comes from an examination of industry financial statements. NHTSA examined industry 10-K submissions to the Securities and Exchange Commission from the period 1972-1997.[363] The cost information in these submissions represents all industry operations, including both OEM and supplier-sourced technologies. During this period, the RPE averaged 1.5 while varying slightly, but never dropped below 1.4 or exceeded 1.6. At no time did the average RPE approach the 2.0 value advocated by NADA. The results are shown, together with the 2007 results from Rogozhin et al in the following figure:



361 NRC, ibid, pp. 3-22, 6-16.
362 Importantly, application of the 2.0x RPE in the "OEM as primary manufacturer" case would be done to a smaller direct cost since the OEM has produced the part in-house and, thus, is not paying the full supplier-level indirect costs that would be included in a part purchased from a supplier. The end result should be a total cost roughly equivalent or less than a 1.5x RPE applied to the supplier-produced part. If not, the manufacturer should probably not produce in-house and should, instead, purchase parts since they would be less costly (all other considerations being equal).
363 Spinney, B.C., Faigin, B.M, Bowie, N.N, Kratzke, S.R., Advanced Air Bag Systems Cost, Weight, and Lead Time Analysis Summary Report, Contract No. DTNH22-96-0-12003, Task Orders – 001, 003, and 005.

We note, without specifically commenting on the quality of the studies, that none of the papers NADA cites in support of an RPE of 2x was published in a peer-reviewed journal, and none of the studies claim to have been peer-reviewed. In contrast, the research in Rogozhin et al. (2009) was peer-reviewed twice: as documented in the Peer Review Report, and when it was submitted (and accepted) for publication in the *International Journal of Production Economics*. A full reading of the literature on RPEs thus shows little support for a value of 2x.

Sixth, the comparison of the Vega and the Cruze uses circular logic; it assumes its conclusion. The direct costs of the vehicles are calculated using an RPE of 2, and the NADA analysis then calculates a quality difference based on the change in direct costs. The magnitude of the quality difference is then discovered to correspond to an RPE of 2, although it is also an inevitable result of the initial assumption of an RPE of 2. The analysis provided can be replicated with any value of RPE. This argument thus provides no evidence on the value of the RPE.

For these reasons, we do not accept NADA's request to use an RPE of 2x, and instead continue with our use of ICMs as the basis for our central analysis. However, the agencies recognize that there is uncertainty regarding the impact on indirect costs of changes imposed by CAFE regulations. For this reason, both agencies have conducted sensitivity analyses using different indirect cost estimates. EPA presents its sensitivities in Chapter 3 of its final RIA. NHTSA presents the impact of using the RPE as a basis for indirect costs in its analysis in Chapters 7 and 10 of NHTSA's FRIA. In addition, RPEs are incorporated into the Probabilistic Uncertainty analysis in Chapter 12 of NHTSA's FRIA.

ICCT Comments on Indirect Costs

ICCT supported the use of ICMs as a method for estimating indirect costs, stating that it agreed "with the use of indirect cost multipliers (ICM) instead of Retail Price Equivalent (RPE) and the general approach of assigning technologies to several complexity classes for determining the ICM value." ICCT further stated that "Trying to determine the indirect multiplier for each technology would be extremely difficult and time consuming, but it is also important to use more appropriate and targeted adjustments than a single, indiscriminant RPE." Most of ICCTs subsequent discussion repeated the description of the ICM process and the nature of ICMs and the RPE supplied in the NPRM technical documents. However, ICCT then commented that NHTSA should remove any sensitivity analyses which examine the impact of using RPEs rather than ICMs in this rulemaking, arguing that "…the use of RPE for these two sensitivity analyses is inappropriate and distorts the cost results."

ICCT's request is unique in that it argues, not for a change in the central values, which already are based on ICMs, but for removal of any discussion that would quantify the impacts of the decision to use ICMs instead of the RPE. NHTSA has considered these arguments, but has retained the sensitivity analysis using RPEs for the final rule.

OMB Circular No. A-94 establishes guidelines for conducting benefit-cost analysis of Federal programs. The circular states that "Estimates of benefits and costs are typically uncertain because of imprecision in both underlying data and modeling assumptions. Because such uncertainty is basic to many analyses, its effects should be analyzed and reported. Useful information in such a report would include the key sources of uncertainty; expected value estimates of outcomes; the sensitivity of results to important sources of uncertainty; and where possible, the probability distributions of benefits, costs, and net benefits." NHTSA agrees with this guidance, and routinely conducts sensitivity analyses in its rulemakings to examine uncertainty around specific assumptions, as well as probabilistic uncertainty analyses to examine the cumulative impact of uncertainty surrounding the major inputs that drive the costs and benefits of its analyses. Thus, it is in no way novel that NHTSA should conduct sensitivity analyses to examine the impacts of particular inputs.

By requesting that NHTSA remove the sensitivity analysis using RPEs, ICCT appears to be suggesting that there is zero uncertainty with regard to how indirect costs should be accounted for in rulemaking analysis. ICCT says as much when it states that the RPE sensitivity analysis "distorts the cost results." Again, the purpose of sensitivity analysis is to examine the effects of different inputs on a cost-benefit analysis – thus, characterizing such an analysis as a "distortion" of the primary analysis seems to mistake its purpose. Additionally, ICCT provided no new information as to why there is zero uncertainty with regard to the agency's use of ICMs for the central analysis, and largely recounted the agencies' own discussions on the merits of ICMs. Having participated in the writing of that discussion, NHTSA is aware of those merits, but nonetheless found there to be value in analyzing RPEs as a sensitivity in the NPRM, and continues to find such value for this final rule.

NHTSA acknowledges the theoretical advantage that comes with a more disaggregated approach to assigning indirect cost multipliers. This is the rationale for selecting ICMs as the basis for the central calculations in this analysis. However, there are over 60 technologies being applied to vehicles and only 4 of these technologies are actually examined under the ICM process. NHTSA believes that the small number of technologies actually examined together with the lack of validation of the ICM factors estimated for those 4 technologies creates sufficient uncertainty to support examination of alternative estimates as required by Circular A-94. We note further that the National Research Council (NRC) of the National Academy of Sciences (NAS) has also expressed uncertainty regarding the application of ICMs or the RPE to measure indirect costs, stating that "….At the present time, a rigorous and robust method for estimating these differential impacts does not exist…Therefore, it is not clear that the accuracy of fuel consumption cost assessment would be increased by the use of technology-specific, as opposed to an industry-average, markup factor." NRC also conducted its own studies on two different vehicles and found that retail prices for those vehicles were roughly 50% above their direct manufacturing costs. Another commenter to the NPRM, NADA, stated that "…There is no reason to believe that NHTSA and EPA, or even manufacturers have the ability to anticipate how a given regulation will impact indirect costs."

NHTSA believes that it is appropriate to examine the RPE as an alternative for several reasons. First, historically, the RPE has been used as the basis for most regulatory analyses. The RPE has been used for decades to mark up costs to the retail price level. Shifting to ICMs is a departure from NHTSA's standard practice, and it is reasonable to conduct an analysis using RPE to consider how the results could be impacted. Second, the RPE is the only markup basis available that is derived from empirical data. During the roughly three decades for which RPE data has been tracked, the aggregate value of retail prices have been set roughly 50% above direct manufacturing costs. Third, this rulemaking is projected to affect most major components and vehicle systems, if not nearly the whole vehicle in some instances. This strengthens the reasons for conducting a sensitivity case using RPE, which is based on the relationship between retail prices and the direct costs of producing the complete vehicle. Finally, there is no broad consensus as to whether ICMs or the RPE provide the more accurate estimate of indirect costs, as evidenced by the comments to the proposal and the National Academy of Sciences study.

NHTSA therefore believes that examining the impacts of alternate measures is an appropriate analytical exercise that provides useful information to decision makers. We note that while the RPE predicts higher vehicle costs than do the current ICM estimates, under both assumptions, the rule is highly cost-beneficial. NHTSA believes this is a valid consideration for policy makers, and in line with OMB guidance for treatment of uncertainty when analyzing the impacts of Federal programs. ICCT offered no information that leads the agency to conclude that a different approach is appropriate for the final rule. For these reasons, NHTSA has included the sensitivity analysis examining the impact of the RPE in the FRIA for this final rule.

Learning Curves

NHTSA applies estimates of learning curves to the various technologies that will be used to meet CAFE standards. Learning curves reflect the impact of experience and volume on the cost of production. As manufacturers gain experience through production, they refine production techniques, raw material and component sources, and assembly methods to maximize efficiency and reduce production costs. Typically, learning curves reflect initial learning rates that are relatively high, followed by slower learning as the easier improvements are made and production efficiency peaks. This eventually produces an asymptotic shape to the learning curve as small percent decreases are applied to gradually declining cost levels (see figure 1).

Learning Applications in Previous Rulemakings

Over previous rulemakings, NHTSA has estimated the impact of learning using a variety of methods as our thinking about learning has evolved due to research, public comment, and methodology development. In the 2008 NPRM, working in conjunction with the EPA, NHTSA applied learning factors to technology costs for the first time. The factors were developed using three parameters which include learning threshold, learning rate, and the initial technology cost, and were based on the "experience curve" concept which describes reductions in production costs as a function of accumulated production volume. As noted above, the typical curve shows a relatively steep initial decline in cost which flattens out to a gentle downwardly sloping line as the volume increase to large values. In the 2008 NPRM, the agencies applied a learning rate discount of 20 percent for each successive doubling of production volume (on a per manufacturer basis), and a learning threshold of 25,000 units was assumed (thus a technology was viewed as being fully learned out at 100,000 units). The factor was only applied to certain technologies that were considered emerging or newly implemented on the basis that significant cost improvements would be achieved as economies of scale were realized (*i.e.*, the technologies were on the steep part of the curve).

In the MY 2011 final rule, the agencies continued to use this learning factor, referring to it as volume-based learning since the cost reductions were determined by production volume increases, and again only applied it to low volume, emerging technologies. However, in response to comments, the agencies revised the assumptions on learning threshold, basing them instead on an industry-wide production basis, and increasing the threshold to 300,000 units annually (thus a technology was considered to be fully learned out at 1.2M annual units).

Additionally, commenters to the 2008 NPRM also described another type of learning factor which NHTSA, working in conjunction with its contractor Ricardo, adopted and implemented for the MY 2011 final rule. Commenters described a relatively small negotiated cost decrease that occurred on an annual basis through contractual agreements with first tier component and systems suppliers. These agreements were generally only applicable to readily available, high volume technologies that were commonly in use by multiple OEMs. Based on the same experience curve principle, however at production volumes that were on the extended, flatter part of the curve (and thus the types of volumes that more accurately represent an annual industry-wide production volume), the agencies adopted this type of learning and referred to it as time-based learning. An annual cost reduction of 3 percent in the second and each subsequent year, which was consistent with estimates from commenters and supported by work that Ricardo conducted for NHTSA, was used in the 2011 final rule.

In response to the 2012-2016 NPRM, NHTSA received comments from ICCT and Ferrari related to learning curves. ICCT stated the agencies could improve the accuracy of the learning curve assumptions if they used a more dynamic or continuous learning curve that is more technology-specific, rather than using step decreases as the current time- and volume-based learning curves appear to do. ICCT also commented on the appropriate application of volume- versus time-based learning, and stated further that worldwide production volumes should be taken into account when developing learning curves. Ferrari commented that it is more difficult for small-volume manufacturers to negotiate cost decreases from things like cost learning effects with their suppliers, implying that learning effects may not be applicable equally for all manufacturers.

NHTSA agreed that a continuous curve, if implemented correctly, could potentially improve the accuracy of modeling cost-learning effects. To implement a continuous curve, however, NHTSA would need to develop a learning curve cost model to be integrated into the agency's existing model for CAFE analysis. Due to time constraints in the MY 2012-2016 rulemaking, the agencies were not able to then investigate fully the use of a continuous cost-learning effects curve for each technology, but noted that we would investigate the applicability of this approach for future rulemakings.

Additionally, while NHTSA agreed that worldwide production volumes can impact learning curves, the agency does not forecast worldwide vehicle production volumes in addition to the already complex task of forecasting the U.S. market. That said, the agency does consider current and projected worldwide technology proliferation when determining the maturity of a particular technology used to determine the appropriateness of applying time- or volume-based learning, which helps to account for the effect of globalized production.

With regard to ICCT's comments on the appropriate application of volume- versus time-based learning, however, it seems as though ICCT is referencing a study that defines volume- and time-based learning in a different manner than the current definitions used by NHTSA. NHTSA uses "volume-based" learning for non-mature technologies that have the potential for significant cost reductions through learning, while "time-based" learning is used for mature technologies that have already had significant cost reductions and only have the potential for smaller cost reductions. For "time-based" learning, the agencies chose to emulate the small year-over-year cost reductions manufacturers realize through defined cost reductions, approximately 3 percent per year, negotiated into contracts with suppliers.

And finally, in response to Ferrari's comment, NHTSA recognizes that cost negotiations can be different for different manufacturers, but believes that on balance, cost learning at the supplier level will generally impact costs to all purchasers. Thus, if cost reductions are realized for a particular technology, all entities that purchase the technology will benefit from these cost reductions.

In developing the MY2012-2016 final rule, NHTSA, taking into account comments received, reviewed both types of learning factors, and the thresholds (300,000) and cost reduction rates (20 percent for volume, 3 percent for time-based) they rely on, as implemented in the MY 2011 final rule and the MY2012-2016 NPRM, and concluded that both learning factors continued to be appropriate. NHTSA therefore continued to implement both time- and volume-based learning in the analyses that supported the MY2012-2016 final rule. Noting that only one type of learning can be applied to any single technology, if any learning is applied at all, NHTSA reviewed each technology to determine which if any learning factor was appropriate.

Working under the principle that volume-based learning is applicable to lower volume, higher complexity, emerging technologies while time-based learning is appropriate for high volume, established and readily available technologies, NHTSA established a series of learning schedules which were applied to specific technologies (see Table V-8 in the 2012-2016 FRIA). These factors closely resemble the settings used in the 2011 final rule with the exception of PSHEV which was revised from time-based to volume-based learning. No learning was applied to technologies which are potentially affected by commodity costs (LUB, ROLL) or that have loosely-defined bill of materials (EFR, LDB) in this analysis, as was also the case in the MY 2011 final rule analysis. Where volume-based learning was applied, NHTSA took great care to ensure that the initial costs (before learning is applied) properly reflect low volume, unlearned cost estimates (*i.e.*, any high volume cost estimates used in the analysis have been appropriately "reverse learned" so as not to underestimate the final learned costs).

Regarding these initial volume-based learning costs, ICCT commented that it would be helpful to clarify the assumed production volumes to better interpret the costs of technologies, which are eligible for "volume-based" learning. The agencies did not define the specific cumulative production volume for technologies that are eligible for volume-based learning. When developing the costs for these technologies it was assumed that cumulative production volumes had not exceeded 300,000 but the agencies did not try to specify the exact production volume. Due to the uncertainty of projected production volumes the agency did not believe it appropriate to define costs based on a finer level of detail.

Learning Application in the Current Rulemaking

The learning curves the agency currently uses represent the agency's best estimates regarding the pace of learning. Depending on the technology, the curves assume a learning rate of 3% over the previous years' cost for a number of years, followed by 2% over several more years, followed by 1% indefinitely. In a few cases, larger decreases of 20% are applied every 2 years during the initial years of production before learning decreases to the more typical levels described above. This occurs for the changes that involve relatively new emerging technologies that are not yet mature enough to warrant the slower learning rates.

For this NPRM the agency has, however, adopted new terminology to distinguish the two different learning applications. Emerging technologies are adjusted using what we now call the "steep "learning schedule, which involves the larger 20% decreases, while mature technologies are modified using one of a number of "flat" schedules, involving the smaller 3%, 2%, or 1% decreases. These revised terms reflect the portion of a typical learning curve that would best represent the production history of each technology. Some schedules include both steep and flat characteristics as technologies transition through these phases during the years covered by this analysis. Again, these terms replace the "volume based" and "time based" learning terminology that was used in previous CAFE analyses. All learning essentially derives from knowledge gained through accumulated production experience, and the time based terminology seemed to create some confusion among commenters. The modified terminology helps to clarify this point reflects the portion of the volume based learning process that is likely to impact any specific technology.

Table VII-10 lists the various learning schedules that NHTSA applies to technologies for the 2017-2025 FRIA. The schedules are identified by a reference schedule number that was originally assigned to each schedule during the development of the agencies learning methodology. Many other schedules were originally developed, but only those shown in Table VII-10 were considered relevant to the technology costs used in the current analysis. The table illustrates cost reduction rates for years 2010 through 2030. However, only a subset of these years is relevant to each technology, depending on the year in which its direct cost estimate is based and the years in which the technology is applied. The second line in the table indicates the base year that the direct manufacturing costs used by the agencies represent. The learning rates that are indicated prior to the direct manufacturing costs (DMC) base year reflect "prior learning" that was estimated to occur before the base year direct manufacturing cost estimate used by the agencies were developed. So, for example, if a cost estimate for a mature technology reflects expected conditions in MY 2012, there would have already been learning prior to that which would have impacted the MY 2012 costs. Additional learning would then commence in MY 2013.

Table VII-11 lists the technologies that manufacturers may use to achieve higher CAFE levels, and the learning schedule that is applied to each technology. Selection of specific learning curves was based on the agency's best judgment as to the maturity of each technology and where they would best fit along the learning curve, as well as the year on which their direct manufacturing costs are based.

For example, schedules 11, 12, and 21 are appropriate for technologies that are more mature and have already passed through the steep portion of the learning curve, while schedules 16, 19, 24, and 25 are more appropriate for emerging technologies that will be experiencing learning along the steep part of the curve between MYs 2014-2025.

Table VII-10
Learning Schedules by Model Year Applied to Specific CAFE Technologies

Schedule # = **DMC Year =** Model Year	**6** N/A	**11** 2012	**12** 2015	**16** 2015	**19** 2025	**21** 2017	**24** 2017	**25** 2017
2010	0	0.03	0.03	0	0	0.03	0	0
2011	0	0.03	0.03	0	0	0.03	0	0
2012	0	0.03	0.03	0	0	0.03	0	0
2013	0	0.03	0.03	0	0	0.03	0	0
2014	0	0.03	0.03	0.20	0.20	0.03	0.20	0
2015	0	0.03	0.03	0.20	0	0.03	0	0
2016	0	0.03	0.03	0	0.20	0.03	0.20	0
2017	0	0.02	0.02	0.03	0	0.03	0	0
2018	0	0.02	0.02	0.03	0.20	0.03	0.03	0
2019	0	0.02	0.02	0.03	0	0.03	0.03	0.20
2020	0	0.02	0.02	0.03	0.20	0.03	0.03	0
2021	0	0.02	0.02	0.03	0	0.03	0.03	0.2
2022	0	0.02	0.02	0.03	0	0.03	0.03	0.03
2023	0	0.02	0.02	0.03	0	0.02	0.03	0.03
2024	0	0.02	0.02	0.03	0	0.02	0.03	0.03
2025	0	0.02	0.02	0.03	0.20	0.02	0.03	0.03
2026	0	0.01	0.01	0.02	0.03	0.02	0.02	0.03
2027	0	0.01	0.01	0.02	0.03	0.02	0.02	0.02
2028	0	0.01	0.01	0.02	0.03	0.01	0.02	0.02
2029	0	0.01	0.01	0.02	0.03	0.01	0.02	0.02
2030	0	0.01	0.01	0.02	0.03	0.01	0.02	0.02

Table VII-11
Learning Schedules for Specific CAFE Technologies

Technology	**Learning Schedule**
Low Friction Lubricants - Level 1	6
Engine Friction Reduction - Level 1	6
Low Friction Lubricants and Engine Friction Reduction - Level 2	6
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	12
Discrete Variable Valve Lift (DVVL) on SOHC	12
Cylinder Deactivation on SOHC	11
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	12
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	12
Discrete Variable Valve Lift (DVVL) on DOHC	12
Continuously Variable Valve Lift (CVVL)	12
Cylinder Deactivation on DOHC	11
Stoichiometric Gasoline Direct Injection (GDI)	11
Cylinder Deactivation on OHV	12
Variable Valve Actuation - CCP and DVVL on OHV	12
Stoichiometric Gasoline Direct Injection (GDI) on OHV	11
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement – Turbo	11
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement - Downsize	11
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement –Turbo	11
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement - Downsize	11
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement – Turbo	11
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement - Downsize	11
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement - Turbo	11
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement - Downsize	11

Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement - Turbo	11
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement - Downsize	11
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement - Turbo	11
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement - Downsize	11
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement - Turbo	11
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement – Downsize	11
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement - Turbo	11
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement – Downsize	11
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement – Turbo	11
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement – Downsize	11
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement – Turbo	11
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement – Downsize	11
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement – Turbo	11
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement – Downsize	11
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement – Turbo	11
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement – Downsize	11
Advanced Diesel - Small Displacement	11
Advanced Diesel - Medium Displacement	11
Advanced Diesel - Large Displacement	11
6-Speed Manual/Improved Internals	12
Improved Auto. Trans. Controls/Externals	12
6-Speed Trans with Improved Internals (Auto)	11
6-speed DCT	11
8-Speed Trans (Auto or DCT)	11
High Efficiency Gearbox w/ dry sump (Auto or DCT)	21
Shift Optimizer	21

Electric Power Steering	12
Improved Accessories - Level 1	12
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	12
12V Micro-Hybrid (Stop-Start)	16
Integrated Starter Generator	16
Strong Hybrid (Powersplit or 2-Mode) - Level 1 – Battery	24
Strong Hybrid (Powersplit or 2-Mode) - Level 1 - Non-Battery	11
Conversion from SHEV1 to SHEV2	N/A
Strong Hybrid (P2 Parallel or 2-Mode) - Level 2 – Battery	24
Strong Hybrid (P2 Parallel or 2-Mode) - Level 2 - Non-Battery	11
Plug-in Hybrid - 20 mi range – Battery	19
Plug-in Hybrid - 20 mi range - Non-Battery	11
Plug-in Hybrid - 40 mi range – Battery	19
Plug-in Hybrid - 40 mi range - Non-Battery	11
Electric Vehicle (Early Adopter) - 75 mile range – Battery	19
Electric Vehicle (Early Adopter) - 75 mile range - Non-Battery	21
Electric Vehicle (Early Adopter) - 100 mile range – Battery	19
Electric Vehicle (Early Adopter) - 100 mile range - Non-Battery	21
Electric Vehicle (Early Adopter) - 150 mile range – Battery	19
Electric Vehicle (Early Adopter) - 150 mile range - Non-Battery	21
Electric Vehicle (Broad Market) - 150 mile range – Battery	19
Electric Vehicle (Broad Market) - 150 mile range - Non-Battery	21
Charger-PHEV20	19
Charger-PHEV40	19
Charger-EV	19
Charger Labor	6
Mass Reduction - Level 1	21

Mass Reduction - Level 2	21
Mass Reduction - Level 3	21
Mass Reduction - Level 4	21
Mass Reduction - Level 5	21
Low Rolling Resistance Tires - Level 1	6
Low Rolling Resistance Tires - Level 2	25
Low Rolling Resistance Tires - Level 3	N/A
Low Drag Brakes	6
Secondary Axle Disconnect	12
Aero Drag Reduction, Level 1	12
Aero Drag Reduction, Level 2	12

Table VII-12 was created to illustrate the level of the estimated direct cost reduction that occurs as a result of learning. The base model year for the cost comparison is MY 2012, in which the direct cost for each technology is assumed to be 100 percent. Due to learning, the direct cost will either stay the same or decrease in the subsequent model years. The table shows the estimated direct cost for each technology in each model year as a percentage of the cost in MY 2012. For an example, in 2021, estimated PHEV20 battery direct cost is 41percent of the estimated battery direct cost in MY2012.

As explained above, the estimates in this table represent the direct manufacturing cost due to learning. The estimates do not include the effects of changes in indirect manufacturing costs over time, which the agencies account for through the use of short term and long term ICMs. For most technologies, the ICM is assumed to decrease in the later model years of the analysis as described in the previous section of this Chapter.

Table VII-12 Technology Cost Reduction Due to Learning

Technology	Tech Abbr.	Learning Factor Code	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Low Friction Lubricants - Level 1	LUB1	6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Engine Friction Reduction - Level 1	EFR1	6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Low Friction Lubricants and Engine Friction Reduction - Level 2	LUB2_EFR2	6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	CCPS	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cylinder Deactivation on SOHC	DEACS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	ICP	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	DCP	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Continuously Variable Valve Lift (CVVL)	CVVL	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cylinder Deactivation on DOHC	DEACD	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cylinder Deactivation on OHV	DEACO	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Variable Valve Actuation - CCP and DVVL on OHV	VVA	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Stoichiometric Gasoline Direct Injection (GDI) on OHV	SGDIO	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement - Turbo	TRBDS1_SD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement - Downsize	TRBDS1_SD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement -Turbo	TRBDS1_MD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement - Downsize	TRBDS1_MD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement - Turbo	TRBDS1_LD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement - Downsize	TRBDS1_LD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%

Technology	Tech	Learning Factor Code	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement - Turbo	TRBDS2_SD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement - Downsize	TRBDS2_SD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement - Turbo	TRBDS2_MD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement - Downsize	TRBDS2_MD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement - Turbo	TRBDS2_LD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement - Downsize	TRBDS2_LD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement - Turbo	CEGR1_SD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement - Downsize	CEGR1_SD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement - Turbo	CEGR1_MD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement - Downsize	CEGR1_MD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement - Turbo	CEGR1_LD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement - Downsize	CEGR1_LD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement - Turbo	CEGR2_SD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement - Downsize	CEGR2_SD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement - Turbo	CEGR2_MD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement - Downsize	CEGR2_MD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement - Turbo	CEGR2_LD_TB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%

Technology	Tech	Learning Factor Code	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement - Downsize	CEGR2_LD_DS	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Advanced Diesel - Small Displacement	ADSL_SD	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Advanced Diesel - Medium Displacement	ADSL_MD	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Advanced Diesel - Large Displacement	ADSL_LD	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
6-Speed Manual/Improved Internals	6MAN	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Improved Auto. Trans. Controls/Externals	IATC	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
6-Speed Trans with Improved Internals (Auto)	NAUTO	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
6-speed DCT	DCT	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
8-Speed Trans (Auto or DCT)	8SPD	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
High Efficiency Gearbox w/ dry sump (Auto or DCT)	HETRANS	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Shift Optimizer	SHFTOPT	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Electric Power Steering	EPS	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Improved Accessories - Level 1	IACC1	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	IACC2	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
12V Micro-Hybrid (Stop-Start)	MHEV	16	100%	100%	80%	64%	64%	62%	60%	58%	57%	55%	53%	52%	50%	49%
Integrated Starter Generator - Battery	ISG_B	24	100%	100%	80%	80%	64%	64%	62%	60%	58%	57%	55%	53%	52%	50%
Integrated Starter Generator - Non-Battery	ISG_NB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Strong Hybrid (Powersplit or 2-Mode) - Level 1 - Battery	SHEV1_B	24	100%	100%	80%	80%	64%	64%	62%	60%	58%	57%	55%	53%	52%	50%
Strong Hybrid (Powersplit or 2-Mode) - Level 1 - Non-Battery	SHEV1_NB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Strong Hybrid (P2 Parallel or 2-Mode) - Level 2 - Battery	SHEV2_B	24	100%	100%	80%	80%	64%	64%	62%	60%	58%	57%	55%	53%	52%	50%
Strong Hybrid (P2 Parallel or 2-Mode) - Level 2 - Non-Battery	SHEV2_NB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Plug-in Hybrid - 20 mi range - Battery	PHEV1_B	19	100%	100%	80%	80%	64%	64%	51%	51%	41%	41%	41%	41%	41%	33%
Plug-in Hybrid - 20 mi range - Non-Battery	PHEV1_NB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Plug-in Hybrid - 40 mi range - Battery	PHEV2_B	19	100%	100%	80%	80%	64%	64%	51%	51%	41%	41%	41%	41%	41%	33%
Plug-in Hybrid - 40 mi range - Non-Battery	PHEV2_NB	11	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%

Technology	Tech	Learning Factor Code	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Electric Vehicle (Early Adopter) - 75 mile range - Battery	EV1_B	19	100%	100%	80%	80%	64%	64%	51%	51%	41%	41%	41%	41%	41%	33%
Electric Vehicle (Early Adopter) - 75 mile range - Non-Battery	EV1_NB	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Electric Vehicle (Early Adopter) - 100 mile range - Battery	EV2_B	19	100%	100%	80%	80%	64%	64%	51%	51%	41%	41%	41%	41%	41%	33%
Electric Vehicle (Early Adopter) - 100 mile range - Non-Battery	EV2_NB	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Electric Vehicle (Early Adopter) - 150 mile range - Battery	1. EV3 _B	19	100%	100%	80%	80%	64%	64%	51%	51%	41%	41%	41%	41%	41%	33%
Electric Vehicle (Early Adopter) - 150 mile range - Non-Battery	EV3_NB	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Electric Vehicle (Broad Market) - 150 mile range - Battery	EV4_B	19	100%	100%	80%	80%	64%	64%	51%	51%	41%	41%	41%	41%	41%	33%
Electric Vehicle (Broad Market) - 150 mile range - Non-Battery	EV4_NB	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Charger-PHEV20	PHEV1_C	19	100%	100%	80%	80%	64%	64%	51%	51%	41%	41%	41%	41%	41%	33%
Charger-PHEV40	PHEV2_C	19	100%	100%	80%	80%	64%	64%	51%	51%	41%	41%	41%	41%	41%	33%
Charger-EV	EV_C	19	100%	100%	80%	80%	64%	64%	51%	51%	41%	41%	41%	41%	41%	33%
Charger Labor	CHRG_L	6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Mass Reduction - Level 1	MR1	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Mass Reduction - Level 2	MR2	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Mass Reduction - Level 3	MR3	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Mass Reduction - Level 4	MR4	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Mass Reduction - Level 5	MR5	21	100%	97%	94%	91%	89%	86%	83%	81%	78%	76%	74%	72%	71%	69%
Low Rolling Resistance Tires - Level 1	ROLL1	6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Low Rolling Resistance Tires - Level 2	ROLL2	25	100%	100%	100%	100%	100%	100%	100%	80%	80%	64%	62%	60%	58%	57%
Low Drag Brakes	LDB	6	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%
Secondary Axle Disconnect	SAX	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Aero Drag Reduction, Level 1	AERO1	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%
Aero Drag Reduction, Level 2	AERO2	12	100%	97%	94%	91%	89%	87%	85%	83%	82%	80%	78%	77%	75%	74%

Application of a Continuous Learning Curve to CAFE Technologies

The purpose of the schedules employed by NHTSA is to approximate a learning curve. An alternate approach would be to apply a learning curve directly to the current cost estimates. As noted above, in response to comments received during previous rulemakings, NHTSA agreed that a continuous curve, if implemented correctly, could potentially improve the accuracy of modeling cost-learning effects, and noted that we would investigate the applicability of this approach for future rulemakings. Following are the results of this analysis.

The basis for a continuous learning curve has been established in the literature. The method commonly mentioned in the literature estimates learning as a function of cumulative production. Essentially, each doubling of cumulative production results in a specified percentage reduction in costs. The specified reduction percentage is a function of the "progress rate." The progress rate represents the portion of costs that remain after each step of learning. The progress rate usually cited is 0.8, implying that each doubling of cumulative production results in a 20% reduction in costs[364].

According to Dutton and Thomas[365], the most common formulation of the progress function is the log-linear form:

$$y = ax^{-b}$$

Where:

y=input cost for the xth unit

x= cumulative number of units produced

a=input cost for the first unit

b= progress rate

Figure 1 portrays an example of cost decreases that occur over successive doublings of cumulative production under an assumed learning rate. The increments indicated on the x axis of

364 Dutton, John M, and Thomas, Annie, "Treating Progress Functions as a Managerial Opportunity", Academy of Management Review, 1984, Vol. 9, No. 2, pp.235-247

365 Ibid

Figure 1 represent successive instances of doubling of cumulative volume. The rate of cost decline is initially steep, but flattens out naturally over subsequent production increases. Doubling during the earlier years of a technologies life can occur relatively quickly once production is initiated in large portions of the fleet. Thus, for example, a single year's production could produce 3 or 4 instances of doubling. However, as cumulative volume grows, the rate of doubling decreases since annual increases in cumulative production are limited to one year's production level, while cumulative volume increases indefinitely. Successive doublings may require ever increasing multiples of years to occur.

Figure 2 illustrates the practical impact of cumulative learning over time using a hypothetical production schedule for a new technology. The increments indicated on the x axis of Figure 2 represent successive years in a technologies production life. In this example, successive doublings of cumulative production occur in the first few years as production is ramped up over the initial levels that occurred as the technology was introduced into the fleet, possibly in luxury or specialty vehicles. However, within a few years cumulative volume exceeds the stabilized annual production volume, and doubling becomes increasingly difficult to obtain. Both Figure 1 and Figure 2 are based on the same learning rate, but figure 2 reflects the natural limitation on increases in cumulative volume (and thus learning) that result from the finite nature of annual production levels.

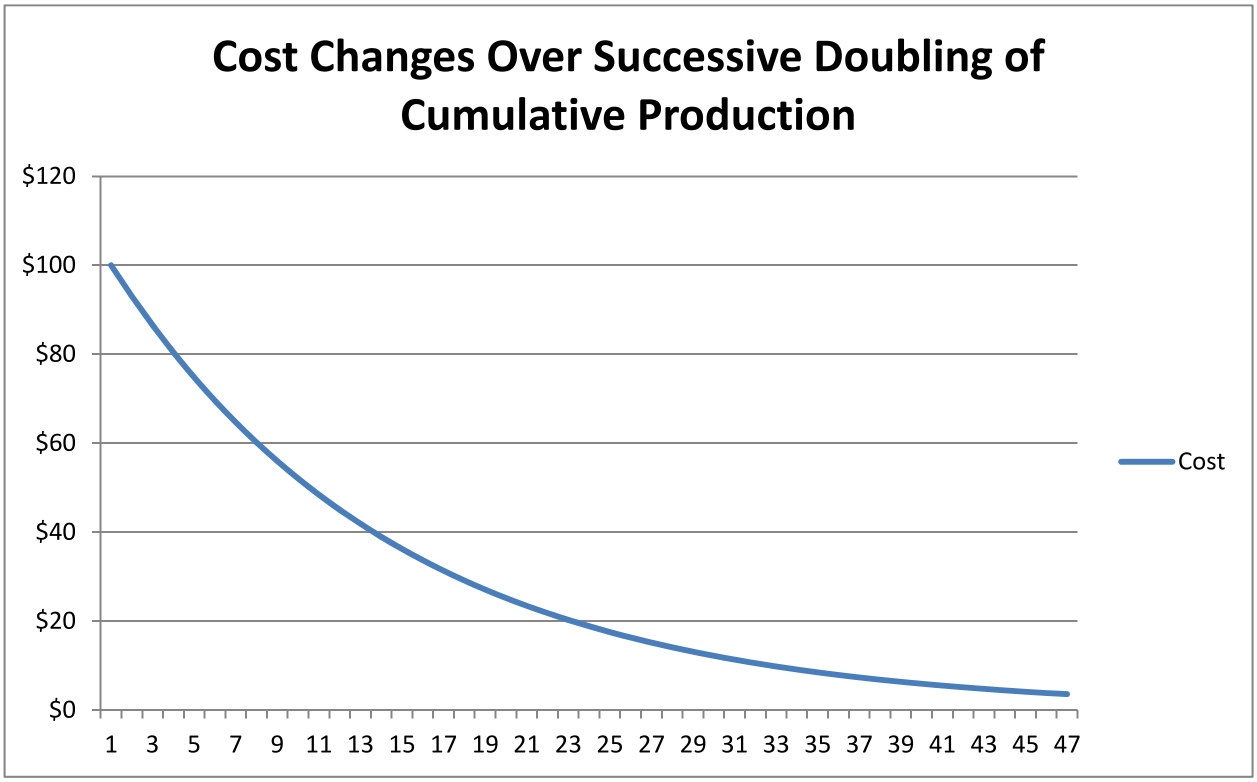
Figure 1 also illustrates a practical limitation to the application of learning curves. If followed to its natural conclusion, the indefinite application of learning curves, even at relatively low rates, implies that technology costs will eventually approach zero, an infeasible result for virtually all automotive technologies. This in turn implies that there is likely some point at which learning will basically be exhausted and will cease to have an observable impact on costs – a threshold at which further application of learning would no longer be appropriate. Very few of the technologies used to improve CAFE are expected to last for more than 20 years, so practically speaking, the application of learning within the context of CAFE analyses is unlikely to produce such a result. While some breakthrough technologies have experienced significant cost reductions to levels that are a fraction of their original cost, it is likely that for most motor vehicle technologies, real reductions in cost began to be less feasible as they drop beyond a certain level. Baloff[366] examined automotive assembly labor costs for 4 different start-up scenarios during the late 1960s and found that in 3 of the 4 scenarios, assembly costs reached a steady state condition where no further learning occurred when cumulative output reached 40 percent of the total annual production. Assembly labor is only one aspect of total production

[366] Baloff, Nicholas, Extension of the Learning Curve – Some Empirical Results, Operational Research Quarterly (1970-0971), Vol 22, No. 4 (Dec., 1971, pp.32-43.

costs – production techniques can be refined, material prices can change as cheaper sources are found, etc., but it seems likely that a practical floor exists for most if not all aspects of production. The National Research Council of the National Academy of Sciences warns against applying traditional learning curves to mature technologies for this same reason.[367]

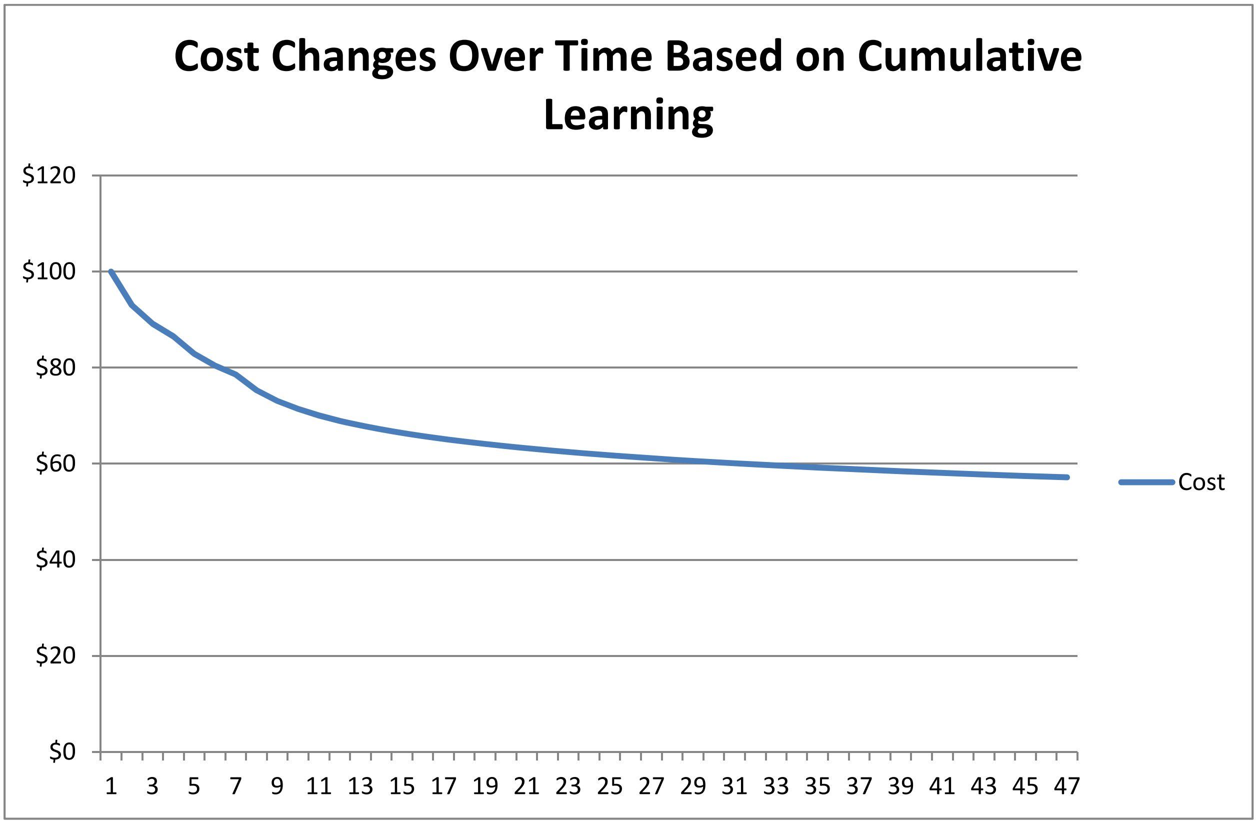
Neither the cumulative production method, nor the proxy learning schedules currently used by NHTSA and EPA recognize a steady state cost level, but as can be seen in Figure 2, they do eventually reach a point where costs decline at such a slow rate that the impact of further production is relatively insignificant. The agencies do not currently have data to determine whether the timing of real world steady state cost trends is consistent with the trends that result from our learning curve estimates.

Figure 1



[367] National Research Council of the National Academies, Committee on the Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy, *Assessment for Fuel Economy Technologies for Light-Duty Vehicles*, Washington D.C.: The National Academies Press, June 2011, p. 25.

Figure 2



As noted in the previous discussion, over the past several rulemakings NHTSA has attempted to simulate the learning process using a variety of methods and assumptions. NHTSA has not directly employed a cumulative volume algorithm for this purpose because to do so would require specific assumptions regarding the appropriate progress ratio for each technology, as well as information regarding the cumulative volume of each technology concurrent with its cost basis. The progress rate most often cited in the literature, 80%, is a general average derived from Dutton and Thomas' 1984 compilation of over 100 empirical studies of progress curves in a large variety of industries between 1920 and 1980[368]. However, as those authors are careful to point out, the average progress rate across all of these studies has not been found to be a good predictor for specific industries. Baloff too warns against use of this simple average, referring to it as "the infamous "80 percent" curve"[369].

[368] Dutton op.cit.
[369] Baloff op. cit, p.41

Table VII-12 summarizes the progress rates, along with the implied cost reduction rates for a variety of technologies gathered from more recent studies. For these technologies, a range of progress rates are indicated, averaging closer to 90% than 80%. However, none of these technologies are produced within the light vehicle industry or in volumes similar to those produced in that industry (although PV inverters require electronics technology similar to that used in some automotive applications).

Table VII-13
Progress Rates and Learning Rates for Selected Technologies

Technology	Progress Rate	Learning Rate
Solar Power[370]	0.77	0.23
Wind Power[371]	0.87	0.13
Ethanol[372]	0.85	0.15
PV Inverters[373]	0.94	0.06
Solar Thermal[374]	0.97	0.03
Flue Gas DeSOx[375]	0.89	0.11
Flue Gas DeNOx[376]	0.88	0.12

To properly estimate the impact of learning under the cumulative volume approach, five things are required:

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370 The Carbon Productivity Challenge: Curbing Climate Change and Sustaining Economic Growth, McKinsey Climate Change Special Initiative, McKinsey Global Institute, June 2008 (quoting from UC Berkeley Energy Resource Group, Navigant Consulting). *Available at* http://www.mckinsey.com/insights/mgi/research/natural_resources/the_carbon_productivity_challenge. Docket No. NHTSA-2010-0131.
371 Ibid
372 Ibid
373 Ibid
374 Ibid
375 Technology Innovation for Climate Mitigation and its Relation to Government Policies, Edward S. Rubin, Carnegie Mellon University, Presentation to the UNFCCC Workshop on Climate Change Mitigation, Bonn, Germany, June 19, 2004. *Available at* http://www.cmu.edu/epp/iecm/rubin/PDF%20files/2004/2004ti%20Rubin,%20UNFCCC%20Workshop%20Jun%20(c).pdf. Docket No. NHTSA-2010-0131.
376 Ibid

1) A progress rate representing the remaining portion of the price after each doubling of cumulative volume
2) The direct cost of the technology at time n1
3) An estimate of the cumulative production volume for the specific technology at time n1
4) The direct cost of the technology at time n2
5) A history of the production of the technology between time n1 and n2

In an effort to explore the potential impacts of adopting a cumulative production curve (rather than simulating one with proxy estimates contained in schedules), NHTSA has examined the cost and production changes for several light vehicle technologies. NHTSA routinely performs evaluations of the costs and benefits of safety standards that were previously promulgated. To estimate costs, the agency conducts a tear down study of the technologies used to meet the standards. In some cases, the agency has performed multiple evaluations over a span of years. For example, a tear down study may be performed to support the agency's initial estimates of costs that will result from the regulation, and again 5 years later to evaluate the impacts of the regulation after it has been in effect. These data, together with actual production data, supply 4 of the 5 items required to develop a learning curve for the technology. Combining them with the methods previously discussed, we were able to derive a progress rate specific to each technology.

The technologies that were examined were air bags, antilock braking systems, 3-point manual outboard safety belts with retractors, dual master brake cylinders, and adjustable head restraints. The derived progress rates for each technology are summarized in Table VII-14:

Table VII-14
Progress Rates and Learning Rates for Automotive Safety Technologies

Technology	Progress Rate	Learning Rate
Driver Air Bags	0.93	0.07
Antilock Braking Systems	0.90	0.10
Manual Lap/Shoulder Belts	0.96	0.04
Adjustable Head Restraints	0.91	0.09
Dual Master Brake Cylinders	0.95	0.05

The results range from 0.90 for antilock brakes to 0.96 for 3-point belts with retractors. The average progress rate for these 5 technologies is 0.93. This limited sample of these safety related automotive technologies thus indicates a progress rate for technologies used in passenger vehicles that is roughly .10-.15 higher than the all-industry average noted in Dutton and Thomas and others.

NHTSA does not have similar data for the specific technologies that will be used to meet CAFE standards. Specifically, we do not have cost teardown information over at least 2 time periods for these technologies, and in most cases we do not have the cumulative production volume associated with the cost estimates that are used in the Volpe model. However, we were able to determine the cumulative volume production for two specific technologies - turbochargers (TRBDS) and electronic power steering (EPS). These data were gathered from Ward's Automotive Reports annuals, which specify production levels for some selected technologies, and from AA1CAR.com. In cases where data was not yet available though the year of the cost estimate, a conservative estimate based on the most recent years production or projections derived from the Volpe model was added to the total to represent the few missing years. We thus had a current cost estimate and the cumulative production that was concurrent with that cost estimate. In addition, we had our own projections for future production of these technologies through 2025, and our own calculated price for that technology through 2025 reflecting our current learning schedules. Using these data, we estimated the implied progress ratio that was consistent with the learning schedules we apply in our models that would produce the same cost estimate in MY 2025 as is predicted in our models. The resulting progress rates were 0.92 for turbochargers and .90 for electronic power steering. We note that, unlike the 5 safety technologies discussed above, these are not actual measurements of the learning curve progress rate for these technologies, rather they are measurements of the implied progress rate that results from the learning schedules we are applying. The implication is that we are applying learning schedules for these two technologies that would be consistent with progress rates of roughly 0.92 and 0.90[377]. These are somewhat lower than, but reasonably consistent with, the average measured progress rates for the 5 safety technologies.

As a final step in this analysis, NHTSA ran a comparison of the price trends that result from application of the current learning schedules to the trends that would result from applying the cumulative learning procedure assuming the average progress ratio of 0.93 derived from the 5 vehicle safety technologies. The results are illustrated in Figures 3 and 4 below. In each case the technologies were assigned a token cost of $100 to facilitate examination of the results. In the

[377] Note that these progress rates were derived based on the curve that matched the Volpe model predicted costs in MY 2025. They were not necessarily best fit curves over the entire time span. Based on an examination of the curves in figures 3 and 4, we believe a best fit curve would produce a nearly identical progress ratio for the turbo, and would produce a slightly higher progress rate for electronic power steering.

case of turbos, the cumulative production method produces cost estimates that range from near zero in the early years to about 4% more than the current learning schedule over by MY2025. In the case of electronic power steering, the cumulative production method produces cost estimates that exceed the current learning schedule by near zero in the early years but that steadily rise to 7% by MY 2025.

This analysis indicates that the learning schedules used in the NPRM for these technologies provides cost estimates that are within 4-7% of cost estimates derived using a cumulative production basis, with smaller differences in earlier years. However, a number of caveats are required. The most obvious is that it is not certain that the average progress rate derived from the 5 safety technologies is actually representative of the progress rate that should be applicable to the roughly 40 different fuel economy technologies that will be incorporated into vehicle designs for CAFE. Although the range of progress rates for these safety technologies, 90-96%, is relatively narrow, if real data were available to measure the progress rate for all 40 CAFE technologies, it is likely that the range may be wider. It is uncertain how this would directionally affect the average.

Figure 3
TRBDS Cost Trend Under Current Learning Schedule and Cumulative Learning Basis

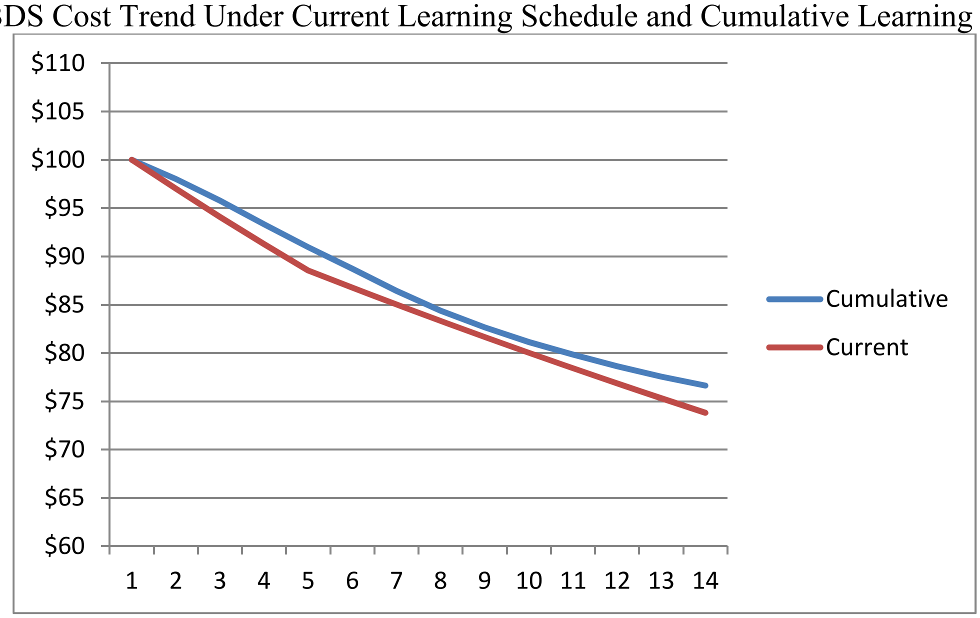
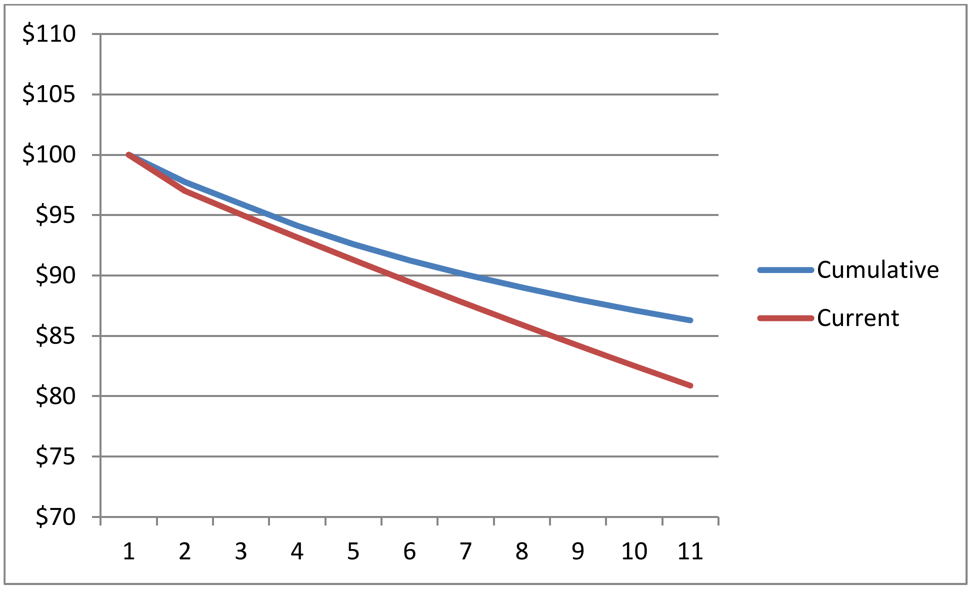


Figure 4

EPS Cost Trend Under Current Learning Schedule and Cumulative Learning Basis



A second caveat is that calculations of derived progress rates are highly sensitive to estimates of cumulative production. Empirical observations from this exercise indicate that each doubling or halving of the assumed initial cumulative production can shift calculated progress rates by 0.01-0.02 or more, depending on the historical sales profile. It is thus important that initial cost estimates properly match up with the correct assessment of the cumulative production volumes that coincide with those costs, and for most technologies, this data is elusive. Although the cumulative production method has theoretical advantages over using a series of learning schedules based on expert judgment, as a practical matter, an inability to obtain this data could lead to the adoption of assumed or roughly estimated levels of cumulative production. This might result in replacing one set of judgments with another, and it is unclear which would have the greater margin of error.

We note that the cost estimates provided in the FEV report represent the cost to annually produce mature technologies in a volume of 450,000 units. Mature technologies as defined in that study have mature product designs, high production volumes, significant marketplace competition, and established manufacturing processes. Presumably, in order for a technology to be considered mature it would have already been produced for a number of years so that production and assembly techniques had been refined to a level of efficiency where it could be considered a mature technology. For each of the 2 technologies examined above, cumulative production volume through 2009 was over 4 million units, but these technologies are projected to grow at noticeably different rates in response to CAFE standards after 2009. It is likely that cumulative production for the 40+ technologies estimated in this study will have a wide range of cumulative volumes for MY 2012 (the base year for most technologies in the FEV report) , which could make application of a single assumed cumulative volume level problematic.

In summary, to actually adopt a cumulative production based learning methodology that is confidently more accurate than current methods, NHTSA would have to develop at least 2 historical cost estimates for each technology, a cumulative production volume estimate coinciding with the initial cost estimate, and a schedule of cumulative production between the cost estimates. With these data we could derive an accurate progress rate to apply to each technology going forward using the projected increase in cumulative production volume that is predicted to result from CAFE standards. This initial analysis of only two CAFE technologies and five safety technologies indicates that adopting a cumulative production basis for learning applications could produce cost estimates that are within 4-7% of those used in the NPRM by 2025, with less variation in earlier years. However, this analysis is based on a very small sample of technologies and the data required to more precisely evaluate this issue are currently unavailable. Further, these data may not be obtainable without an extensive research effort, if at all.

Overall, NHTSA acknowledges that there is uncertainty regarding the rate of learning that will occur for specific CAFE technologies. The schedules that are applied in this analysis represent our best effort to approximate the learning history that would typically occur over the course of a technology's lifetime, with NHTSA's best judgment as to the position of each technology along the learning curve. The agency requests comments regarding the learning rates currently used in this analysis, the application of cumulative learning curves to technologies, and any data sources that might assist in developing learning rates for specific CAFE technologies.

Potential opportunity costs of improved fuel economy

An important concern is whether achieving the fuel economy improvements required by alternative CAFE standards would require manufacturers to compromise the performance, carrying capacity, safety, or comfort of their vehicles. If it did so, the resulting sacrifice in the value of these attributes to vehicle buyers would represent an additional cost of achieving the required improvements in fuel economy, and thus of manufacturers' compliance with stricter CAFE standards. While exact dollar values of these attributes to buyers are extremely difficult to infer from vehicle purchase prices, it is nevertheless clear that changes in these attributes can affect the utility that vehicles provide to their owners, and thus their value to potential buyers.

The agency has approached this potential problem by developing cost estimates for fuel economy-improving technologies that include any additional manufacturing costs that would be necessary to maintain the performance, comfort, capacity, or safety of any vehicle to which those technologies are applied. Theoretically, opportunity costs could also include any foregone opportunities to enhance these products for consumers. However, estimating values for foregone opportunities is an even tougher task. So, the agency followed the precedent established by the National Academy of Sciences (NAS) in its 2002 analysis of the costs and benefits of improving fuel economy by raising CAFE standards.[378] The NAS study estimated "constant performance and utility" costs for fuel economy technologies, and the agency has used these as the basis for developing the technology costs it employed in analyzing manufacturer's costs for complying with alternative standards.

NHTSA fully acknowledges the difficulty of estimating technology costs that include costs for the accompanying changes in vehicle design that are necessary to maintain performance, capacity, and utility. This is particularly difficult for electric vehicles and the potential effect that reduced driving distance could have on buying patterns and sales. This will be discussed further in Chapter VIII in the section on "The Value to Consumers of Changes in Driving Range."

Financial Impacts of Raising CAFE Standards

Market forces are already requiring manufacturers to improve the fuel economy of their vehicles, as shown both by changes in product plans reported to NHTSA, and by automaker public announcements. The various compliance flexibility mechanisms permitted by EISA, including flexible and alternative fuel vehicles, banking, averaging, and trading of fuel economy credits will also reduce compliance costs to some degree. By statute, NHTSA is not permitted to consider the benefits of flexibility mechanisms in setting fuel economy standards.

[378] National Academy of Sciences, ***Costs and Effectiveness of Increasing Corporate Average Fuel Economy Standards***, 2002.

President Obama announced plans for these rules on July 29, 2011 and NHTSA and EPA issued a Supplemental Notice of Intent (NOI) outlining the agencies' plans for proposing the MY 2017-2025 standards and program.[379]

This proposal reflects an agreement between EPA, NHTSA, CARB, 13 automobile companies, and general support from the United Auto Workers on desirable and achievable fuel economy standards. We believe that this agreement reflects the view of the industry that given current economic conditions that the standards finalized here are economically practicable. On the other hand, the agency is mindful that CAFE standards could affect the relative competitiveness of different vehicle manufacturers.

Given the foregoing, therefore, the agency has decided that in this exceptional situation, economic practicability must be determined based on whether the expenditures needed to achieve compliance with the final MY 2017-2021 and augural MY 2022-2025 standards are "within the financial capability of the industry, but not so stringent as to threaten substantial economic hardship for the industry."

One of the primary ways in which the agency seeks to ensure that its standards are within the financial capability of the industry is to attempt to ensure that manufacturers have sufficient lead time to modify their manufacturing plans to comply with the final standards in the model years covered by them. Employing appropriate assumptions about lead time in our analysis helps to avoid applying technologies before they are ready to be applied, or when their benefits are insufficient to justify their costs. It also helps avoid basing standards on the assumption that technologies could be applied more rapidly than practically achievable by manufacturers. NHTSA considers these matters in its analysis of issues including refresh and redesign schedules, phase-in caps, and learning rates.

The agency has neither the capability to predict the capital investment needs of the automobile industry to install fuel economy technologies, nor the capability to determine the level of capital investments available to specific manufacturers in the future.

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[379] 76 FR 48758 (August 9, 2011).

Sales and Employment

Projected Sales of MY 2017-2025 Passenger Cars and Light Trucks

All projections of total passenger car and light truck sales for future years in the case of the MY 2008 baseline fleet were obtained using the Annual Energy Outlook 2011 (AEO 2011) version of Energy Information Administration's (EIA's) National Energy Modeling System (NEMS), as described in the agencies' joint Technical Support Document (TSD) supporting this rule. AEO is a standard government reference for projections of energy production and consumption in different sectors of the U.S. economy. In using these forecasts, NHTSA made the simplifying assumption that the NEMS-based projected sales of cars and light trucks during each calendar year from 2017 through 2025 represented the likely production volumes for the corresponding model year. The agency did not attempt to establish the exact correspondence between projected sales during individual calendar years and production volumes for specific model years; instead, the analysis is done on a model year basis.

As also discussed in the TSD, in the case of the MY 2008 baseline fleet, NHTSA and EPA jointly made use of a custom long-range forecast purchased from CSM Worldwide. This forecast addresses trends such as changes in individual manufacturers' shares of the U.S. light vehicle market and changes in the prominence of different market segments (*e.g.*, crossover vehicles). Although not yet ready for use in this final rulemaking, NHTSA is developing a vehicle choice model to better analyze sales by manufacturer and sales of individual market segments.[380]

The final market forecast applied by NHTSA reflects growth of the overall fleet to match the NEMS-based forecast of the overall size of the fleet, as well as normalization of the production volumes of individual vehicle models in consideration of (a) NEMS-based estimates of the sizes of the passenger car and light truck fleets, (b) CSM-based estimates of individual manufacturers' market shares, and (c) CSM-based estimates of the prominence of specific market segments. These adjustments were conducted through an iterative process also described in the TSD, and result in the production (for the U.S. market) volumes shown below.

[380] Further details regarding the planned vehicle choice model are discussed below, see section titled "How does NHTSA plan to address this issue in the mid-term review and in future rulemakings?"

Sales projections of future vehicles derived from the MY 2010 baseline fleet were developed analogously to those of the MY 2008 baseline fleet with the exception that NHTSA and EPA jointly made use of J.D. Power and Associates forecasts of trends such as changes in individual manufacturer's shares of the U.S. light vehicle market and changes in the prominence of different market segments. The final market forecast applied in the analysis of future vehicle sales derived from the MY 2010 baseline is consistent with the approach described above for the MY 2008 baseline; however, NHTSA utilized the Annual Energy Outlook 2012 Early Release (AEO 2012) version of Energy Information Administration's (EIA's) National Energy Modeling System (NEMS), as described in the agencies' joint Technical Support Document (TSD) supporting this rule.

Sales projections shown in Table VII-15 must be noted with the caveat that in the absence of a credible consumer choice model that incorporates a feedback loop between rule-driven vehicle price increases and consumer valuations of fuel economy, that an implicit assumption of zero price elasticity of demand with respect to vehicles for the program cost analysis. Should a peer-reviewed consumer choice model of vehicle sales be developed, it is likely that such a model will incorporate a feedback loop into the sales projections of the main analysis such that the price elasticity of demand will change to a nonzero value.

Table VII-15a
Sales Projections – Passenger Cars

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	634 - 1,035	617 - 1,051	620 - 1,072	620 - 1,034	623 - 1,058	626 - 1,049	630 - 1,041	634 - 1,141	639 - 1,182
BMW	2010 2008	320,634 - 313,022	318,821 - 322,939	327,091 - 346,075	329,304 - 357,942	335,753 - 359,098	341,613 - 360,034	346,903 - 360,561	357,948 - 388,193	363,380 - 405,256
Daimler	2010 2008	252,820 - 284,847	240,222 - 276,409	245,807 - 281,425	245,888 - 290,989	249,219 - 300,378	251,461 - 304,738	253,688 - 312,507	258,742 - 332,337	261,242 - 340,719
Fiat	2010 2008	730,695 - 429,308	737,850 - 408,386	771,092 - 402,389	788,181 - 425,814	806,958 - 431,743	830,509 - 435,220	852,268 - 435,071	879,629 - 437,157	901,736 - 447,647
Ford	2010 2008	1,348,543 - 1,299,899	1,347,544 - 1,311,467	1,341,628 - 1,332,039	1,347,596 - 1,378,789	1,359,990 - 1,401,617	1,377,947 - 1,415,221	1,394,907 - 1,474,797	1,418,568 - 1,503,670	1,441,350 - 1,540,109
Geely	2010 2008	60,422 - 88,234	57,655 - 89,394	60,338 - 91,575	60,040 - 93,003	61,433 - 92,726	62,399 - 92,512	63,076 - 96,840	65,157 - 99,181	65,883 - 101,107
General Motors	2010 2008	1,652,946 - 1,516,867	1,616,449 - 1,539,537	1,611,415 - 1,563,210	1,612,666 - 1,610,404	1,624,561 - 1,628,896	1,638,066 - 1,640,878	1,652,324 - 1,667,884	1,676,558 - 1,699,093	1,696,474 - 1,737,321
Honda	2010 2008	1,122,558 - 1,154,600	1,139,856 - 1,138,087	1,147,055 - 1,144,639	1,167,627 - 1,163,666	1,187,756 - 1,198,880	1,212,900 - 1,237,504	1,238,278 - 1,265,564	1,267,745 - 1,307,851	1,295,234 - 1,340,321
Hyundai	2010 2008	865,069 - 592,027	849,727 - 578,373	857,497 - 582,971	861,062 - 598,283	873,625 - 613,355	887,004 - 627,964	899,936 - 634,308	918,938 - 657,710	935,619 - 677,250
Kia	2010 2008	345,314 - 322,044	339,180 - 312,370	328,872 - 314,879	327,694 - 323,676	330,416 - 331,319	335,846 - 339,102	338,791 - 342,746	346,828 - 351,882	350,765 - 362,783
Lotus	2010 2008	374 - 240	364 - 243	365 - 250	365 - 266	367 - 278	368 - 290	371 - 299	374 - 308	377 - 316
Mazda	2010 2008	254,270 - 234,781	249,048 - 242,561	247,203 - 246,902	248,350 - 247,929	249,288 - 249,694	252,522 - 253,955	254,751 - 267,692	259,488 - 272,237	262,732 - 278,952
Mitsubishi	2010 2008	61,058 - 77,014	58,152 - 75,114	60,387 - 75,168	60,619 - 76,241	61,785 - 77,011	63,390 - 78,382	63,937 - 78,940	67,026 - 82,118	67,925 - 84,829
Nissan	2010 2008	889,039 - 870,797	867,771 - 849,678	873,076 - 854,400	874,098 - 882,791	879,450 - 912,629	884,816 - 937,447	893,622 - 954,340	907,823 - 982,771	919,920 - 1,014,775
Porsche	2010 2008	18,430 - 35,093	18,138 - 35,444	17,255 - 36,116	17,065 - 35,963	17,289 - 36,475	17,216 - 36,607	17,292 - 36,993	17,517 - 39,504	17,609 - 40,696

Spyker	2010 2008	-- 20,024	-- 20,007	-- 20,144	-- 21,069	-- 21,294	-- 21,709	-- 22,410	-- 22,800	-- 23,130
Subaru	2010 2008	209,137 - 224,112	205,550 - 216,598	205,868 - 217,095	205,749 - 223,466	206,863 - 230,780	209,828 - 238,613	211,621 - 241,612	215,567 - 248,283	218,870 - 256,970
Suzuki	2010 2008	43,253 - 90,708	42,515 - 89,932	43,399 - 90,568	44,081 - 93,548	44,765 - 95,725	45,769 - 97,599	46,590 - 99,263	47,824 - 100,447	48,710 - 103,154
Tata	2010 2008	28,012 - 55,881	27,188 - 56,222	28,194 - 57,267	28,430 - 58,182	28,977 - 58,677	29,416 - 59,349	29,898 - 60,639	30,546 - 63,728	30,949 - 65,418
Tesla	2010 2008	-- 27,986	-- 28,435	-- 28,990	-- 27,965	-- 28,623	-- 28,369	-- 28,150	-- 30,862	-- 31,974
Toyota	2010 2008	1,528,208 - 1,849,196	1,501,492 - 1,834,181	1,509,270 - 1,836,306	1,515,051 - 1,883,734	1,530,699 - 1,903,706	1,548,354 - 1,986,077	1,567,676 - 2,036,992	1,598,715 - 2,080,528	1,622,242 - 2,108,053
Volkswagen	2010 2008	481,894 - 551,638	470,826 - 540,036	463,329 - 537,114	459,868 - 554,822	460,777 - 585,607	465,011 - 593,314	467,170 - 596,749	475,903 - 605,336	479,423 - 630,163
Total/Average	2010 2008	10,213,312 - 10,039,354	10,088,966 - 9,966,465	10,139,761 - 10,060,594	10,194,353 - 10,349,575	10,310,594 - 10,559,569	10,455,061 - 10,785,934	10,593,727 - 11,015,396	10,811,530 - 11,307,137	10,981,082 - 11,592,126

Table VII-15b
Sales Projections – Light Trucks

Manufacturer	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Aston Martin	2010 2008	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --
BMW	2010 2008	106,150 - 138,053	104,625 - 131,942	105,104 - 131,373	101,805 - 128,339	101,238 - 128,724	100,345 - 128,899	99,084 - 127,521	101,174 - 146,525	101,013 - 145,409
Daimler	2010 2008	99,125 - 86,913	108,510 - 83,651	108,294 - 88,188	108,598 - 92,919	110,235 - 99,449	112,133 - 100,935	113,550 - 105,315	116,867 - 107,084	119,090 - 101,067
Fiat	2010 2008	774,065 - 405,833	743,375 - 383,710	749,206 - 362,541	740,640 - 357,098	733,257 - 344,942	735,937 - 359,099	731,269 - 357,102	722,213 - 341,263	726,403 - 328,252
Ford	2010 2008	1,035,400 - 763,549	1,023,955 - 748,829	1,016,328 - 717,773	995,702 - 717,037	990,243 - 714,181	990,827 - 714,266	985,782 - 700,005	991,767 - 688,854	997,694 - 684,476
Geely	2010 2008	35,087 - 41,887	32,438 - 42,187	33,299 - 43,125	32,149 - 42,615	31,977 - 41,768	31,598 - 41,686	31,007 - 42,031	31,796 - 42,461	31,528 - 42,588
General Motors	2010 2008	1,213,192 - 1,308,099	1,201,479 - 1,372,894	1,217,167 - 1,435,327	1,211,435 - 1,465,333	1,218,265 - 1,465,400	1,226,184 - 1,445,331	1,232,502 - 1,435,430	1,244,178 - 1,431,308	1,261,546 - 1,460,623
Honda	2010 2008	536,998 - 596,481	525,327 - 544,619	527,814 - 527,535	517,268 - 525,089	512,800 - 535,916	515,656 - 539,235	509,628 - 536,898	505,534 - 536,994	504,020 - 557,697
Hyundai	2010 2008	131,912 - 152,885	127,289 - 151,461	122,193 - 155,642	118,265 - 154,173	117,565 - 156,466	116,208 - 157,493	115,339 - 161,189	116,430 - 166,092	117,662 - 168,136
Kia	2010 2008	43,374 - 98,702	43,209 - 98,280	41,648 - 100,679	40,270 - 96,535	39,205 - 95,432	38,857 - 94,694	38,203 - 95,688	38,034 - 96,119	37,957 - 97,653
Lotus	2010 2008	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --
Mazda	2010 2008	59,862 - 70,547	59,114 - 77,485	55,108 - 77,542	53,334 - 80,303	52,946 - 84,273	52,752 - 87,502	52,158 - 91,184	52,998 - 90,348	53,183 - 89,220
Mitsubishi	2010 2008	13,701 - 25,717	13,840 - 24,857	14,276 - 24,112	14,262 - 24,054	14,307 - 24,149	14,778 - 24,106	14,824 - 24,209	15,229 - 24,612	15,464 - 24,863
Nissan	2010 2008	305,943 - 444,938	306,537 - 412,383	309,179 - 398,559	304,196 - 397,869	303,616 - 408,029	304,381 - 411,883	304,703 - 417,121	308,510 - 422,217	312,005 - 426,454
Porsche	2010 2008	20,105 - 13,233	19,647 - 12,001	19,573 - 11,469	18,851 - 11,141	18,863 - 11,242	18,598 - 11,385	18,562 - 11,370	18,861 - 11,409	19,091 - 11,219

Spyker	2010 2008	-- 2,871	-- 3,596	-- 3,826	-- 3,509	-- 3,560	-- 3,461	-- 3,435	-- 3,426	-- 3,475
Subaru	2010 2008	96,938 - 78,242	94,441 - 75,152	92,177 - 72,832	90,751 - 72,458	91,673 - 72,773	91,940 - 72,736	92,337 - 73,022	94,300 - 74,142	96,326 - 74,722
Suzuki	2010 2008	3,399 - 22,109	3,347 - 21,385	3,690 - 20,692	3,676 - 20,675	3,760 - 20,767	3,879 - 20,734	3,939 - 20,803	4,085 - 21,162	4,173 - 21,374
Tata	2010 2008	54,033 - 57,579	53,423 - 56,606	52,682 - 57,854	51,461 - 56,213	50,984 - 58,153	50,767 - 58,590	50,280 - 58,865	50,340 - 57,981	50,369 - 56,805
Tesla	2010 2008	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --	-- --
Toyota	2010 2008	966,417 - 1,330,511	955,281 - 1,223,415	951,691 - 1,142,104	932,267 - 1,154,304	927,227 - 1,215,539	925,277 - 1,235,052	918,749 - 1,224,980	918,479 - 1,208,013	921,183 - 1,210,016
Volkswagen	2010 2008	103,088 - 128,819	100,596 - 145,491	102,910 - 146,891	100,916 - 146,700	101,344 - 148,734	102,022 - 146,750	101,558 - 153,927	104,673 - 156,939	105,009 - 154,284
Total/Average	2010 2008	5,598,788 - 5,766,967	5,516,434 - 5,609,945	5,522,339 - 5,518,064	5,435,847 - 5,546,364	5,419,506 - 5,629,497	5,432,139 - 5,653,839	5,413,473 - 5,640,093	5,435,470 - 5,626,950	5,473,718 - 5,658,333

The Impact of Higher Prices on Sales and Employment

The effect of this rule on sales of new vehicles depends largely on how potential buyers evaluate and respond to its effects on vehicle prices and fuel economy. The rule will make new cars and light trucks more expensive, as manufacturers attempt to recover their costs for complying with the rule by raising vehicle prices. At the same time, the rule will require manufacturers to improve the fuel economy of many of their models, which will lower the operating costs of those models. While the initial purchase price of those vehicles will increase, the overall cost of owning them -- including their operating costs -- will decrease, because their fuel consumption will decline significantly. The net effect on sales will depend on the extent to which consumers are willing to pay for higher fuel economy and the resulting savings in operating costs, versus their sensitivity to changes in vehicles' initial purchase prices, and is thus challenging to evaluate.

The agency anticipates that consumers will place some value on improved fuel economy, both because it reduces the operating cost of the vehicles, and because recently promulgated EPA and DOT regulations require vehicles sold during 2017 through 2025 to display labels that more clearly communicate to potential buyers the fuel savings, economic, and environmental benefits of owning more fuel-efficient vehicles. We recognize that the magnitude of this effect cannot be predicted at this time, and that how consumers value fuel economy is a subject of ongoing debate. We also expect that consumers may consider other factors besides direct purchase price increases that affect the costs they pay for new vehicles, and have included these factors in the analysis.

There is a broad consensus in the economic literature that the price elasticity of demand for automobiles is approximately –1.0,[381, 382, 383, 384] meaning that every one percent increase in the

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[1]Kleit, A.N. (1990). "The Effect of Annual Changes in Automobile Fuel Economy Standards," *Journal of Regulatory Economics*, vol. 2, pp 151-172. Available at http://www.springerlink.com/content/m04787480k056018/ (last accessed August 1, 2012) or Docket No. NHTSA-2010-0131

[382]Bordley, R. (1994). "An Overlapping Choice Set Model of Automotive Price Elasticities," *Transportation Research B*, vol 28B, no 6, pp 401-408. Available at http://www.sciencedirect.com/science/article/B6V99-466M3VD-1/2/3ecfe61bac45f1afb8d9b370330e3f0c (last accessed August 1, 2012)

[383] McCarthy, P.S. (1996). "Market Price and Income Elasticities of New Vehicle Demands," *The Review of Economics and Statistics*, vol. LXXVII, no. 3, pp. 543-547. Available at http://econpapers.repec.org/article/tprrestat/v_3a78_3ay_3a1996_3ai_3a3_3ap_3a543-47.htm (last accessed August 1, 2012) or Docket No. NHTSA-2010-0131

[384] This elasticity is generally considered to be a short-run elasticity, reflecting the immediate impacts of a price change on vehicle sales. For a durable good such as an auto, the elasticity may be smaller in the long run: though people may be able to change the timing of their purchase when price changes in the short run, they must eventually make the investment. Using a smaller elasticity would reduce the magnitude of the estimates presented here for vehicle sales, but it would not change the direction. A short-run elasticity is more valid for initial responses to changes in price, but, over time, a long-run elasticity may better reflect behavior; thus, the results presented for the initial years of the program may be more appropriate for modeling with the short-run elasticity than the later years of the program. A search of the literature has not found studies more recent than the 1970s that specifically investigate

price of the vehicle would reduce sales by one percent (assuming no change in fuel economy, quality, or other attributes of vehicles). NHTSA typically assumes that manufacturers will be able to pass all of their costs to improve fuel economy on to consumers in the form of higher sales prices for models offering higher fuel economy. The subsequent discussion of consumer welfare, however, suggests that by itself, a net decrease in overall operating costs may not necessarily produce a net increase in sales. Many consumers are more sensitive to vehicles' initial purchase prices than to their subsequent operating costs, and thus may not be willing to purchase vehicles with higher fuel economy even when it appears that doing so would reduce their overall costs to own a vehicle.

There is considerable uncertainty in the economics literature about the extent to which consumers value fuel savings from increased fuel economy, and there is still more uncertainty about possible changes in consumer behavior over time (especially with the likelihood of consumer learning) and the extent to which this final rule could affect consumer behavior. In addition, consumers' valuation of fuel economy improvements depends upon the price of gasoline, which has recently been very volatile. On balance, the effect of this final rule on vehicle sales will depend upon whether the value that potential buyers place on the increased fuel economy that this rule requires is greater or less than the increase in vehicle prices that results from the rule, as well as on how automakers interpret buyers' likely responses to higher prices and increased fuel economy. Additional data would enhance the accuracy of predictions on these issues. In addition, it would be helpful to assess important emerging trends, such as the degree that longer financing terms affect consumers' decisionmaking as they weigh operating costs versus upfront costs, and the degree to which extreme and continued volatility itself in gas prices affects assumptions about likely returns on upfront technology investments.

How do consumers value fuel economy?

The first question to evaluate is how consumers value fuel economy, or more accurately, how they value fuel savings attributable to increased fuel economy. Two interrelated economic concepts are commonly used to summarize how consumers appear to value future fuel savings that result from higher fuel economy. The first relates to the length of time that consumers consider when valuing fuel savings, or "payback period," while the second relates to the discount rate that consumers apply to future savings. Although either of these two concepts can be used by itself to indicate how buyers value future fuel savings, our analysis uses a combination of the two to characterize consumers' valuation of future fuel savings.

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long-run elasticities. *See.*, *e.g.*, Hymans, Saul H., "Consumer Durable Spending: Explanation and Prediction," Brookings Papers on Economic Activity 1 (1970), which finds a short-run elasticity of auto expenditures (not sales) with respect to price of 0.78 to 1.17, and a long-run elasticity of 0.3 to 0.46 (pp. 173-206). Available at: http://www.brookings.edu/about/projects/bpea/editions/~/media/Projects/BPEA/1970%202/1970b_bpea_hymans_ackley_juster.PDF or Docket No. NHTSA-2010-0131 (last accessed August 1, 2012)

The length of time that consumers consider when valuing future fuel savings can significantly affect their comparisons of fuel savings to the increased cost of purchasing a vehicle that offers higher fuel economy. For example, there will be a significant difference in aggregate fuel savings if consumers consider 1 year, 3 years, 5 years, 10 years, or the lifetime of the vehicle as the relevant payback period. The discount rate that consumers use to discount future fuel savings to their present value can also have a significant impact; higher discount rates will reduce the importance of future fuel savings relative to a vehicle's initial purchase price. If consumers value fuel savings over a short payback period, such as 1 to 2 years, then the discount rate will be less important, but if consumers consider fuel savings over a longer period, then the discount rate will become important.

The payback period and discount rate are conceptual proxy measures for consumer decisions that may often be made without any explicit quantitative analysis. For example, some buyers choosing among a set of vehicles may know what they have been paying recently for fuel, what they are likely to pay to buy each of the vehicles considered, and some attributes—including labeled fuel economies—of those vehicles. However, these buyers may then make a choice without actually trying to estimate how much they would pay to fuel each of the vehicles they are considering buying; for such buyers, the idea of a payback period and discount rate may have no explicit meaning. This does not, however, limit the utility of these concepts for the agency's analysis. If, as a group, buyers behave *as if* they value fuel consumption by considering an explicit payback period and discount rate, these concepts remain useful as a basis for estimating the market response to increases in fuel economy accompanied by increases in price.

Information regarding the number of years that consumers value fuel savings comes from several sources. In past analyses, NHTSA has used five years as representing the average payback period, because this is the average length of time of a financing agreement.[385] We conducted a search of the literature for additional estimates of consumer valuation of fuel savings, in order to determine whether the 5 year assumption was accurate or should be revised. A recent paper by David Greene[6] examined studies from the past 20 years of consumers' willingness to pay for fuel economy and found that "the available literature does not provide a reasonable consensus," although the author states that "manufacturers have repeatedly stated that consumers will pay, in increased vehicle price, for only 2 - 4 years in fuel savings" based on manufacturers' own market research. The National Research Council[386] also used a 3 year payback period as one way to compare consumer valuation of benefits to a full lifetime value. A survey conducted for the Department of Energy in 2004, which asked 1,000 households how much they would pay for a

[385] National average financing terms for automobile loans are available from the Board of Governors of the Federal Reserve System G.19 "Consumer Finance" release. *See* http://www.federalreserve.gov/releases/g19/ (last accessed August 25, 2011). The average new car loan at an auto finance company in the first quarter of 2011 is for 62 months at 4.73 %.

[386] National Research Council (2002), "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards", National Academies Press, Washington D.C.

vehicle that saved them $400 or $1,200 per year in fuel costs, found implied payback periods of 1.5 to 2.5 years. In reviewing this survey, Greene concluded: "The striking similarity of the implied payback periods from the two subsamples would seem to suggest that consumers understand the questions and are giving consistent and reliable responses: they require payback in 1.5 to 2.5 years." However, Turrentine and Kurani's[387] in-depth interviews of 57 households found almost no evidence that consumers think about fuel economy in terms of payback periods. When asked such questions, some consumers became confused while others offered time periods that were meaningful to them for other reasons, such as the length of their car loan or lease.

The effective discount rate that consumers have used in the past to value future fuel economy savings has been studied in many different ways and by many different economists. Greene examined and compiled many of these analyses and found: "Implicit consumer discount rates were estimated by Greene (1983) based on eight early multinomial logit choice models. …The estimates range from 0 to 73% ... Most fall between 4 and 40%." Greene added: "The more recent studies exhibit as least a wide a range as the earlier studies."

This is an extremely broad range. With such uncertainty about how consumers value future fuel savings and the discount rates they might use to determine the present value of future fuel savings, NHTSA chose for purposes of this analysis to utilize the standard 3 and 7 percent social discount rates recommended by OMB guidance to evaluate the costs and benefits of regulation. To the extent that some consumers appear to apply higher discount rates, the analysis of likely sales consequences would be different. This review leads us to conclude that consumer valuation of future fuel savings is highly uncertain, leading to different potential scenarios for vehicle sales. A negative impact on sales is possible if consumers don't value the fuel savings or desire very short payback periods, because the final rule will lead to an increase in the perceived ownership cost of vehicles. In addition, sales decreases are possible if gasoline prices are lower than projected by manufacturers and the agencies or technology costs are higher than projected. A positive impact on sales is also possible, because the final rule will lead to a significant decrease in the lifetime cost of vehicles, and with consumer learning over time, this effect may produce an increase in sales. Whether a change in sales will result from this final rule, or will result from other factors that affect the way drivers consider fuel economy in their purchasing decisions, is subject to uncertainty.

How do manufacturers believe consumers value fuel savings attributable to higher fuel economy?

Although some manufacturers have indicated in public remarks or confidential statements to NHTSA that their plans to apply fuel-saving technology depend on fuel prices and consumers' willingness to pay for fuel economy improvements, the agency does not have specific and robust

[387] Turrentine, T.S. and K.S. Kurani, 2007. "Car Buyers and Fuel Economy," *Energy Policy*, vol. 35, pp. 1213-1223.

information regarding how manufacturers interpret consumers' valuation of fuel savings. Based on our review of the literature and available evidence, it is not clear how accurately manufacturers are accounting for consumer valuation of fuel economy in making their pricing decisions, nor how that accuracy will be affected in the future as manufacturers' costs to produce vehicles rise in response to the final standards. In standard economic theory, if manufacturers believe that consumers value the fuel savings at a higher dollar level than the technology costs, then manufacturers' profit motives would lead them to voluntarily add the cost-effective technologies to their vehicles in the absence of government mandates, in the belief that their sales and profits would increase.

This concept ties into the basic question of whether manufacturers are providing the amount of fuel economy that consumers wish to purchase—whether there is matching between consumers' demand for fuel economy and the firms' supply of fuel economy. It is possible that the light-duty vehicle market is currently operating according to standard economic assumptions, and manufacturers are providing approximately the amount of fuel economy that consumers wish to purchase, because they correctly interpret consumers' valuation of fuel economy. On the other hand, it is possible that manufacturers are providing more or less fuel economy than consumers wish to purchase, because they do not correctly understand consumers' valuation of fuel economy. Because NHTSA does not know which scenario is correct today, and cannot predict which will apply in the future, we evaluate the response of sales under both scenarios in the following sections in order to assess the range of potential impacts that could be attributable to this final rule.

As discussed above, it is very difficult to determine how consumers will react to fuel economy improvements, and manufacturers presumably face this same challenge. Consumer consideration of fuel economy appears to evolve based on a variety of factors (fuel price, recessions, marketing), and consumers can react quickly to changes in these factors, sometimes more rapidly than the industry is able to change its product offerings. There have been examples of periods when demand for fuel efficient vehicles exceeded the available supply of highly efficient vehicles, and other periods where very efficient vehicle models were introduced into the market but sales stalled. If manufacturers did not accurately forecast consumers demand for fuel efficient vehicles, manufacturers' investment in vehicle technologies would not result in desired payoff. Manufacturers may be likely to be particularly risk averse with regard to future changes in fuel prices, in large part due to the substantial capital investments that are necessary to develop and market fuel-efficient models. If a manufacturer invests substantially in fuel efficient technologies expecting higher consumer demand than realized, then the manufacturer has incurred the costs of investment but not reaped the benefits of those investments. On the other hand, if a manufacturer does not invest in fuel efficient technologies, then the manufacturers may lose some market share in the short run if demand for fuel economy is higher than expected, but they still retain the option of investing in fuel efficient technologies. The predicted level of investment under uncertainty related to consumer demand for fuel efficient vehicles and irreversibility of investment for fuel efficient technologies would be less than the predicted level of investment under no uncertainty and complete reversibility.

In addition, there is reason to believe there may be risk aversion on the consumer side. The simultaneous investment by all companies may also encourage consumer confidence in the new technologies. If only one company adopted new technologies, early adopters might gravitate toward that company, but early adopters tend to be a relatively small portion of the public. More cautious buyers, who are likely to be more numerous, might wait for greater information before moving away from well-known technologies. If all companies adopt advanced technologies at the same time, though, potential buyers may perceive the new technologies as the new norm rather than as a risky innovation. They will then be more willing to move to the new technologies. As some commenters have pointed out, simultaneous action required by the rule may change buyers' expectations (their reference points) for fuel economy, and investing in more fuel economy may seem less risky than in the absence of the rule.[388]

Further, the certainty of the regulations reduces the costs of meeting them, because there will be a) more economies of scale and more learning curve benefits due to greater cumulative production of fuel-efficient technologies and b) more incentive for automakers and suppliers to invest in R&D to create future fuel-efficient technologies.[389] We note that this risk aversion by itself does not indicate a market failure; it is the fact that the risk aversion leads to under provision of social benefits (e.g., reduction in greenhouse gas emissions).

How did NHTSA attempt to calculate potential impacts of the final rule on vehicle sales under the different scenarios discussed above?

Given the considerable uncertainty associated with consumer valuation of fuel savings and manufacturers' understanding of that valuation, NHTSA sought to assess potential sales impacts under two possible basic scenarios: first, one in which the light-duty vehicle market is currently operating according to standard theoretical economic principles, and manufacturers are providing *exactly* the amount of fuel economy that consumers wish to purchase, because they perfectly understand consumers' valuation of fuel economy; and second, one in which manufacturers are *not* providing the exact amount of fuel economy that consumers wish to purchase (either too much or too little), because they do not have perfect information regarding consumers' valuation of fuel economy. In the first scenario, manufacturers and consumers would behave as though they are assuming the same payback period (and/or discount rate) for fuel savings attributable to

[388] We note that this risk aversion by itself does not indicate a market failure; but that the risk aversion leads to under-provision of social benefits (e.g., reduction in greenhouse gas emissions)

[389] The literature reviewed by Popp, Newell, and Jaffe (2010) shows that environmental regulation has played an important role in inducing innovation that reduces the cost of achieving environmental goals; Popp (2011) provides evidence that consumer pressure alone is rarely sufficient to achieve broad diffusion of environmentally-friendly technologies.

higher fuel economy; in the second, manufacturers and consumers would behave as though they are assuming different payback periods (and/or discount rates).

For years, consumers have been learning about the benefits that accrue to them from owning and operating vehicles with greater fuel efficiency. This type of learning is expected to continue before and during the model years affected by this rule, particularly given the new fuel economy labels that clarify potential economic effects and should therefore reinforce that learning. Therefore, some increase in the demand for, and production of, more fuel efficient vehicles is incorporated in the market driven baseline.

The fuel savings associated with operating more fuel efficient vehicles will be more salient to individuals who own them, causing their subsequent purchase decisions to shift closer to minimizing the total cost of ownership over the lifetime of the vehicle. Second, this appreciation may spread across households through word of mouth and other forms of communications. Third, as more motorists experience the time and fuel savings associated with greater fuel efficiency, the price of used cars will better reflect such efficiency, further reducing the cost of owning more efficient vehicles for the buyers of new vehicles (since the resale price will increase). If these induced learning effects are strong, the rule could potentially increase total vehicle sales over time. These increased sales would not occur in the model years first affected by the rule, but they could occur once the induced learning takes place. It is not possible to quantify these learning effects years in advance and that effect may be speeded or slowed by other factors that enter into a consumer’s valuation of fuel efficiency in selecting vehicles.

The possibility that the rule will (after a lag for consumer learning) increase sales need not rest on the assumption that automobile manufacturers are failing to pursue profitable opportunities to supply the vehicles that consumers demand. In the absence of the rule, no individual automobile manufacturer would find it profitable to move toward the more efficient vehicles mandated under the rule. In particular, no individual company can fully internalize the future boost to demand resulting from the rule. If one company were to make more efficient vehicles, counting on consumer learning to enhance demand in the future, that company would capture only a fraction of the extra sales so generated, because the learning at issue is not specific to any one company's fleet. Many of the extra sales would accrue to that company's competitors.

In the language of economics, consumer learning about the benefits of fuel efficient vehicles involves positive externalities (spillovers) from one company to the others.[390] These positive externalities may lead to benefits for manufacturers as a whole. We emphasize that this discussion has been tentative and qualified. Social learning of related kinds has been identified in

[390] Industry-wide positive spillovers of this type are hardly unique to this situation. In many industries, companies form trade associations to promote industry-wide public goods. For example, merchants in a given locale may band together to promote tourism in that locale. Antitrust law recognizes that this type of coordination can increase output.

a number of contexts,[391] and the agency expects that it will influence consumers' future valuation of fuel economy. Thus, while it is difficult to determine how consumers will react to fuel economy improvements attributable to the final rule, we believe that it is likely that consumers will learn more about and increasingly value fuel economy improvements in the future. If manufacturers assume that consumers value fuel economy less than consumers *actually* value fuel economy, there will be a demand pull for better fuel economy vehicles into the market, and by virtue of the final standards forcing manufacturers to increase better fuel economy product offerings; it is possible that sales could increase as a result.

How did NHTSA illustrate these scenarios analytically?

The agency examined a number of cases to illustrate these scenarios. Sales impacts were determined for 6 cases that are combinations of manufacturers' beliefs of how consumers value fuel savings and consumers' valuation of fuel savings. The first two cases assume a flat baseline (no voluntary improvement in fuel economy above the MY 2016 standards by manufacturers absent new regulations), consistent with the agency's main analysis in this rulemaking. In these first two cases we assume consumers value fuel savings for a 3 year period or a 5 year period (the average length of a loan), and we also determine the breakeven point of consumer valuation of fuel savings, where there would be no impact on sales, assuming all other factors remain constant. As can be seen in Table VII-17 below, with a flat baseline and assuming that consumers consider fuel economy benefits over a 3 or 5 year period, benefits exceed costs to the point that consumers will purchase more vehicles and sales will increase. NHTSA estimates a break-even point of 2.35 years for scenarios with a flat baseline; that is, if consumers value fuel savings over an average 2.35 years, neither an increase nor a decrease in sales is expected.

The next 4 cases assume that manufacturers will, absent new regulations, implement technologies in response to their belief that consumers have either a 1 year, 3 year, or 5 year payback period, and for 3 of these scenarios where the consumer also values fuel economy over the same payback periods assumed by manufacturers. For example, the agency also examined the impact on sales and employment under the sensitivity analysis assumption that the baseline fleet included the manufacturers voluntarily implementing any technology that had a 1 year or less payback period for consumers. In this analysis, the least expensive technologies relative to their effects on fuel economy improvement (those that had a consumer payback where fuel savings over the first year of use were higher than new vehicle price increases) were assumed to be voluntarily implemented by manufacturers, resulting in improved fuel economy in the baseline case which would have occurred without adoption of this rule. The same methodology was used in the cases where both manufacturers and consumers value fuel savings over either a 3

[391] See Hunt Alcott, Social Norms and Energy Conservation, Journal of Public Economics (March 2011), available at http://opower.com/uploads/library/file/1/allcott_2011_jpubec_- _social_norms_and_energy_conservation.pdf (last accessed August 1, 2012); Christophe Chamley, Rational Herds: Economic Models of Social Learning (Cambridge, 2004), available at http://bilder.buecher.de/zusatz/21/21995/21995098_lese_1.pdf (last accessed August 1, 2012)

year period or a 5 year period. All three of these cases result in reductions in sales, with the impact decreasing as the manufacturer's baseline increases from 1 year to 3 year to 5 years. In a final case we assume that manufacturers voluntarily implement any technology that had a 1 year or less payback period for consumers, but that consumers value fuel savings over a 3 year period.

Under that case, the breakeven point for consumers is about 3.1 years – meaning that if consumers valued their fuel savings over 3.1 years in this scenario, there would be no impact on sales; in other words if the payback period of the fuel saving technologies was less than 3.1 years, then the vehicle sales would increase and vice versa.

For the reader's reference, Table VII-16 below shows the included combinations of payback periods assumed—for these different cases—to represent consumers' and manufacturers' decisions. The agency considered these different cases to represent an illustrative range of possible outcomes under the scenarios described above.

Table VII-16
Scenarios Considered for Sales Impact Analysis

Payback Period Representing Manufacturers' Decisions	Payback Period Representing Buyers' Decisions		
	1 Year	3 Years	5 Years
0 Years (Flat)		Included	Included
1 Year	Included	Included	
3 Years		Included	
5 Years			Included

For the analysis for each of these cases, NHTSA makes several assumptions. For the fuel savings part of the equation, as shown in the table, we assumed that the average purchaser considers the fuel savings they would receive over a 1, 3, or 5 year timeframe. The present values of these savings were calculated using a 3 and 7 percent discount rate. We used a fuel price forecast that included taxes, because this is what consumers must pay. Fuel savings were calculated over the first 1, 3, or 5 years and discounted back to a present value.

The agency believes that consumers may consider several other factors over the 5 year horizon when contemplating the purchase of a new vehicle. The agency added some of these factors into the calculation to represent how an increase in technology costs might affect consumers' buying considerations.

First, consumers might consider the sales taxes they have to pay at the time of purchasing the vehicle. As these costs are transfer payments, they are not included in the societal cost of the program, but they are included as one of the increased costs to the consumer for these standards. We took the most recent auto sales tax by state[392] and weighted them by population by state to determine a national weighted-average sales tax of 5.46 percent (hereafter rounded to 5.5 percent in the discussion). NHTSA sought to weight sales taxes by new vehicle sales by state; however, such data were unavailable. NHTSA recognizes that for this purpose, new vehicle sales by state is a superior weighting mechanism to Census population; in an effort to approximate new vehicle sales by state NHTSA studied the change in new vehicle registrations (using R.L. Polk data) by state across recent years and developed a corresponding set of weights. The resulting national weighted-average sales tax rate was almost identical to that resulting from the use of Census population estimates as weights, just slightly above 5.5 percent. NHTSA opted to utilize Census population rather than the registration-based proxy of new vehicle sales as the basis for computing this weighted average, as the end results were negligibly different and the analytical approach involving new vehicle registrations had not been as thoroughly reviewed.

Second, we considered insurance costs over the 5 year period. More expensive vehicles will require more expensive collision and comprehensive (*e.g.*, theft) car insurance. The increase in insurance costs is estimated from the average value of collision plus comprehensive insurance as a proportion of average new vehicle price. Collision plus comprehensive insurance is the portion of insurance costs that depend on vehicle value. A recent study by Quality Planning[393] provides the average value of collision plus comprehensive insurance for new vehicles, in 2010$, is $521 ($396 of which is collision and $125 of which is comprehensive). The average consumer expenditure for a new passenger car in 2011, according to the Bureau of Economic Analysis was $24,572 and the average price of a new light truck was $31,721 in $2010.[394] Using sales volumes from the Bureau, we determined an average passenger car and an average light truck price was $27,953 in $2010 dollars.[395] Average prices and estimated sales volumes are needed because

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[392] See http://www.factorywarrantylist.com/car-tax-by-state.html (last accessed August 1, 2012). Note that county, city, and other municipality-specific taxes were excluded from NHTSA's weighted average, as the variation in locality taxes within states, lack of accessible documentation of locality rates, and difficulty in obtaining reliable sets of weights to apply to locality taxes complicates the ability to perform this analysis. Localities with relatively high automobile sales taxes may have relatively fewer auto dealerships, as consumers would likely endeavor to purchase vehicles in areas with lower locality taxes.
[393] "During Recession, American Drivers Assumed More Risk to Reduce Auto Insurance Costs," Quality Planning, March 2011. See https://www.qualityplanning.com/media/4312/110329%20tough%20times_f2.pdf (last accessed August 1, 2012).
[394] U.S. Department of Commerce, Bureau of Economic Analysis, Table 7.2.5S. Auto and Truck Unit Sales, Production, Inventories, Expenditures, and Price, Available at http://www.bea.gov/itable/ (last accessed August 1, 2012)
[395] http://www.bls.gov/cpi/cpid11av.pdf, Table 1A. Consumer Price Index for All Urban Consumers (CPI-U): U.S. city average, by expenditure category and commodity and service group, for new vehicles. (Last accessed August 1, 2012)

price elasticity is an estimate of how a percent increase in price[396] affects the percent decrease in sales. Dividing the cost to insure a new vehicle by the average price of a new vehicle gives the proportion of comprehensive plus collision insurance as 1.86 percent of the price of a vehicle. As vehicles' values decline with vehicle age, comprehensive and collision insurance premiums likewise decline. Data on the change in insurance premiums as a function of vehicle age are scarce; however, NHTSA utilized data from the aforementioned Quality Planning study that cite the cost to insure the average vehicle on the road today (average age 10.8 years)[397] to enable a linear interpolation of the change in insurance premiums during the first 11 years of a typical vehicle's life. Using this interpolation, as a percentage of the base vehicle price of $27,953, the cost of collision and comprehensive insurance in each of the first five years of a vehicle's life is 1.86 percent, 1.82 percent, 1.75 percent, 1.64 percent, and 1.50 percent, respectively, or 8.57 percent in aggregate. Discounting that stream of insurance costs back to present value indicates that the present value of the component of insurance costs that vary with vehicle price is equal to 8.0 percent of the vehicle's price at a 3 percent discount rate.

Third, we considered that 70 percent of new vehicle purchasers take out loans to finance their purchase.[398] Using proprietary forecasts available from Global Insight, NHTSA developed an average of 48-month[399] bank and auto finance company loan rates for years 2017 through 2025, which – when deflated by Global Insight's corresponding forecasts of the CPI – is 5.16 percent. In the construction of this estimate, NHTSA assumed an equal distribution of bank and auto finance company loans – an assumption necessitated by the lack of data on the distribution of the volume of loans between the differing types of creditors. NHTSA opted to adjust future loan rates using the CPI rather than the GDP deflator as this analysis is intended to facilitate further analysis from the perspective of the consumer, for which the CPI is the preferred deflation factor. At these terms the average person taking a loan will pay 13.7 percent more (undiscounted) for their vehicle over the 5 years than a consumer paying cash for the vehicle at the time of purchase. Discounting future loan payments at a 3 percent discount rate, a consumer financing a vehicle purchase pays 5.43 percent more as opposed to an all cash purchase. Taking into account to make the total baseline price for MY 2017 $25,443 ($24,572 + $871), for light trucks $1,090 was added to the average price of a MY 2011 light truck to make the total baseline price for MY

[396] When estimating the sales impact, the price of the vehicle was increased from these MY 2011 prices based on the costs of estimated safety and MY 2011-2016 fuel economy rules. See the cumulative impact section for an estimate of those costs. For passenger cars $871 was added to the average price of a MY 2011 passenger car to make the total baseline price for MY 2017 $25,443 ($24,572 + $871), for light trucks $1,090 was added to the average price of a MY 2011 light truck to make the total baseline price for MY 2017 $32,811 ($31,721 + $1,090). All of these values are in 2010 dollars.

[397] See https://www.polk.com/company/news/average_age_of_vehicles_reaches_record_high_according_to_polk (last accessed August 1, 2012).

[398] Bird, Colin. "Should I Pay Cash, Lease or Finance My New Car?" http://www.cars.com/go/advice/Story.jsp?section=fin&story=should-i-pay-cash&subject=loan-quick-start&referer=advice&aff=sacbee, July 12, 2011, citing CNW Marketing Research. (Last accessed August 1, 2012)

[399] No projections were available for rates of loan terms of 60 months. NHTSA compared the historical difference of 48-month and 60-month loan rates and determined the 48-month rate to be a suitable proxy for the 60-month rate.

2017 $32,811 ($31,721 + $1,090). All of these values are in 2010 dollars. Assuming that only 70 percent of vehicle purchases are financed, the average consumer would pay 3.80 (=0.70 * 5.43 percent) percent more than the retail price of a vehicle.

Fourth, we considered the residual value (or resale value) of the vehicle after 5 years and expressed this as a percentage of the new vehicle price. If the price of the vehicle increases due to fuel economy technologies, the resale value of the vehicle will go up proportionately. The average resale price of a vehicle after 5 years is about 35 percent[400] of the original purchase price. Discounting the residual value back 5 years using a 3 percent discount rate (=35 percent * .8755) gives an effective residual value of 30.64 percent. Note that added CAFE technology could also result in more expensive or more frequent repairs. However, we do not have data to verify the extent to which this would be a factor during the first 5 years of vehicle life. We add these four factors together. At a 3 percent discount rate, the consumer considers that he could get 30.64 percent back upon resale in 5 years, but will pay 5.5 percent more for taxes, 8.0 percent more in insurance, and 5.1 percent more for loans, resulting in an 12.0 percent return on the increase in price for fuel economy technology (=30.6 percent - 5.5 percent - 8.0 percent - 5.1 percent). Thus, the increase in price per vehicle would be multiplied by 0.88 (=1 - 0.12) before subtracting the fuel savings to determine the overall net consumer valuation of the increase of costs on this purchase decision. This process results in estimates of the payback period for MY 2025 vehicles of 2 years for light trucks and 4 years for passenger cars at a 3 percent discount rate. For ease of presentation, we combine the impact on passenger car and light truck sales for the Preferred Alternative only for the combined 9 year period of 2017-2025, and we compare the sales impact for both the MY 2010 baseline and for the MY 2008 baseline at the 3 percent and 7 percent discount rates. There is not a significant difference in sales impacts depending upon the baseline considered (2010 versus 2008) and the discount rate impact is predictable, with sales increasing to a lesser extent under a 7 percent discount rate than in the case of a 3 percent discount rate, since benefits are valued lower with a higher discount rate.

[400] Consumer Reports, August 2008, "What That Car Really Costs to Own," Available at http://www.consumerreports.org/cro/cars/pricing/what-that-car-really-costs-to-own-4-08/overview/what-that-car-really-costs-to-own-ov.htm (last accessed August 1, 2012).

Table VII-17
Potential Sales Impact for Passenger Cars and Light Trucks

Vehicles in Thousands

Years Fuel Valued by Manufacturers	Years Fuel Valued by Consumers	MYs 2017-2025 Sales Impact in Thousands and in Percent of Total Sales (3% discount rate) (000's)	(%)	MYs 2017-2025 Sales Impact in Thousands and in Percent of Total Sales (7% discount rate) (000's)	(%)
2008 Baseline					
0 Flat	3 yr.	911	0.6	757	0.5
0 Flat	5 yr.	3,784	2.7	3,232	2.3
1 yr. *	1 yr. *	-2,696	-1.9	-2,322	-1.6
1 yr.	3 yr.	-360	-0.3	-445	-0.3
3 yr. *	3 yr. *	-530	-0.4	-542	-0.4
5 yr. *	5 yr. *	-3	-0.0	-36	-0.0
2010 Baseline					
0 Flat	3 yr.	988	0.7	867	0.6
0 Flat	5 yr.	3,804	2.7	3,261	2.3
1 yr. *	1 yr. *	-2,405	-1.7	-2,611	-1.8
1 yr.	3 yr.	-50	-0.0	-130	-0.1
3 yr. *	3 yr. *	-309	-0.2	-314	-0.2
5 yr. *	5 yr. *	124	0.1	94	0.1

* These scenarios are presented as theoretical cases. NHTSA believes it is unlikely that manufacturers and consumers would value improvements in fuel economy identically, and believes that on average, manufacturers will behave more conservatively in their assumptions of how consumers value fuel economy than how on average consumers will actually behave. NHTSA expects that in practice the number of years fuel is valued by manufacturers will be shorter than the number of years fuel is valued by consumers.

What have commenters and other sources said in terms of potential sales impacts attributable to the final rule?

A recent study on the effects on sales, attributable to NHTSA regulatory programs, including the fuel economy program was undertaken by the Center for Automotive Research (CAR).[401] CAR examined the impacts of alternative fuel economy increases of 3%, 4%, 5%, and 6% per year on the outlook for the U.S. motor vehicle market, including the impacts of likely increases in costs

[401] "The U.S. Automotive Market and Industry in 2025," Center for Automotive Research, June 2011, available at http://www.cargroup.org/assets/files/ami.pdf (last accessed August 1, 2012).

for increased fuel economy (based on the NAS report, which estimates higher costs than NHTSA's current estimates) and required safety features. The CAR analysis also examined the technologies that would be used to achieve higher fuel economy, and how their production and use would affect the new vehicle market, production volumes, and automotive manufacturing employment in the year 2025. The required safety mandates were assumed to cost $1,500 per vehicle in 2025, but CAR did not evaluate the value of those safety mandates to consumers. Thus the CAR study cannot be compared to other studies, as it combines the cost of additional safety mandates along with costs for fuel economy improvements. The CAR study likely underestimates sales (that is, it overestimates the reduction in sales resulting from increased CAFE standards alone), as it assigns no value to consumers' perceived values of additional safety features. In any case, unlike other analyses discussed in this final rule, sales changes shown cannot be solely attributed to the rulemaking.

There are many factors that go into the CAR analysis of sales. CAR assumes a 22.0 mpg baseline, two gasoline price scenarios of $3.50 and $6.00 per gallon, VMT schedules by age, and a rebound rate of 10 percent (although it appears that the CAR report assumes a rebound effect even for the baseline and thus negates the impact of the rebound effect). Fuel savings are assumed to be valued by consumers over a 5 year period at a 10 percent discount rate. The impact on sales varies by scenario, the estimates of the cost of technology, the price of gasoline, etc. At $3.50 per gallon, the net change in consumer savings (costs minus the fuel savings valued by consumers) is a net cost to consumers of $359 for the 3% scenario, a net cost of $1,644 for the 4% scenario, a net cost of $2,858 for the 5% scenario, and a net consumer cost of $6,525 for the 6% scenario. At $6.00 per gallon, the net change in consumer savings (costs minus the fuel savings valued by consumers) is a net savings to consumers of $2,107 for the 3% scenario, a net savings of $1,131 for the 4% scenario, a net savings of $258 for the 5% scenario, and a net consumer cost of $3,051 for the 6% scenario. Thus, the price of gasoline can be a significant factor in affecting how consumers view whether they are getting value for their expenditures on technology. Table 14 on page 42 of the CAR report presents the results of their estimates of the 4 alternative mpg scenarios and the 2 prices of gasoline on light vehicle sales and automotive employment. The table below shows these estimates. The baseline for the CAR report is 17.9 million sales and 877,075 employees. The price of gasoline at $6.00 per gallon, rather than $3.50 per gallon results in about 2.1 million additional sales per year and 100,000 more employees in year 2025.

Table VII-18 CAR Report Estimates of
Sales and Employment Impacts in 2025

Gasoline at $3.50	CAFE requirement of a 3% increase in mpg per year	CAFE requirement of a 4% increase in mpg per year	CAFE requirement of a 5% increase in mpg per year	CAFE requirement of a 6% increase in mpg per year

Sales (millions)	16.4	15.5	14.7	12.5
Employment	803,548	757,700	717,626	612,567
Gasoline at $6.00				
Sales	18.5	17.6	16.9	14.5
Employment	903,135	861,739	826,950	711,538

Figure 13 on page 44 of the CAR report shows a graph of historical automotive labor productivity, indicating that there has been a long term 0.4 percent productivity growth rate from 1960-2008, to indicate that there will be 12.26 vehicles produced in the U.S. per worker in 2025 (which is higher than NHTSA's estimate – see below). In addition, the CAR report discusses the jobs multiplier. For every one automotive manufacturing job, they estimate the economic contribution to the U.S. economy of 7.96 jobs[402] stating "In 2010, about 1 million direct U.S. jobs were located at an auto and auto parts manufacturers; these jobs generated an additional 1.966 million supplier jobs, largely in non-manufacturing sectors of the economy. The combined total of 2.966 jobs generated a further spin-off of 3.466 million jobs that depend on the consumer spending of direct and supplier employees, for a total jobs contribution from U.S. auto manufacturing of 6.432 million jobs in 2010. The figure actually rises to 7.96 million when direct jobs located at new vehicle dealerships (connected to the sale and service of new vehicles) are considered."

CAR uses econometric estimates of the sensitivity of new vehicle purchases to prices and consumer incomes and forecasts of income growth through 2025 to translate these estimated changes in net vehicle prices to estimates of changes in sales of MY 2025 vehicles; higher net prices – which occur when increases in vehicle prices exceeds the value of fuel savings – reduce vehicle sales, while lower net prices increase new vehicle sales in 2025. We do not have access to the statistical models that CAR develops to estimate the effects of price and income changes on vehicle sales. CAR's analysis assumes continued increases in labor productivity over time and then translates the estimated impacts of higher CAFE standards on net vehicle prices into estimated impacts on sales and employment in the automobile production and related industries.

The agency disagrees with the cost estimates in the CAR report for new technologies, the addition of safety mandates into the costs, and various other assumptions. Many commenters

[402] Kim Hill, Debbie Menk, and Adam Cooper, "Contribution of the Automotive Industry to the Economies of All Fifty States and the United States," The Center for Automotive Research, Ann Arbor MI, April 2010. *Available at* http://www.cargroup.org/?module=Publications&event=View&pubID=16. Docket No. NHTSA-2010-0131.

stated that they expected vehicle sales to increase as a result of the final rule, and cited an analysis conducted by Ceres and Citigroup Global Markets Inc.[403] that examined the impact on automotive sales in 2020, with a baseline assumption of an industry fuel economy standard of 42 mpg, a $4.00 price of gasoline, a 12.2 percent discount rate and an assumption that buyers value 48% of fuel savings over seven years in purchasing vehicles. The main finding on sales was that light vehicle sales were predicted to increase by 6% from 16.3 million to 17.3 million in 2020. That analysis has subsequently been revised to predict a 4% increase from 15.8 million to 16.4 million.[404] Elasticity is not provided in the report but it states that they use a complex model of price elasticity and cross elasticities developed by GM. A fuel price risk factor[405] was utilized. Little rationale was provided for the baseline assumptions, but sensitivity analyses were examined around the price of fuel ($2, $4, and $7 per gallon), the discount rate (5.2%, 12.2%, 17.2%), purchasers consider fuel savings over (3, 7, or 15 years), fuel price risk factor of (30%, 70%, or 140%), and VMT of (10,000, 15,000, and 20,000 in the first year and declining thereafter).

The UAW, along with NRDC and the National Wildlife Foundation, also submitted reports indicating their assessment that the additional technology content needed to meet higher fuel economy standards would lead to considerable sales and employment growth. For example, the 2010 UAW/NRDC/Center for American Progress study, "Driving Growth," concluded that if 75 percent of the additional content needed for the vehicle fleet to reach an average 40 mpg by 2020 was produced in the U.S., as many as 150,000 jobs would be created.[406] Similarly, the 2011 UAW/NRDC/NWF study, "Supplying Ingenuity," found that 504 facilities across 43 states employing over 500,000 people are devoted to researching, developing, or producing clean-car technologies, and that 67 percent of these jobs are related to advanced conventional technologies such as better engines and transmissions and components like electric power steering and high strength steel.

Based on all of the above, what does NHTSA believe the likely impact on vehicle sales attributable to this final rule will be?

[403] "U.S. Autos, CAFE and GHG Emissions", March 2011, Citi Ceres, UMTRI, Baum and Associates, Meszler Engineering Services, and the Natural Resources Defense Council, available at http://www.ceres.org/resources/reports/fuel-economy-focus (last accessed August 1, 2012)
[404] "U.S. Autos, CAFE and GHG Emissions", March 2011, Citi Ceres, UMTRI, Baum and Associates, Meszler Engineering Services, and the Natural Resources Defense Council, available at http://www.ceres.org/resources/reports/fuel-economy-focus (last accessed August 1, 2012)
[405] Fuel price risk factor measures the rate at which consumers are willing to trade reductions in fuel costs for increases in purchase price. For example, a fuel price risk factor of 1.0 would indicate the consumers would be willing to pay $1 for an improvement in fuel economy that resulted in reducing by $1 the present value of the savings in fuel costs.
[406] UAW/NRDC/Center for American Progress, "Driving Growth: How Clean Cars and Climate Policy Can Create Jobs," March 2010. NHTSA-2010-0131

While NHTSA conducted and considered a variety of vehicle sales "cases" as presented above, we do not believe that we can state with certainty that any given case is "correct" for the rulemaking timeframe. Given that this final rule affects multiple years, many years in the future, and that during that time there will be a dynamic situation occurring with dramatically changing fuel economy levels and technology being added to vehicles, we anticipate that consumers' consideration of fuel economy will evolve over time. NHTSA believes that there is much uncertainty in how much consumers' consideration of fuel economy will change as a result of this final rule alone, as compared to other rules such as the MYs 2012-2016 CAFE and GHG emissions rules and the Fuel Economy Labeling rule, or manufacturers' marketing efforts. We anticipate that manufacturers will be tracking consumers' behavior and marketing their products to affect consumer behavior, as they always have. We have made several simplifying assumptions in order to estimate the potential impact on sales, but as discussed above, there are uncertainties in how this final rule will affect sales and employment. We note, as is likely evident in the table above, that the impact on sales in this analysis is heavily impacted by the difference between manufacturers' beliefs of how consumers value fuel savings and consumers' valuation of fuel savings.

This uncertainty, however, supports our conclusion in Section IV.F of the preamble that higher standards than the ones finalized in this rulemaking may not be economically practicable. The agency has tried to grapple with potential sales impacts as an important aspect of economic practicability, but reaching no definitive conclusion, believes that a conservative approach will be most likely to help us avoid setting standards that are beyond what would be economically practicable, and thus beyond the maximum feasible levels. NHTSA will monitor sales trends going forward, and anticipates that the intervening years between this final rule and the future rulemaking to develop and establish final standards for MYs 2022-2025 will provide significant additional insight into the questions of how consumers value fuel savings associated with increased fuel economy, how manufacturers believe consumers value that fuel savings, and corresponding effects on vehicle sales attributable to CAFE standards.

As discussed elsewhere in the preamble and FRIA, the literature provides mixed evidence that consumers consistently value future fuel savings consistent with shorter payback periods and/or higher discount rate than the full lifetime value of fuel savings over the useful life of vehicles discounted as the social discount rates. That also provides an explanation for one of the potential reasons that manufacturers do not voluntarily provide all of the fuel saving technologies that are cost-effective and available, on a societal basis considered over the lifetime of the vehicle. In the past, consumers have not been willing to pay the additional price for such fuel economy improvements. One question is whether consumers will place a greater value on fuel savings as a result of this rule, and only as a result of this rule. In the past, large spikes in gasoline prices and consistently high gasoline prices have spurred consumers to consider fuel economy more prevalent in their purchasing decisions. The agency believes that the new and improved fuel economy labels and the large increase in fuel economy required as a result of the MY 2012-2016 fuel economy standards, may all have an impact on consumer valuation of fuel savings. However, these effects are not due to this rule. This final rule with its very large increase in average fuel economy, as well as manufacturers marketing these increased fuel economy levels, should also have a significant effect on consumers' realization that fuel economy is changing rapidly and significantly. As a result, we believe consumers will pay more attention to fuel savings as a result of this final rule assuming that fuel prices do not decrease significantly, but there is uncertainty whether all sales impacts will be the result of this final rule alone. It is possible that consumers will not demand increased fuel economy even when such increases would reduce overall costs for them. Some vehicle owners may also react to persistently higher vehicle costs by owning fewer vehicles, and keeping existing vehicles in service for somewhat longer. For these consumers, the possibility exists that there may be permanent sales losses, compared with a situation in which vehicle prices are lower. There is a wide variety in the number of miles that owners drive per year. Some drivers only drive 5,000 miles per year and others drive 25,000 miles or more. Rationally those that drive many miles have more incentive to buy vehicles with high fuel economy levels. In summary, there are a variety of types of consumers that are in different financial situations and drive different mileages per year. Since consumers are different and use different reasoning in purchasing vehicles, and we do not yet have an account of the distribution of their preferences or how that may change over time as a result of this rulemaking, the answer is quite ambiguous. Some may be induced by better fuel economy to purchase vehicles more often to keep up with technology, some may purchase no new vehicles because of the increase in vehicle price, and some may purchase fewer vehicles and hold onto their vehicles longer. There is great uncertainty about how consumers value fuel economy, and for this reason, the impact of this fuel economy proposal on sales is uncertain.

While it is difficult to determine how consumers will react to fuel economy improvements attributable to the final rule, we believe that it is likely that consumers will learn more about and increasingly value fuel economy improvements in the future, but we also believe that manufacturers and consumers are unlikely to place identical valuation on fuel economy benefits. We believe for the reasons discussed above that manufacturers will behave more conservatively in their assumptions of how consumers value fuel economy than how on average consumers will actually behave.

Some commenters stated that sales will increase as a result of the rule, as evidenced above in the above discussion of comments from Ceres and the UAW. Others, including NADA, expressed concern that sales may fall.

How does NHTSA plan to address this issue in the future?

NHTSA is currently sponsoring work to develop a vehicle choice model for potential use in the agency's future rulemaking analyses—this work may help to better estimate the market's effective valuation of future fuel economy improvements. This rule did not rely on a vehicle choice model. With an integrated market share model, the CAFE model would estimate how the sales volumes of individual vehicle models would change in response to changes in fuel economy levels and prices throughout the light vehicle market, possibly taking into account interactions with the used vehicle market. Having done so, the model would replace the sales estimates in the original market forecast with those reflecting these model-estimated shifts, repeating the entire modeling cycle until converging on a stable solution. We sought comment on the potential for this approach to help the agency estimate sales effects. Several commenters wanted the agency to either have the vehicle choice model go through a full peer review (the Alliance) or to be provided for public comment and review (NRDC) before being used. There was wide disparity in the comments on the concept of using a vehicle choice model to estimate the impacts on sales. The Alliance supported the use of a vehicle choice model. The American Fuel and Petrochemical Manufacturers[407] stated that it was concerned that the analysis is not based on a model that considered consumer choices and the impacts on different industries and individual that would be affected. The Natural Resources Defense Council (NRDC)[408] and Union of Concerned Scientists (UCS)[409] did not support the use of a consumer choice model and stated that the agencies should not rely on a highly uncertain and idealized consumer choice model.

NRDC stated that a consumer choice model could only rely on stated or revealed preferences based on existing vehicles in the market place and such a model is inappropriate for standards that drive the use of new technology. In response, NHTSA agrees that further work on the vehicle choice model is necessary, and is continuing to develop it. Section IV.C.4 of the preamble discusses the current progress with the choice model and next steps, and we refer the reader there for more information.

Potential Impact on Employment in the Automotive Industry in the Short Run

There are three potential areas of employment in the automotive industry that fuel economy standards could affect.[410] We briefly outline those areas here.

1. The first is the hiring of additional engineers by automobile companies and their suppliers to do research and development and testing on new technologies to determine their capabilities, durability, platform introduction, etc. The agency anticipates that there may be some level of additional job creation due to the added research and development, overall program management, and subsequent sales efforts required to market vehicles that have been redesigned for significant improvements in fuel economy, especially for revolutionary technologies such as hybrid and electric vehicles. In this respect, the final

[407] See EPA Docket EPA-HQ-OAR-2010-0799-9485.
[408] See EPA Docket EPA-HQ-OAR-2010-0799-0284.
[409] *Id*.
[410] For a general analysis of the potentially complex employment effects of regulation, see Morgenstern, Richard D., William A. Pizer, and Jhih-Shyang Shih. "Jobs Versus the Environment: An Industry-Level Perspective." Journal of Environmental Economics and Management 43 (2002): 412-436 (Docket EPA-HQ-OAR-2010-0799).

rule will likely have a positive effect on employment. At the same time, the levels of added employment are uncertain. In addition, it is not clear how much of this effort will be accomplished by added employment and how much by diverting existing employees to focus on CAFE instead of other company priorities such as improved acceleration performance, styling, marketing, new vehicle concepts, etc.

2. The second area is the impact that new technologies would have on production employment, both at suppliers and at auto assemblers. Added parts, like turbochargers, or complexity of assembly could have a positive impact on employment. The use of more exotic steels, aluminum, or other materials to save weight could affect the number of welds or attachment methods It is uncertain to what extent new CAFE technologies would require added steps in the assembly process that would necessitate new hiring, but generally when content is added, the number of employees in the supplier industry and on the assembly line goes up.

3. The third area is the potential impact that sales gains or losses could have on production employment. This area is potentially much more sensitive to change than the first two areas discussed above, although for reasons discussed above its estimation is highly uncertain. An increase in sales, produced for example by consumer attention to overall costs and learning over time, would have a positive effect on employment. A decrease in sales, produced by increases in initial costs, would have a negative effect.

We received a number of comments (from the Defour Group and some private individuals) asserting that there will be decreases in employment as a result of the costs of the rule, and a number of comments (from the United Auto Workers, environmental organizations, sustainable business groups, some private individuals, and others) asserting increases in employment, based on the development of advanced technologies and the reduction in net costs due to fuel savings. An assessment by the Defour Group predicts a loss of 155,000 jobs in manufacturing and supply, plus another 50,000 in distribution.[411] A study by Ceres predicts job gains of 43,000 in the auto industry and 484,000 economy-wide.[412] Some comments cite a study by the Natural Resources Defense Council, National Wildlife Federation, and United Auto Workers that 150,000 auto workers already are working to supply clean, fuel-efficient technologies.[413] The differences in results for quantitative employment impacts are mainly due to difference in the price impacts.

Estimates of decreases in employment commonly come from studies that use cost estimates higher than those estimated by the agencies, and sometimes lower benefits estimates, resulting in

[411] Walton, Thomas F., and Dean Drake, Defour Group LLC (February 13, 2012). "Comments on the Notice of Proposed Rulemaking and Preliminary Regulatory Impact Analysis for MY 2017 to 2025 Fuel Economy Standards." Docket EPA-HQ-OAR-2010-0799-9319.

[412] Management Information Services, Inc. (July 2011). "More Jobs per Gallon: How Strong Fuel Economy/GHG Standards Will Fuel American Jobs." Boston, MA: Ceres. Docket EPA-HQ-OAR-2010-0799-0709.

[413] Natural Resources Defense Council, National Wildlife Federation, and United Auto Workers (August 2011). "Supplying Ingenuity: U.S. Suppliers of Clean, Fuel-Efficient Vehicle Technologies," available at http://www.nrdc.org/transportation/autosuppliers/files/SupplierMappingReport.pdf (last accessed August 1, 2012). (Docket EPA-HQ-OAR-2010-0799)

reductions in vehicle sales. For instance, some comments from individuals cite the National Automobile Dealers Association and Center for Automotive Research for cost estimates of $5,000 to $6,000 per vehicle, much higher than those estimated by the agencies. Those studies commonly look at the employment associated with vehicle sales, but not the employment associated with producing the technologies needed to comply with the standards, or changes in labor intensity of production. Analyses that find increases in employment commonly start with increased vehicle sales as a result of the rule. Many of these analyses also note that even without increased unit sales, employment is likely to rise due to the additional technology content of the vehicles sold.[414] In both cases, "multiplier" effects, which extend employment impacts beyond the auto sector to impacts on suppliers, other sectors, and expenditure changes by workers, lead to large estimates, either positive or negative, of the employment effects of the rule. We received the suggestion to include in our analysis an alternative scenario where there is less than full employment; the implication of less than full employment is that multiplier effects are more likely. While we examined all of these different employment estimates, we decided to continue using our methodology from previous analyses, with some updates to our method of calculating the impacts.

In order to obtain an estimate of potential job increases per unit sales increase, we examined recent U.S. employment (original equipment manufacturers and suppliers) and U.S. production. Total employment in 2000 reached a peak in the Motor Vehicle and Parts Manufacturing sector of the economy averaging 1,313,500 workers (NAICS codes of 3361, 2, 3). Then there was a steady decline to 1,096,900 in 2006 and more rapid decreases in 2008, and 2009. Employment in 2009 averaged 664,000, employment in 2010 averaged 675,000 and employment in the first six months of 2011 has averaged 699,000. Table VII-19 shows how many vehicles are produced by the average worker in the industry. Averaging the information shown for the even years of 2000-2010, the average U.S. domestic employee produces 11.3 vehicles (the same number as in 2008 and 2010). Thus, assuming that a projected sales gain or loss divided by 11.3 would be one method of estimating the potential employment gain or loss in any one year. This provides a measurement in job years. This method underestimates the number of jobs per vehicle sold under the rule, because it does not take into account the additional employment associated with the additional fuel-saving technologies.

We also examined the employment impact for production and non-supervisory workers from the Bureau of Labor Statistics to see if there was a more direct link between their employment level and production than the white collar workers. There is a closer link between light vehicle production in the U.S. and the number of production and non-supervisory workers (for example, from 2002 to 2010, production fell by 44 percent; the number of production and non-supervisory workers in the industry fell by 44 percent and the number of white collar workers fell by 31

[414] UAW/NRDC/Center for American Progress, "Driving Growth: How Clean Cars and Climate Policy Can Create Jobs," March 2010, p.11

percent). However, in some years (2004 and 2006) the white-collar jobs had a higher percentage loss than the blue-collar jobs. In this analysis, the agency examines all jobs in the industry.

Table VII-19
U.S. Light Duty Vehicle Production and Employment

	U.S. Light Vehicle Production	Motor Vehicle and Parts U.S. Employment[415]	Production per Employee
2000	12,773,714	1,313,500	9.7
2002	13,568,385	1,151,300	11.8
2004	13,527,309	1,112,700	12.2
2006	12,855,845	1,069,800	11.7
2008	9,870,473	875,400	11.3
2010	7,597,147	674,600	11.3
Total/Average	70,192,873	6,197,300	11.3

The Administration projects that full employment will return in 2018.[416] When the economy is at full employment, a fuel economy regulation is unlikely to have much impact on net overall U.S. employment; instead, labor would primarily be shifted from one sector to another. These shifts in employment impose an opportunity cost on society, approximated by the wages of the employees, as regulation diverts workers from other activities in the economy. In this situation, any effects on net employment are likely to be transitory as workers change jobs (*e.g.*, some workers may need to be retrained or require time to search for new jobs, while shortages in some sectors or regions could bid up wages to attract workers). On the other hand, if a regulation comes into effect during a period of high unemployment, a change in labor demand due to regulation may affect net overall U.S. employment because the labor market is not in equilibrium. Schmalansee and Stavins point out that net positive employment effects are possible in the near term when the economy is at less than full employment due to the potential hiring of idle labor resources by the regulated sector to meet new requirements (*e.g.*, to install new equipment) and new economic activity in sectors related to the regulated sector longer run, the net effect on employment is more difficult to predict and will depend on the way in which the related industries respond to the regulatory requirements. This program is expected to affect employment in the regulated sector (auto manufacturing) and other sectors directly affected by the final rule: auto parts suppliers, auto dealers, the fuel supply market (which will face reduced petroleum production due to reduced fuel demand but which may see additional demand for electricity or other fuels). As discussed in the CAR and Ceres reports above, each of these

[415] U.S. employment data is from the Bureau of Labor Statistics, *available at* http://data.bls.gov/timeseries/CES3133600101?data_tool=XGtable (last accessed Aug. 10, 2012)
[416] Based on the Congressional Budget Office January 2012 Report, "The Budget and Economic Outlook, Fiscal Years 2012-2022," which predicted unemployment levels of 5.5% in 2018. See http://www.cbo.gov/publication/42905 (last accessed Aug. 10, 2012)

sectors could potentially have ripple effects throughout the rest of the economy. These ripple effects depend much more heavily on the state of the economy than do the direct effects. As noted above, though, in a full-employment economy, any changes in employment will result from people changing jobs or voluntarily entering or exiting the workforce. In a full-employment economy, employment impacts of this proposal will change employment in specific sectors, but it will have small, if any, effect on aggregate employment.

This rule would take effect in 2017 through 2025; by then, the current high unemployment may be moderated or ended. The Congressional Budget Office has predicted full employment by 2018.[417] To the extent that full employment is achieved, increases in employment are not possible. For that reason, this analysis does not include multiplier effects, but instead focuses on employment impacts in the most directly affected industries. Those sectors are likely to face the most concentrated employment impacts.

Table VII-20 shows the potential cumulative impact on auto sector employment over the MY 2017-2025 period in job years, without considering or quantifying the ripple effect. This table takes the results from sales and divides by 11.3 to obtain the impact on auto sector employment. To estimate the proportion of domestic employment affected by the change in sales, we use data from Ward's Automotive Group for total car and truck production in the U.S. compared to total car and truck sales in the U.S. For the period 2001-2010, the proportion is 66.7 percent. We thus weight sales by this factor to get an estimate of the effect on U.S. employment in the motor vehicle manufacturing sector due to this rule. As in the sales analysis, the table shows the potential impact for the preferred alternative for both the MY 2010 baseline and for the MY 2008 baseline at the 3 percent and 7 percent discount rates for 6 different cases.

Since the impact of this final rule on sales is very difficult to predict, and sales have the largest potential effect on employment, the impact of this final rule on employment is also very difficult to predict. As with sales, the impact on employment is heavily affected by the difference between manufacturers' investments in fuel-saving technologies[418] and consumers' valuation of fuel savings. However, since any negative impact of the rule on unit sales is partially offset by increased employment per vehicle sold, it is highly unlikely that the rule would lead to significant job losses in the short term in the automotive industry.

[417] Based on the Congressional Budget Office January 2012 Report, "The Budget and Economic Outlook, Fiscal Years 2012-2022," which predicted unemployment levels of 5.5% in 2018. See http://www.cbo.gov/publication/42905 *(last accessed Aug. 10, 2012).*

[418] As discussed above, these investments are affected both by manufacturers' beliefs about consumers' valuation of fuel economy, and by competitive dynamics, since the industry is composed of multiple firms, each of which considers the case where a competitor that doesn't invest ends up in a better position due to gas prices at the low end of the expected distribution.

Table VII-20
Analysis of Alternative Scenarios in Automotive Sector Employment[419] (in Thousands of Job Years Over the 9-Year Period 2017-2025)
Passenger Cars and Light Trucks Combined
Preferred Alternative

Years Fuel Valued by Manufacturers	Years Fuel Valued by Consumers	MYs 2017-2025 Employment Impact (3% discount rate) (000's)	MYs 2017-2025 Employment Impact (7% discount rate) (000's)
2008 Baseline			
0 Flat	3 yr.	54	45
0 Flat	5 yr.	223	191
1 yr. *	1 yr. *	-160	-138
1 yr.	3 yr.	-21	-26
3 yr. *	3 yr. *	-31	-32
5 yr. *	5 yr. *	0	-2
2010 Baseline			
0 Flat	3 yr.	59	51
0 Flat	5 yr.	225	193
1 yr. *	1 yr. *	-143	-155
1 yr.	3 yr.	-3	-8
3 yr. *	3 yr. *	-18	-19
5 yr. *	5 yr. *	7	6

* These scenarios are presented as theoretical cases. NHTSA believes it is unlikely that manufacturers and consumers would value improvements in fuel economy identically, and believes that on average, manufacturers will behave more conservatively in their assumptions of how consumers value fuel economy than how on average consumers will actually behave. NHTSA expects that in practice the number of years fuel is valued by manufacturers will be shorter than the number of years fuel is valued by consumers.

Scrappage Rates

The effect of this rule on the use and scrappage of older vehicles will be related to its effects on new vehicle prices, the fuel efficiency of new vehicle models, and the total sales of new vehicles. If the value of fuel savings resulting from improved fuel efficiency to the typical potential buyer of a new vehicle outweighs the average increase in new models' prices, sales of new vehicles will rise, while scrappage rates of used vehicles will increase slightly. This will

[419] The analysis does not reflect the likely positive impact in industry employment due to a change in vehicle content resulting from this rule.

cause the “turnover” of the vehicle fleet – that is, the retirement of used vehicles and their replacement by new models – to accelerate slightly, thus accentuating the anticipated effect of the rule on fleet-wide fuel consumption and CO_2 emissions. However, if potential buyers value future fuel savings resulting from the increased fuel efficiency of new models at less than the increase in their average selling price, sales of new vehicles will decline, as will the rate at which used vehicles are retired from service. This effect will slow the replacement of used vehicles by new models, and thus partly offset the anticipated effects of the final rules on fuel use and emissions.

Because the agencies are uncertain about how the value of projected fuel savings from the final rules to potential buyers will compare to their estimates of increases in new vehicle prices, we have not attempted to estimate explicitly the effects of the rule on scrappage of older vehicles and the turnover of the vehicle fleet.

VIII. BENEFITS FROM IMPROVED FUEL ECONOMY

A. Accounting for the Fuel Economy Rebound Effect

The rebound effect refers to the increase in vehicle use that results when an increase in fuel efficiency lowers the cost of driving, which encourages people to drive slightly more. Because this additional driving consumes fuel and produces emissions, it results in smaller fuel savings and reductions in emissions than would otherwise be expected to result from the standards established by this rulemaking. Thus the magnitude of the rebound effect is an important determinant of the *actual* fuel savings and emission reductions that are likely to result from adopting stricter fuel economy or emissions standards, and is an important parameter affecting EPA's and NHTSA's evaluation of the final standards for MY 2017-25 cars and light trucks.

Ideally, the rebound effect is measured directly by estimating the change in vehicle use, during some time period that results from a change in vehicle fuel efficiency.[420] Because data on vehicle use and fuel efficiency for the same sample of vehicles or time periods are rarely available, however, the rebound effect is often measured by analyzing the response of vehicle use to variation in fuel cost per mile driven, which depends on both vehicle fuel efficiency and fuel prices.[421] Other studies estimate the response of vehicle use or fuel consumption to variation in the price per gallon of gasoline, but these provide only limited guidance about the magnitude of the fuel economy rebound effect.

When expressed as a positive percentage, the elasticity of vehicle use with respect to fuel efficiency or fuel cost per mile driven expresses the percentage increase in vehicle use that results from a one percent increase in fuel efficiency or reduction in fuel cost per mile. For example, a 10 percent rebound effect means that a 20 percent increase in fuel efficiency or reduction in fuel cost per mile is expected to result in a 2 percent increase in VMT. The rebound effect also measures the fraction of fuel savings that would otherwise be expected to result from an increase in fuel efficiency, but is offset by increased vehicle use.

The fuel economy rebound effect for light-duty vehicles has been the subject of extensive research since the early 1980s. Although these studies have reported a wide range of estimates of its exact magnitude, they generally conclude that a significant rebound effect occurs when fuel

[420] Vehicle fuel efficiency is more often measured in terms of fuel consumption (gallons per mile) rather than fuel economy (miles per gallon) in rebound estimates.
[421] Fuel cost per mile is equal to the price of fuel in dollars per gallon divided by fuel economy in miles per gallon (or multiplied by fuel consumption in gallons per mile), so this figure declines when a vehicle's fuel efficiency increases.

efficiency improves or the cost per mile of driving decreases.[422] The most common approach to estimating its magnitude has been to analyze household survey data on vehicle use, fuel efficiency or consumption, fuel prices, and other variables that influence travel behavior. Other studies have used annual data on vehicle use, fuel prices, fuel economy, and other factors affecting motor vehicle travel for the U.S. as a whole, or combined such data for individual states, to estimate the rebound effect.[423] The following sections review these previous studies and summarize recent work on the rebound effect, and explain the basis for the 10 percent rebound effect EPA and NHTSA use in this rulemaking. Because of changes in available measures and data limitations, most studies of the rebound effect rely on data drawn from the period from 1966 through approximately the year 2000. While some older studies provide valuable information on the potential magnitude of the rebound effect, those that include more recent information may provide more reliable estimates of how this rule will affect future driving behavior.

Summary of Past Research on the Rebound Effect

To provide a more comprehensive overview of previous estimates of the rebound effect, EPA and NHTSA reviewed 27 studies of the rebound effect conducted from 1983 through 2011. The agencies then performed a detailed analysis of the 87 separate estimates of the long-run rebound effect reported in these studies, which is summarized in Table VIII-1 below.[424] As the table indicates, estimates of the long-run rebound effect range from as low as 6 percent to as high as 75 percent, with a mean value of 22 percent. Limiting the sample to estimates reported in published studies of the rebound effect narrows their range and increases their mean estimate slightly.

[422] Some studies estimate that the long-run rebound effect is significantly larger than the immediate response to increased fuel efficiency. Although their estimates of the adjustment period required for the rebound effect to reach its long-run magnitude vary, this long-run effect could be more appropriate for evaluating the fuel savings and emissions reductions resulting from stricter standards that would apply throughout the lifetime of future model year vehicles.

[423] In effect, these studies treat U.S. states as a data “panel” by applying appropriate estimation procedures to data consisting of each year’s average values of these variables for the separate states.

[424] In some cases, NHTSA derived estimates of the overall rebound effect from more detailed results reported in the studies. For example, where studies estimated different rebound effects for households owning different numbers of vehicles but did not report an overall value, the agency computed a weighted average of the reported values using the distribution of households among vehicle ownership categories.

Table VIII-1
Summary Statistics for Estimates of the Rebound Effect

Category	Number of Studies	Number of Estimates	Range		Distribution		
			Low	High	Median	Mean	Std. Deviation
All Estimates	27	87	6%	75%	19%	22%	13%
Published Estimates	20	68	7%	75%	19%	23%	13%
Authors' Preferred Estimates	20	20	9%	75%	22%	22%	15%
U.S. Time-Series Estimates	7	34	7%	45%	14%	18%	9%
Household Survey Estimates	17	38	6%	75%	22%	25%	15%
Pooled U.S. State Estimates	3	15	8%	58%	22%	23%	12%
Constant Rebound Effect	18	48	6%	75%	16%	22%	15%
Variable Rebound Effect:							
Reported Estimates	12	37	10%	45%	20%	22%	9%
Updated to Current Conditions	12	37	7%	56%	16%	19%	12%

Table VIII-1 shows that the type of data used to estimate the rebound effect has an important effect on its estimated magnitude. While studies using national and state data on aggregate vehicle use have found relatively consistent long-run estimates of the rebound effect, household surveys display more variability. The 34 estimates derived from analysis of U.S. aggregate time-series data produce a mean estimate of 18 percent for the long-run rebound effect, while the mean of 15 estimates based on state data is somewhat higher (23 percent). A recurring problem with studies that use national or state-level aggregate data on vehicle use is that their measures of fuel efficiency are invariably constructed from data on aggregate fuel consumption and the same aggregate vehicle use measure used as their dependent variables. This means that their measures of fuel efficiency are mathematically related to their dependent variables, and that the usual statistical techniques for minimizing the effect of such joint causality cannot be fully effective. At the same time, their measures of aggregate VMT and average fuel economy reflect the shifting of travel among vehicles with different fuel economy levels during the time period (usually a year) they span, which means that both variables already incorporate the effect the model is attempting to measure. For these reasons, estimates of the rebound effect based on national or state aggregate VMT data need to be interpreted cautiously.

In contrast, the mean of 38 estimates based on household survey data is slightly larger than those based on national and state aggregate data, and there is wider variation in survey-based estimates. There are several possible explanations for this wider variability in estimates based on survey data. One explanation is that some of these studies do not include vehicle age as an explanatory variable, so any correlation between vehicle age and fuel efficiency may cause their estimates of the latter's effect to be less reliable. Another explanation is that most of these studies find that the magnitude of the rebound effect differs according to the number of vehicles a household owns, and the average number of vehicles owned per household differs among the surveys used to derive these estimates. Still another possibility is that it some of these studies cannot distinguish the impact of residential location on vehicle use from that of fuel prices, since households that reside in urban areas are likely to face slightly higher fuel prices.

Another important distinction among studies of the rebound effect is whether they assume that the effect is constant, or varies over time in response to changes in fuel costs, personal income, or vehicle ownership levels. Most studies using aggregate annual data for the U.S. assume a constant rebound effect, although some of these studies test whether the effect can vary as changes in retail fuel prices or average fuel efficiency alter fuel cost per mile driven. Many studies using household survey data estimate significantly different rebound effects for households owning varying numbers of vehicles, with most finding that the rebound effect is larger among households that own more vehicles.[425] Finally, one recent study using state-level

[425] Six of the household survey studies evaluated in Table VIII-1 found that the rebound effect varies in relation to the number of household vehicles. Of those six studies, four found that the rebound effect rises with higher vehicle ownership, and two found that it declines.

data concludes that the rebound effect varies directly in response to changes in personal income and the degree of urbanization of U.S. cities, as well as fuel costs. As Table VIII-1 shows, the 48 estimates assuming a constant rebound effect produce a mean of 22 percent, identical to that of the 37 estimates reported in studies that allowed the rebound effect to vary in response to fuel prices, vehicle ownership, or household income. When they are updated to reflect current fuel prices, income levels, and patterns of automobile ownership, estimates from studies allowing the rebound effect to vary average 19 percent.

More Recent Research on the Rebound Effect

Some recent studies indicate that the rebound effect has decreased over time as incomes have increased and (until recently) fuel costs as a share of total travel costs have declined.[426] One reason the rebound effect might vary over time is that the responsiveness of vehicle use to the fuel component of driving costs will be larger when it represents a larger proportion of the total cost of driving. Similarly, as incomes rise the sensitivity of vehicle use to changes in fuel costs may decrease if people view the cost of time spent driving – which is likely to be related to their income levels – as a larger component of the total cost.

Small and Van Dender combined time series data for individual states to estimate the rebound effect, and used a specification that allowed its magnitude to vary in response to changes in fuel costs and income levels.[427] For the time period from 1966-2001, their study found a long-run rebound effect of 22 percent, which is consistent with previously published studies. For the most recent five year period (1997-2001), however, their estimate of the long-run rebound effect declined to 11 percent. Furthermore, when these authors updated their estimate through 2004, the long-run rebound effect for the most recent five year period (2000-2004) declined further to 6 percent.[428] Finally, using their model to project the future rebound effect for the period 2010-2030 produced estimates even below the 6 percent figure for a range of gasoline price and

[426] While real gasoline prices have varied over time, fuel costs (which reflect both fuel prices and fuel efficiency) as a share of total vehicle operating costs declined substantially from the mid-1970s until the mid-2000s when the share increased modestly (see Greene (2010)). Note that two studies discussed in this section, Small and Van Dender (2007) and Hymel, Small, and Van Dender (2010), find that the rebound effect is more strongly dependant on income than fuel costs. A third study, Greene (2010), did not directly test the effect of fuel cost on rebound, but found evidence supporting the strong effect from income. Although several studies have shown that the rebound effect rises with household vehicle ownership (see section 4.2.5.1), which generally increases with income, these findings indicate that income has had a negative effect on rebound.

[427] Small, K. and K. Van Dender, 2007a. "Fuel Efficiency and Motor Vehicle Travel: The Declining Rebound Effect", The Energy Journal, vol. 28, no. 1, pp. 25-51. Available at http://www.socsci.uci.edu/~ksmall/Rebound_Working_Paper_corrected.pdf (last accessed August 1, 2012)

[428] Small, K. and K. Van Dender, 2007b. "Long Run Trends in Transport Demand, Fuel Price Elasticities and Implications of the Oil Outlook for Transport Policy," OECD/ITF Joint Transport Research Centre Discussion Papers 2007/16, OECD, International Transport Forum. Available at http://trid.trb.org/view.aspx?id=868421 (last accessed August 1, 2012)

income projections, although these projections extended well outside the range of historical experience over which it was estimated.[429] More recently, Hymel extended the Small and Van Dender model to incorporate the effect of traffic congestion on vehicle use.[430] While controlling for congestion increased their estimates of the rebound effect significantly, this more recent study also found that the rebound effect appeared to be declining over time. For the time period from 1966-2004, Hymel, Small, and Van Dender estimated a long-run rebound effect of 24 percent, while for the year 2004 their estimate was 13 percent.

Recent research conducted by Greene under contract to EPA lends further support the hypothesis that the magnitude of the rebound effect may be declining over time.[431] Using national aggregate data on vehicle use for the period 1966-2007, Greene found that fuel prices had a statistically significant impact on VMT, yet increases in average fuel efficiency by themselves did not. Greene also tested Small and Van Dender's specification allowing the elasticity of fuel cost per mile to decrease with increasing income, and confirmed their finding that the rebound effect appears to be declining over time. Using Greene's preferred functional form, the projected rebound effect is approximately 12 percent in 2007, but declines to 10 percent in 2010 and further to 8 percent in 2030. Again, however, these forecasts extrapolate Greene's results well outside the range of historical experience from which they were derived.

More recent research provides conflicting evidence on the magnitude of the rebound effect. Bento *et al.* analyzed data on household vehicle ownership and use from the 2001 National Household Travel Survey using a complex model of household purchases, ownership, retirement, and use of both new and used vehicles.[432] These authors estimated that the rebound effect varied widely among households owning different types and ages of automobiles and having different demographic characteristics, averaging 34 percent for all households. Gillingham used a large sample of vehicles registered in California and detailed estimates of local fuel prices to estimate elasticities of vehicle use with respect to gasoline prices and fuel economy. His estimate of the

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[429] Report by Kenneth A. Small of University of California at Irvine to EPA, "The Rebound Effect from Fuel Efficiency Standards: Measurement and Projection to 2030", June 12, 2009 (Docket EPA-HQ-OAR- 2010-0799-0797).

[430] Hymel, Kent M., Kenneth A. Small, and Kurt Van Dender, "Induced demand and rebound effects in road transport," Transportation Research Part B: Methodological, Volume 44, Issue 10, December 2010, Pages 1220-1241, ISSN 0191-2615, DOI: 10.1016/j.trb.2010.02.007.

[431] Greene, David, "Rebound 2007: Analysis of National Light-Duty Vehicle Travel Statistics," March, 2010. Available at http://www.euro-ciss.eu/fileadmin/user_upload/Redaktion/Seco@home/nachhaltiger_Energiekonsum/Literatur/rebound_effekt/Greene_2010.pdf (last accessed August 1, 2012)

[432] Bento, Antonio M., Lawrence H. Goulder, Mark R. Jacobsen, and Roger H. von Haefen, "Distributional and Efficiency Impacts of Increased US Gasoline Taxes," *American Economic Review* 99 (2009), pp. 1–37. For information on the 2001 National Household Travel Survey, see http://nhts.ornl.gov/introduction.shtml#2001 (last accessed July 17, 2012).

former elasticity was -0.17, while his corresponding estimate of the elasticity of vehicle use with respect to fuel economy was 0.06.[433]

West and Pickrell used a large sample of vehicles from the 2009 National Household Travel Survey to analyze vehicle use decisions among households that own multiple vehicles.[434] Controlling for vehicle type and age as well as for household characteristics and location, they estimated that the fuel economy rebound effect ranged from 0-9 percent among single-vehicle households, 10-26 percent among households owning two vehicles, and 26-34 percent among three-vehicle households. Most recently, Su[435] used quantile regression analysis to analyze variation in the rebound effect among households included in the 2009 National Household Travel Survey. Su's estimates of the rebound effect varied from 11 to 19 percent depending on the total number of miles driven annually by members of the household, with the smallest values applying to households at the extremes of the distribution of annual vehicle use, and the largest values to households in the middle of that distribution.

Basis for Rebound Effect Used by EPA and NHTSA in this Rule

As the preceding discussion indicates, estimates of the historical magnitude of the rebound effect and its projected future value diverge widely, and there is some evidence that the magnitude of the rebound effect appears to be declining over time. NHTSA requires a single point estimate for the rebound effect as an input to its central analysis, although a range of estimates can be used to test the sensitivity to uncertainty about its exact magnitude. Based on a combination of historical estimates of the rebound effect, more recent research, and evidence that its magnitude may be declining, NHTSA used a rebound effect of 10 percent to analyze the impacts of this final rule (*i.e.*, we assume a 10 percent increase in fuel economy resulting from these standards would result in a 1 percent increase in VMT), with a range of 5-25 percent for NHTSA's sensitivity testing.

As Table VIII-1 indicates, the 10 percent estimate is toward the low end of the range reported in previous research, and also below many recent estimates of the rebound effect. However, other recent research – particularly that conducted by Hymel, Small and Van Dender, Small and Van Dender, and Greene – reports evidence that the magnitude of the rebound effect is declining over time. As a consequence, the agencies concluded that a value on the low end of the historical

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433 Gillingham, Kenneth. "The Consumer Response to Gasoline Price Changes: Empirical Evidence and Policy Implications." Ph.D. diss., Stanford University, 2011.

434 West, Rachel, and Don Pickrell, "Factors Affecting Vehicle Use in Multiple-Vehicle Households," http://onlinepubs.trb.org/onlinepubs/conferences/2011/NHTS1/West.pdf (last accessed July 17, 2012). For information on the 2009 National Household Travel Survey, see http://nhts.ornl.gov/introduction.shtml (last accessed July 17, 2012).

435 Su, Qing, "A Quantile Regression Analysis of the Rebound Effect: Evidence from the 2009 National Household Transportation Survey in the United States," *Energy Policy* 45 (2012), pp. 368-377. Available at http://www.sciencedirect.com/science/article/pii/S0301421512001620 (last accessed August 1, 2012)

estimates reported in Table VIII-1 is likely to provide a more reliable estimate of its magnitude during the future period spanned by the lifetimes of the vehicles that are subject to this rule. The 10 percent estimate lies within the 10-30 percent range of estimates for the historical rebound effect reported in most previous research, and at the upper end of the 5-10 percent range of estimates for the future rebound effect derived from recent studies by Small and Van Dender and by Greene. Thus the 10 percent value is not based on a single estimate drawn from particular studies, but instead represents a reasonable compromise between historical estimates of the rebound effect and forecasts of its projected future value.

On-Road Fuel Economy Adjustment

Actual fuel economy levels achieved by vehicles in on-road driving fall significantly short of their levels measured under the laboratory-like test conditions used by EPA to establish its published fuel economy ratings for different models. In analyzing the fuel savings from alternative passenger car and light truck CAFE standards, the agency adjusts the actual fuel economy performance of each passenger car and light truck model downward from its rated value to reflect the expected size of this on-road fuel economy "gap." In December 2006, EPA adopted changes to its regulations on fuel economy labeling, which were intended to bring vehicles' rated fuel economy levels closer to their actual on-road fuel economy levels.[436]

Supplemental analysis reported by EPA as part of its Final Rule indicates that actual on-road fuel economy for light-duty vehicles averages 20 percent lower than published fuel economy levels.[437] For example, if the overall EPA fuel economy rating of a light truck is 20 mpg, the on-road fuel economy actually achieved by a typical driver of that vehicle is expected to be 16 mpg (20*.80). The agency has employed EPA's revised estimate of this on-road fuel economy gap in its analysis of the fuel savings resulting from alternative CAFE standards for MY 2017-2025 passenger cars and light trucks.

An analysis conducted by NHTSA confirmed that EPA's estimate of a 20 percent gap between test and on-road fuel economy is well-founded. The agency used data on the number of passenger cars and light trucks of each model year that were in service (registered for use) during each calendar year from 2000 through 2006, average fuel economy for passenger cars and light trucks produced during each model year, and estimates of average miles driven per year by cars and light trucks of different ages during each calendar year over that period. These data were

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[436] EPA, Fuel Economy Labeling of Motor Vehicles: Revisions To Improve Calculation of Fuel Economy Estimates; Final Rule, 40 CFR Parts 86 and 600, Federal Register, December 27, 2006, pp. 77872-77969, http://www.epa.gov/fedrgstr/EPA-AIR/2006/December/Day-27/a9749.pdf (last accessed on August 1, 2012).

[437] EPA, *Final Technical Support Document: Fuel Economy Labeling of Motor Vehicle Revisions to Improve Calculation of Fuel Economy Estimates*, Office of Transportation and Air Quality EPA420-R-06-017 December 2006, Chapter II, http://www.epa.gov/fueleconomy/420r06017.pdf (last accessed on August 1, 2012).

combined to develop estimates of the usage-weighted average fuel economy that the U.S. passenger car and light truck fleets would have achieved during each year from 2000 through 2006 under test conditions.

B. Benefits to Vehicle Buyers from Improving Fuel Economy

The main source of economic benefits from raising CAFE standards is the value of the resulting fuel savings over the lifetimes of vehicles that are required to achieve higher fuel economy. The annual fuel savings under each alternative CAFE standard are measured by the difference between total annual fuel consumption by passenger cars or light trucks with the fuel economy they are expected to achieve in on-road driving under that alternative standard, and their annual fuel consumption with the fuel economy levels – again adjusted for differences between test and actual on-road driving conditions – they would achieve under the baseline alternative. The sum of these discounted annual fuel savings over each calendar year that cars or light trucks produced during a model year are expected to remain in service represents their cumulative lifetime fuel savings with that alternative CAFE standard in effect.

Vehicle Survival Rates

These annual fuel savings depend on the number of vehicles that remain in use during each year of a model year's lifetimes. The number of passenger cars or light trucks manufactured during a model year that remains in service during each subsequent calendar year is estimated by multiplying the original number expected to be produced during that model year by the proportion of vehicles expected to remain in service to the age they will have reached during that year. The proportions of passenger cars and light trucks expected to remain in service at each age up to their maximum lifetimes (30 and 37 years, respectively) are shown in Table VIII-2.[438] These "survival rates," which are estimated from experience with recent model-year vehicles, are slightly different than the survival rates used in past NHTSA analyses, since they reflect recent increases in durability and usage of more recent passenger car and light truck models.[439]

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[438] The maximum age of cars and light trucks was defined as the age when the number remaining in service declines below two percent of those originally produced. Based on an examination of recent registration data for previous model years, these maximum ages are 30 years for passenger cars and 37 years for light trucks.

[439] The survival rates were calculated from R.L. Polk, National Vehicle Population Profile (NVPP), 1977-2010; see NHTSA, "Vehicle Survival and Travel Mileage Schedules," Office of Regulatory Analysis and Evaluation, NCSA, January 2006, pp. 9-11, Docket No. 22223-2218, for a description of the methodology used. Polk's NVPP is an

Vehicle Use
Annual fuel savings during each year of a model year's lifetime also depend on the number of miles that the remaining vehicles in use are driven. For the analysis supporting this final rule, NHTSA developed updated estimates of average annual miles driven by household vehicles at each age using the Federal Highway Administration's 2009 National Household Transportation Survey (NHTS), which began in March 2008 and continued through April 2009. These updated estimates differ from those employed in previous NHTSA analyses, which were based on the previous 2001 NHTS.[440]

The agency's revised estimates of car and light truck use also differ from its previous estimates because they incorporate the number of fleet vehicles in service during 2008 and their average use, derived from various editions of the U.S. Energy Information Administration's *Annual Energy Outlook*. Fleet vehicles, which include those purchased by corporations and government agencies for use by employees as well as rental vehicles, are driven more intensively than household vehicles. Thus incorporating their presence in the light-duty fleet and higher annual usage raises NHTSA's estimates of vehicle use at low ages; however, fleet vehicles typically enter the used vehicle market and are purchased by households before reaching age 6, so including them does not change the estimates of vehicle use derived from the NHTS after that age.

Table VIII-3 reports NHTSA's updated estimates of average car and light truck use, not adjusted for vehicle survival rates. The estimated ***total*** number of miles driven by passenger cars or light trucks produced in a given model year over the course of the vehicles' lifetimes is estimated by

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annual census of passenger cars and light trucks registered for on-road operation in the United States as of Jul 1 each year. NVPP registration data from vehicle model years 1977 to 2010 were used to develop the survival rates reported in Table VIII-2. Survival rates were averaged for the five most recent model years to reach each age up to 30 years, and polynomial models were fitted to these data using regression analysis to develop smooth relationships between age and the proportion of cars or light trucks surviving to that age.

440 See also NHTSA, "Vehicle Survival and Travel Mileage Schedules," Office of Regulatory Analysis and Evaluation, January 2006, pp. 15-17 (Docket NHTSA-2009-0062-0012.1). The original source of information on annual use of passenger cars and light trucks by age used in this analysis is the 2001 National Household Travel Survey (NHTS), jointly sponsored by the Federal Highway Administration, Bureau of Transportation Statistics, and National Highway Traffic Safety Administration. A process similar to that described in this document was used to develop estimates of the average number of miles driven by household vehicles at each age using the sample of approximately 300,000 vehicles included in the 2009 National Household Travel Survey.

multiplying these age-specific estimates of average car and light truck use by the number of vehicles projected to remain in service during that year.

Applying the survival rates of Table VIII-2 to the age-dependent VMT estimates of Table VIII-3 yields the survival-adjusted VMT projections shown in Table VIII-4. The VMT schedules shown in Tables VIII-3 and VIII-4 are specific to vehicles of MY 2017 and are intended to be illustrative of the VMT schedules in the analysis of this rule's impact; however, VMT schedules vary by model year, for which further explanation and detail are provided in the subsequent section "adjusting vehicle use." The sum of the survival-weighted mileage in Table VIII-4 over the 30-year maximum lifetime of MY 2017 passenger cars is 218,546 miles; over the 37-year maximum lifetime of light trucks, this value is 248,024 miles. Fuel savings and other benefits resulting from higher CAFE standards for passenger cars and light trucks are calculated over their respective lifetimes and total expected mileage. It should be noted, however, that survival-weighted mileage is extremely low (less than 1,000 miles per year) after age 22 for cars and after age 27 for light trucks, and thus has little impact on lifetime fuel savings or other benefits from higher fuel economy, particularly after discounting those benefits to their present values.

In interpreting the survival and annual mileage estimates reported in Tables VIII-2, VIII-3, and VIII-4, it is important to understand that vehicles are considered to be of age 1 during the calendar year that coincides with their model year. For example, model year 2017 vehicles will be considered to be of age 1 during calendar year 2017. This convention is used in order to account for the fact that vehicles produced during a model year are typically first offered for sale in June through September of the preceding calendar year, depending on manufacturer). Thus virtually all of the vehicles produced during a model year will be in use for some or all of the calendar year coinciding with their model year, and they are considered to be of age 1 during that year.[441]

[441] As an illustration, virtually the entire production of model year 2017 cars and light trucks will have been sold by the end of calendar year 2017, so those vehicles are defined to be of age 1 during calendar year 2017. Model year 2017 vehicles are subsequently defined to be of age 2 during calendar year 2018, age 3 during calendar year 2019, and so on. One complication arises because registration data are typically collected for July 1 of each calendar year, so not all vehicles produced during a model year will appear in registration data until the calendar year when they have reached age 2 (and sometimes age 3) under this convention.

Table VIII-2
Survival Rates by Vehicle Age
for Passenger Cars and Light Trucks

Vehicle Age	**Estimated Survival Fraction** **Passenger Cars**	**Estimated Survival Fraction** **Light Trucks**
1	1.0000	1.0000
2	0.9878	0.9776
3	0.9766	0.9630
4	0.9614	0.9428
5	0.9450	0.9311
6	0.9298	0.9152
7	0.9113	0.8933
8	0.8912	0.8700
9	0.8689	0.8411
10	0.8397	0.7963
11	0.7999	0.7423
12	0.7556	0.6916
13	0.7055	0.6410
14	0.6527	0.5833
15	0.5946	0.5350
16	0.5311	0.4861
17	0.4585	0.4422
18	0.3832	0.3976
19	0.3077	0.3520
20	0.2414	0.3092
21	0.1833	0.2666
22	0.1388	0.2278
23	0.1066	0.2019
24	0.0820	0.1750
25	0.0629	0.1584
26	0.0514	0.1452
27	0.0420	0.1390
28	0.0337	0.1250
29	0.0281	0.1112
30	0.0235	0.1028
31		0.0933
32		0.0835
33		0.0731
34		0.0619
35		0.0502
36		0.0384
37		0.0273

Adjusting Vehicle Use

The average number of miles driven by passenger cars and light trucks of each age varies from year to year in the Volpe model, in response to changes in the real price of gasoline. The reference year for determining baseline annual mileage by vehicle age and the accompanying price of gasoline is 2008, the year when most households participating in the 2009 National Household Travel Survey (NHTS) were interviewed. To account for the effect on vehicle use of subsequent increases in fuel prices, the estimates of annual vehicle use derived from the 2009 NHTS and EIA's estimates of fleet vehicle use (as described above) were first adjusted to reflect the forecasts of gasoline prices for future years reported in the AEO 2012 Early Release.

This adjustment accounts for the difference between the average price per gallon of fuel projected for each year over the expected lifetimes of model year 2017-2025 passenger cars and light trucks, and the average price that prevailed in 2008. The elasticity of annual vehicle use with respect to fuel cost per mile corresponding to the 10% fuel economy rebound effect used in this analysis (i.e., an elasticity of -0.10) was applied to the percent difference between each future year's fuel prices and those prevailing in 2008 to adjust the estimates of vehicle use for that baseline year to reflect the effect of future changes in future fuel prices.

In addition, the agency's initial estimates of light-duty vehicles use (which include both household and fleet vehicles, as discussed above) are adjusted to account for differences in the fuel economy of vehicles in use during 2008 and projected fuel economy levels for future model years. For example, the fuel economy of cars and light trucks produced during model year 2017 is projected to be higher than those of the model years making up the light-duty vehicle fleet during 2008, even under the baseline alternative considered for this final rule (which assumes that the MY 2016 standard is extended to apply to subsequent model years).

Thus the annual number of miles driven by MY 2017 cars and light trucks is projected to be higher at each age throughout their lifetimes than for vehicles of that same age in use during 2008. Again for example, MY 2017 light trucks are expected to be driven more in the year 2021, when they will have reached age five, than were MY 2004 light trucks during 2008, when they were also of age five. The magnitude of this adjustment depends on the difference between the (on-road) fuel economy projected for MY 2017 light trucks, and that achieved by MY 2004 light trucks, since the adjustment applies the 10% fuel economy rebound effect to this difference. As a consequence, the magnitude of this adjustment differs for cars and light trucks produced during each model year from 2017 through 2025, and also varies each year of their projected lifetimes. Moreover, its magnitude differs among the regulatory alternatives evaluated for this final rule, because the fuel economy levels of MY 2017-25 cars and light trucks differ among each of these alternatives.

Finally, the estimates of annual miles driven by passenger cars and light trucks at each age were also adjusted to reflect projected future growth in average use of vehicles at all ages during their expected lifetimes. Increases in the average number of miles cars and trucks are driven each year have been an important source of historical growth in *total* car and light truck use, and are expected to represent an important source of future growth in total light-duty vehicle travel as well. As an illustration of the importance of growth in average vehicle use, the total number of miles driven by passenger cars increased 1.5 percent annually from 1985 through 2005, while the total number of cars registered for in the U.S. grew by only about 0.3 percent annually.[442,443] Further, the AEO 2012 Early Release Reference Case forecasts of total car and light truck use and of the number of cars and light trucks in use suggest that their average annual use will continue to increase gradually from 2010 through 2030. For this analysis, annual growth in vehicle miles traveled was assumed to average 0.6% per year annually. Thus in effect, there are a large number of VMT schedules used in the Volpe model, changing each year and changing by alternative because of the rebound effect.

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[442] Calculated from data reported in FHWA, Highway Statistics, Table vm201in files "Summary to 1995", and annual editions ranging from 1996 to 2005, available at http://www.fhwa.dot.gov/policy/ohpi/hss/hsspubs.cfm (last accessed August 1, 2012).

[443] A slight increase in the fraction of new passenger cars remaining in service beyond age 10 has accounted for a small share of growth in the U.S. automobile fleet. The fraction of new automobiles remaining in service to various ages was computed from R.L. Polk vehicle registration data for 1977 through 2005 by the agency's Center for Statistical Analysis.

Table VIII-3
Example Rebound-Adjusted Annual Vehicle-Miles Traveled (VMT)
by Age for MY 2017 Passenger Cars and Light Trucks
Not Adjusted for Survival

Vehicle Age	Example VMT Passenger Cars	Example VMT Light Trucks
1	16,467	18,628
2	16,323	18,396
3	16,147	18,215
4	15,890	17,930
5	15,669	17,682
6	15,397	17,287
7	15,110	16,951
8	14,809	16,489
9	14,481	16,036
10	14,175	15,602
11	13,770	15,059
12	13,437	14,634
13	13,022	14,109
14	12,647	13,622
15	12,222	13,032
16	11,800	12,513
17	11,401	12,065
18	11,016	11,580
19	10,629	11,110
20	10,221	10,703
21	9,879	10,353
22	9,602	10,138
23	9,460	9,884
24	9,171	9,878
25	8,970	9,710
26	8,769	9,728
27	8,648	9,801
28	8,501	9,850
29	8,405	9,900
30	8,365	9,949
31		9,999
32		10,049
33		10,099
34		10,150
35		10,200
36		10,251
37		10,303

Table VIII-4
Example Rebound-Adjusted Annual Vehicle-Miles Traveled (VMT)
by Age for MY 2017 Passenger Cars and Light Trucks
Adjusted for Survival

Vehicle Age	Example VMT Passenger Cars	Example VMT Light Trucks
1	16,467	18,628
2	16,125	17,983
3	15,769	17,540
4	15,277	16,904
5	14,808	16,463
6	14,316	15,821
7	13,770	15,141
8	13,198	14,345
9	12,582	13,487
10	11,903	12,423
11	11,014	11,178
12	10,153	10,120
13	9,187	9,043
14	8,254	7,946
15	7,267	6,972
16	6,267	6,083
17	5,227	5,335
18	4,221	4,604
19	3,271	3,911
20	2,467	3,309
21	1,811	2,761
22	1,332	2,309
23	1,008	1,996
24	752	1,729
25	565	1,538
26	451	1,413
27	363	1,363
28	286	1,231
29	237	1,100
30	197	1,023
31		933
32		839
33		738
34		628
35		512
36		394
37		281

Estimating Annual Fuel Consumption
NHTSA estimated annual fuel consumption during each year of the expected lifetimes of model year 2017-2025 cars and light trucks with alternative CAFE standards in effect by dividing the total number of miles that a model year's surviving vehicles are driven by the fuel economy that they are expected to achieve under each alternative standard.[444] Lifetime fuel consumption by each model year's cars and light trucks is the sum of the annual use by the vehicles produced during that model year that are projected to remain in service during each year of their expected lifetimes. In turn, the *savings* in lifetime fuel consumption by MY 2017-2025 cars and light trucks that would result from alternative increases in CAFE standards is the difference between their lifetime fuel use at the fuel economy level they are projected to attain under the baseline, and their lifetime fuel use at the higher fuel economy level they are projected to achieve under each alternative standard.

NHTSA's analysis values the economic benefits to vehicle owners and to the U.S. economy that result from future fuel savings over the full expected lifetimes of MY 2017-2025 passenger cars and light trucks. This reflects the agency's assumption that while the purchasers of new vehicles might not realize the full lifetime benefits of improved fuel economy, subsequent owners of those vehicles will continue to experience the resulting fuel savings until they are retired from service. Of course, not all vehicles produced during a model year remain in service for the complete lifetimes (30 years for passenger cars or 37 years for light trucks) of each model year. Due to the pattern of vehicle retirements with increasing age, the expected or average lifetimes of typical representative cars and light trucks are approximately half of these figures.

Economic Benefits from Reduced Fuel Consumption
The economic value of fuel savings resulting from alternative CAFE standards is estimated by applying the Reference Case projections of future fuel prices from the Energy Information Administration's Annual Energy Outlook 2012 Early Release to each future year's estimated fuel savings. The AEO 2012 Early Release Reference Case projections of future fuel prices, which is reported in Table VIII-5a, represents retail prices per gallon of fuel, including federal, state, and any applicable local taxes. While the retail price of fuel is the proper measure for valuing fuel savings from the perspective of *vehicle owners*, two adjustments to the retail prices are necessary in order to accurately reflect the economic value of fuel savings to *the U.S. economy*. NHTSA utilizes AEO Reference Case fuel price projections in the impact analysis of each of the

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[444] The total number of miles that vehicles are driven each year is slightly different under each alternative as a result of the fuel economy "rebound effect," which is discussed in detail elsewhere in this chapter.

alternative fuel economy scenarios examined; this approach implicitly assumes that the CAFE standards will have no impact on fuel prices.

First, federal, state, and local taxes are excluded from the social value of fuel savings because these do not reflect costs of resources used in fuel production, and thus do not reflect resource savings that would result from reducing fuel consumption. Instead, fuel taxes simply represent resources that are transferred from purchasers of fuel to road and highway users, since fuel taxes primarily fund construction and maintenance of those facilities. Any reduction in local, state, or federal fuel tax payments by fuel purchasers will reduce government revenues by the same amount, thus ultimately reducing the value of government-financed services by approximately that same amount. The benefit derived from lower taxes to individuals is thus likely to be offset exactly by a reduction in the value of services funded using those tax revenues.

Second, the economic cost of externalities generated by U.S. consumption and imports of petroleum products will be reduced in proportion to fuel savings resulting from higher CAFE standards. The estimated economic value of these externalities, which is discussed in detail in the subsequent section of this chapter, is converted into its per-gallon equivalent and added to the pre-tax price of gasoline in order to measure this additional benefit to society for each gallon of fuel saved. This also allows the magnitude of these externalities to be easily compared to the value of the resources saved by reducing fuel production and use, which represents the most important component of the social benefits from saving gasoline.

Table VIII-5a illustrates the adjustment of projected retail fuel prices to remove the value of fuel taxes and add the value of economic externalities from petroleum imports and use. AEO 2012 Early Release Reference Case fuel price projections are available through 2040; however, NHTSA's analysis of the value of fuel savings over the lifetimes of MY 2017-2025 cars and light trucks requires fuel price projections beyond this horizon, as calendar year 2061 is the last year during which a significant number of MY 2025 vehicles are projected to remain in service.[445] To obtain fuel price projections for the years 2041 through 2061, the agency assumes that retail fuel prices will continue to increase after 2040 at the average rates reported in the AEO 2012 Early Release Reference Case projections over the period from 2010 through 2040 (in

[445] The agency defines the maximum lifetime of vehicles as the highest age at which more than 2 percent of those originally produced during a model year remain in service. In the case of light-duty trucks, this occurs at vehicle age of 37 years.

constant-dollar terms).[446] As Table VIII-5a shows, the projected retail price (including taxes) of gasoline expressed in 2010 dollars rises steadily over the projection period, from \$3.43 in 2011 to \$5.81 in 2061.

The agency has updated its estimates of gasoline taxes (all expressed in 2010 dollars) for federal taxes (\$0.18 per gallon) state taxes (\$0.22 per gallon), and local taxes (\$0.02 per gallon), consistent with tax rates used by EIA in the AEO 2012 Early Release. NHTSA followed EIA's assumptions that state and local gasoline taxes will keep pace with inflation in nominal terms, and thus remain at current levels when expressed in constant 2010 dollars. Federal gasoline taxes, however, are projected by EIA to remain unchanged in *nominal* terms, and thus decline throughout future years when expressed in constant 2010 dollars. NHTSA also incorporated this assumption in its projections. These differing assumptions about the likely future behavior of federal and state/local fuel taxes are consistent with recent historical experience, which reflects the fact that federal motor fuel taxes as well as most state and local fuel taxes are specified on a cents-per-gallon basis (some state taxes are levied as a percentage of the wholesale price of fuel), and typically require legislation to change.

[446] The average rate of growth is calculated as: ((AEO-forecasted 2040 fuel price)/(AEO 2010 fuel price))^(1/30), which yields an average growth rate of approximately 1.47%.

Table VIII-5a
Adjustment of Projected Retail Gasoline Prices
to Reflect the Economic Value of Fuel Savings

Year	**AEO 2012 Projection of Retail Gasoline Price, Including Federal, State, and Local Taxes**	**Projected Federal, State, and Local Taxes**	**Projected Gasoline Price, Excluding Taxes**
	(2010 $/gallon)	(2010 $/gallon)	(2010 $/gallon)
2010	$2.76	$0.42	$2.34
2011	$3.43	$0.42	$3.01
2012	$3.31	$0.41	$2.90
2013	$3.28	$0.41	$2.87
2014	$3.41	$0.41	$3.00
2015	$3.53	$0.40	$3.13
2016	$3.57	$0.40	$3.17
2017	$3.64	$0.40	$3.24
2018	$3.66	$0.39	$3.27
2019	$3.70	$0.39	$3.31
2020	$3.75	$0.39	$3.36
2021	$3.77	$0.38	$3.39
2022	$3.76	$0.38	$3.38
2023	$3.77	$0.38	$3.39
2024	$3.81	$0.38	$3.43
2025	$3.84	$0.37	$3.47
2026	$3.86	$0.37	$3.49
2027	$3.88	$0.37	$3.51
2028	$3.91	$0.37	$3.54
2029	$3.93	$0.37	$3.56
2030	$3.96	$0.36	$3.60
2031	$4.08	$0.36	$3.72
2032	$3.96	$0.36	$3.60
2033	$3.98	$0.36	$3.62
2034	$4.01	$0.35	$3.66
2035	$4.04	$0.35	$3.69
2036	$4.06	$0.35	$3.71
2037	$4.13	$0.35	$3.78
2038	$4.20	$0.34	$3.85
2039	$4.21	$0.34	$3.87

2040	$4.27	$0.34	$3.93
2041	$4.34	$0.34	$4.00
2042	$4.40	$0.34	$4.06
2043	$4.46	$0.33	$4.13
2044	$4.53	$0.33	$4.20
2045	$4.60	$0.33	$4.27
2046	$4.66	$0.33	$4.34
2047	$4.73	$0.33	$4.41
2048	$4.80	$0.33	$4.48
2049	$4.87	$0.32	$4.55
2050	$4.94	$0.32	$4.62
2051	$5.02	$0.32	$4.70
2052	$5.09	$0.32	$4.77
2053	$5.17	$0.32	$4.85
2054	$5.24	$0.31	$4.93
2055	$5.32	$0.31	$5.01
2056	$5.40	$0.31	$5.09
2057	$5.48	$0.31	$5.17
2058	$5.56	$0.31	$5.25
2059	$5.64	$0.31	$5.33
2060	$5.72	$0.30	$5.42
2061	$5.81	$0.30	$5.50

Impact of Increased Fuel Economy on Fuel Tax Revenues

While NHTSA excludes fuel taxes from the estimation of net social benefits due to the fact that taxes are transfer payments, the agency recognizes the importance of fuel tax revenue in policymakers' budgetary decisions. By applying projected fuel tax rates to estimates of gallons of fuel saved for each of the calendar years in which vehicles of model years covered by this rule are expected to remain on the road, the agency developed approximate schedules shown in Tables VIII-5b and VIII-5c documenting the net changes in fuel tax revenues under the preferred alternative at federal, state, and local levels. The projections in Tables VIII-5b and VIII-5c are consistent with the aforementioned AEO assumptions regarding the relationship of real future fuel tax rates to their present levels.

Table VIII-5b
Projected Annual Net Decrease in Fuel Tax Revenue
Resulting From MY 2017-2025 CAFE Standards
(Millions of 2010$, 3% Discount Rate)

Year	Baseline Fleet	Federal	State	Local
2011	2010 2008	$0 - $1	$0 - $2	$0 - $0
2012	2010 2008	$3 - $5	$4 - $6	$0 - $1
2013	2010 2008	$10 - $14	$13 - $18	$1 - $2
2014	2010 2008	$28 - $27	$36 - $35	$3 - $3
2015	2010 2008	$55 - $44	$75 - $61	$7 - $6
2016	2010 2008	$96 - $72	$132 - $99	$12 - $9
2017	2010 2008	$148 - $116	$204 - $159	$19 - $14
2018	2010 2008	$209 - $187	$307 - $275	$28 - $25
2019	2010 2008	$335 - $312	$492 - $457	$45 - $42
2020	2010 2008	$490 - $481	$719 - $706	$65 - $64
2021	2010 2008	$644 - $640	$1,011 - $1,006	$92 - $91
2022	2010 2008	$832 - $848	$1,307 - $1,333	$119 - $121
2023	2010 2008	$1,041 - $1,062	$1,636 - $1,669	$149 - $152
2024	2010 2008	$1,277 - $1,296	$2,007 - $2,036	$182 - $185
2025	2010 2008	$1,402 - $1,435	$2,372 - $2,429	$216 - $221
2026	2010 2008	$1,307 - $1,335	$2,212 - $2,259	$201 - $205
2027	2010 2008	$1,219 - $1,240	$2,064 - $2,099	$188 - $191
2028	2010 2008	$1,125 - $1,144	$1,904 - $1,936	$173 - $176
2029	2010 2008	$1,038 - $1,051	$1,757 - $1,778	$160 - $162
2030	2010 2008	$876 - $883	$1,607 - $1,619	$146 - $147
2031	2010 2008	$787 - $792	$1,444 - $1,452	$131 - $132
2032	2010 2008	$708 - $712	$1,299 - $1,305	$118 - $119

2033	2010 2008	$633 - $637	$1,161 - $1,168	$106 - $106
2034	2010 2008	$515 - $517	$1,029 - $1,035	$94 - $94
2035	2010 2008	$451 - $453	$901 - $906	$82 - $82
2036	2010 2008	$384 - $387	$783 - $787	$71 - $72
2037	2010 2008	$323 - $325	$670 - $675	$61 - $61
2038	2010 2008	$269 - $270	$568 - $571	$52 - $52
2039	2010 2008	$221 - $222	$475 - $478	$43 - $43
2040	2010 2008	$179 - $179	$391 - $393	$36 - $36
2041	2010 2008	$142 - $143	$317 - $318	$29 - $29
2042	2010 2008	$111 - $111	$253 - $254	$23 - $23
2043	2010 2008	$86 - $86	$200 - $200	$18 - $18
2044	2010 2008	$66 - $66	$157 - $157	$14 - $14
2045	2010 2008	$51 - $51	$124 - $124	$11 - $11
2046	2010 2008	$40 - $40	$99 - $98	$9 - $9
2047	2010 2008	$32 - $32	$81 - $80	$7 - $7
2048	2010 2008	$26 - $26	$66 - $66	$6 - $6
2049	2010 2008	$21 - $21	$55 - $54	$5 - $5
2050	2010 2008	$17 - $17	$46 - $45	$4 - $4
2051	2010 2008	$14 - $14	$39 - $38	$4 - $3
2052	2010 2008	$11 - $11	$32 - $31	$3 - $3
2053	2010 2008	$9 - $9	$26 - $25	$2 - $2
2054	2010 2008	$7 - $7	$21 - $20	$2 - $2
2055	2010 2008	$5 - $5	$16 - $15	$1 - $1
2056	2010 2008	$4 - $4	$13 - $12	$1 - $1
2057	2010 2008	$3 - $3	$10 - $9	$1 - $1
2058	2010 2008	$2 - $2	$7 - $6	$1 - $1
2059	2010 2008	$1 - $1	$4 - $4	$0 - $0
2060	2010 2008	$1 - $1	$2 - $2	$0 - $0

2061	2010 2008	$0 - $0	$1 - $1	$0 - $0
Total		$17,260 - $17,339	$30,151 - $30,313	$2,741 - $2,756

Table VIII-5c
Projected Annual Net Decrease in Fuel Tax Revenue
Resulting From MY 2017-2025 CAFE Standards
(Millions of 2010$, 7% Discount Rate)

Year	Baseline Fleet	Federal	State	Local
2011	2010 2008	$0 - $1	$0 - $2	$0 - $0
2012	2010 2008	$3 - $5	$4 - $6	$0 - $1
2013	2010 2008	$10 - $14	$13 - $18	$1 - $2
2014	2010 2008	$28 - $26	$36 - $34	$3 - $3
2015	2010 2008	$53 - $43	$74 - $59	$7 - $5
2016	2010 2008	$93 - $69	$127 - $95	$12 - $9
2017	2010 2008	$142 - $111	$195 - $152	$18 - $14
2018	2010 2008	$199 - $179	$292 - $263	$27 - $24
2019	2010 2008	$319 - $298	$468 - $437	$43 - $40
2020	2010 2008	$464 - $458	$680 - $672	$62 - $61
2021	2010 2008	$605 - $605	$951 - $951	$86 - $86
2022	2010 2008	$775 - $794	$1,218 - $1,248	$111 - $113
2023	2010 2008	$962 - $984	$1,512 - $1,547	$137 - $141
2024	2010 2008	$1,170 - $1,189	$1,838 - $1,869	$167 - $170
2025	2010 2008	$1,272 - $1,305	$2,152 - $2,209	$196 - $201
2026	2010 2008	$1,142 - $1,170	$1,933 - $1,980	$176 - $180
2027	2010 2008	$1,027 - $1,048	$1,739 - $1,773	$158 - $161
2028	2010 2008	$914 - $931	$1,547 - $1,576	$141 - $143
2029	2010 2008	$813 - $825	$1,376 - $1,396	$125 - $127

2030	2010 2008	$662 - $668	$1,213 - $1,225	$110 - $111
2031	2010 2008	$573 - $577	$1,050 - $1,058	$95 - $96
2032	2010 2008	$497 - $500	$910 - $917	$83 - $83
2033	2010 2008	$428 - $432	$785 - $791	$71 - $72
2034	2010 2008	$336 - $338	$671 - $676	$61 - $61
2035	2010 2008	$283 - $285	$567 - $571	$52 - $52
2036	2010 2008	$233 - $235	$475 - $479	$43 - $44
2037	2010 2008	$189 - $191	$393 - $396	$36 - $36
2038	2010 2008	$152 - $153	$321 - $323	$29 - $29
2039	2010 2008	$121 - $121	$259 - $261	$24 - $24
2040	2010 2008	$94 - $95	$206 - $207	$19 - $19
2041	2010 2008	$72 - $72	$161 - $162	$15 - $15
2042	2010 2008	$54 - $55	$124 - $124	$11 - $11
2043	2010 2008	$41 - $41	$94 - $94	$9 - $9
2044	2010 2008	$30 - $30	$71 - $71	$6 - $6
2045	2010 2008	$22 - $22	$54 - $54	$5 - $5
2046	2010 2008	$17 - $17	$41 - $41	$4 - $4
2047	2010 2008	$13 - $13	$32 - $32	$3 - $3
2048	2010 2008	$10 - $10	$26 - $25	$2 - $2
2049	2010 2008	$8 - $8	$21 - $20	$2 - $2
2050	2010 2008	$6 - $6	$17 - $16	$2 - $1
2051	2010 2008	$5 - $5	$13 - $13	$1 - $1
2052	2010 2008	$4 - $4	$11 - $10	$1 - $1
2053	2010 2008	$3 - $3	$8 - $8	$1 - $1
2054	2010 2008	$2 - $2	$6 - $6	$1 - $1
2055	2010 2008	$2 - $2	$5 - $5	$0 - $0
2056	2010 2008	$1 - $1	$4 - $3	$0 - $0
2057	2010 2008	$1 - $1	$3 - $3	$0 - $0

2058	2010 2008	$1 - $1	$2 - $2	$0 - $0
2059	2010 2008	$0 - $0	$1 - $1	$0 - $0
2060	2010 2008	$0 - $0	$1 - $1	$0 - $0
2061	2010 2008	$0 - $0	$0 - $0	$0 - $0
Total		$13,850 - $13,943	$23,699 - $23,882	$2,154 - $2,171

Benefits from Additional Driving

The increase in travel associated with the rebound effect produces additional benefits to vehicle owners, which reflect the value to drivers and other vehicle occupants of the added (or more desirable) social and economic opportunities that become accessible with additional travel. As evidenced by the fact that they elect to make more frequent or longer trips when the cost of driving declines, the benefits from this added travel exceed drivers' added outlays for the fuel it consumes (measured at the improved level of fuel economy resulting from stricter CAFE standards).[447] The amount by which the benefits from this increased driving travel exceed its increased fuel costs measures the net benefits they receive from the additional travel, usually are referred to as increased consumer surplus.

NHTSA's analysis estimates the economic value of the increased consumer surplus provided by added driving using the conventional approximation, which is one half of the product of the decline in vehicle operating costs per vehicle-mile and the resulting increase in the annual number of miles driven. Because it depends on the extent of improvement in fuel economy, the value of benefits from increased vehicle use changes by model year and varies among alternative CAFE standards. Under even those alternatives that would impose the highest standards, however, the magnitude of benefits from additional vehicle use represents a small fraction of the total benefits from requiring cars and light trucks to achieve higher fuel economy.

Benefits due to reduced refueling frequency

[447] These benefits are included in the value of fuel savings reported throughout this analysis.

Direct estimates of the value of extended vehicle range are not available in the literature, so NHTSA conducted a study to estimate those benefits resulting from this rule. The benefits were determined by calculating the reduction in the required annual number of refueling cycles due to improved fuel economy assuming no fuel tank downsizing in response to improvements in fuel economy, and assessing the economic value of the resulting benefits. Chief among these benefits is the time that owners save by spending less time both in search of fueling stations and in the act of pumping and paying for fuel. As follow-up to that work, NHTSA conducted an analysis of the MY 2010 fleet to determine how manufacturers balanced vehicle range and fuel tank downsizing as fuel economy increases.

The economic value of refueling time savings was calculated by applying DOT-recommended valuations for travel time savings to estimates of how much time is saved.[448] The value of travel time depends on average hourly valuations of personal and business time, which are functions of total hourly compensation costs to employers. The total hourly compensation cost to employers, inclusive of benefits, in 2010$ is $29.68.[449] Table VIII-6 demonstrates the agency's approach to estimating the value of travel time ($/hour) for both urban and rural (intercity) driving. This approach relies on the use of DOT-recommended weights that assign a lesser valuation to personal travel time than to business travel time, as well as weights that adjust for the distribution between personal and business travel.

[448] See http://ostpxweb.dot.gov/policy/Data/VOT97guid.pdf and http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf (last accessed August 1, 2012).
[449] Total hourly employer compensation costs for 2010 (average of quarterly observations across all occupations for all civilians). See http://www.bls.gov/ect/ (last accessed April 27, 2012).

Table VIII-6
Estimating the Value of Travel Time for Urban and Rural (Intercity) Travel ($/hour)

Urban Travel			
	Personal travel	**Business Travel**	**Total**
Wage Rate ($/hour)	$29.68	$29.68	--
DOT-Recommended Value of Travel Time Savings, as % of Wage Rate	50%	100%	--
Hourly Valuation (=Wage Rate * DOT-Recommended Value)	$14.84	$29.68	--
% of Total Urban Travel	94.4%	5.6%	100%
Hourly Valuation (Adjusted for % of Total Urban Travel)	$14.01	$1.66	**$15.67**
Rural (Intercity) Travel			
	Personal travel	**Business Travel**	**Total**
Wage Rate ($/hour)	$29.68	$29.68	--
DOT-Recommended Value of Travel Time Savings, as % of Wage Rate	70%	100%	--
Hourly Valuation (=Wage Rate * DOT-Recommended Value)	$20.77	$3.86	--
% of Total Rural Travel	87.0%	13.0%	100%
Hourly Valuation (Adjusted for % of Total Rural Travel)	$18.07	$3.86	**$21.93**

The estimates of the hourly value of urban and rural travel time (\$15.67 and \$21.93, respectively) shown in Table VIII-6 must be adjusted to account for the nationwide ratio of urban to rural driving. By applying this adjustment (as shown in Table VIII-7), an overall estimate of the hourly value of travel time – independent of urban or rural status – may be produced. Note that the calculations above assume only one adult occupant per vehicle. To fully estimate the average value of vehicle travel time, the agency must account for the presence of additional adult passengers during refueling trips. NHTSA applies such an adjustment as shown in Table VIII-7; this adjustment is performed separately for passenger cars and for light trucks, yielding occupancy-adjusted valuations of vehicle travel time during refueling trips for each fleet. Note that children (persons under age 16) are excluded from average vehicle occupancy counts, as it is assumed that the opportunity cost of children's time is zero.

Table VIII-7
Estimating the Value of Travel Time for Light-Duty Vehicles ($/hour)

	Unweighted Value of Travel Time ($/hour)	**Weight (% of Total Miles Driven)[450]**	**Weighted Value of Travel Time ($/hour)**
Urban Travel	$15.67	67.1%	$10.51
Rural Travel	$21.93	32.9%	$7.22
Total	--	100.0%	$17.73

	Passenger Cars	**Light Trucks**
Average Vehicle Occupancy During Refueling Trips (persons)[451]	1.21	1.23
Weighted Value of Travel Time ($/hour)	$17.73	$17.73
Occupancy-Adjusted Value of Vehicle Travel Time During Refueling Trips ($/hour)	**$21.45**	**$21.81**

The agency estimated the amount of refueling time saved using (preliminary) survey data gathered as part of our 2010-2011 National Automotive Sampling System's Tire Pressure Monitoring System (TPMS) study.[452] The study was conducted at fueling stations nationwide,

[450] Weights used for urban vs. rural travel are computed using cumulative 2011 estimates of urban vs. rural miles driven provided by the Federal Highway Administration. *Available at* http://www.fhwa.dot.gov/policyinformation/travel_monitoring/tvt.cfm (last accessed April 27, 2012).
[451] Source: National Automotive Sampling System 2010-2011 Tire Pressure Monitoring System (TPMS) study. See next page for further background on the TPMS study. TPMS data are preliminary at this time and rates are subject to change pending availability of finalized TPMS data. Average occupancy rates shown here are specific to refueling trips, and do not include children under 16 years of age.
[452] TPMS data are preliminary and not yet published. Estimates derived from TPMS data are therefore preliminary and subject to change. Observational and interview data are from distinct subsamples, each consisting of

and researchers made observations regarding a variety of characteristics of thousands of individual fueling station visits from August, 2010 through April, 2011.[453] Among these characteristics of fueling station visits is the total amount of time spent pumping and paying for fuel. From a separate sample (also part of the TPMS study), researchers conducted interviews at the pump to gauge the distances that drivers travel in transit to and from fueling stations, how long that transit takes, and how many gallons of fuel are being purchased.

NHTSA focused on the interview-based responses in which respondents indicated the primary reason for the refueling trip was due to a low reading on the gas gauge.[454] This restriction was imposed so as to exclude distortionary effects of those who refuel on a fixed (*e.g.*, weekly) schedule and may be unlikely to alter refueling patterns as a result of increased driving range. The relevant TPMS survey data on average refueling trip characteristics are presented below in Table VIII-8.

Table VIII-8
Average Refueling Trip Characteristics for Passenger Cars and Light Trucks

	Gallons of Fuel Purchased	**Round-Trip Distance to/from Fueling Station (miles)**	**Round-Trip Time to/from Fueling Station (minutes)**	**Time to Fill and Pay (minutes)**	**Total Time (minutes)**
Passenger Cars	9.8	0.97	2.28	4.10	6.38
Light Trucks	13.0	1.08	2.53	4.30	6.83

As an illustration of how we estimate the value of extended refueling range, assume a small light truck model has an average fuel tank size of approximately 20 gallons, and a baseline actual on-road fuel economy of 24 mpg (its assumed level in the absence of a higher CAFE standard for

approximately 7,000 vehicles. For more information on the National Automotive Sampling System and to access TPMS data when they are made available, see http://www.nhtsa.gov/NASS.

453 The data collection period for the TPMS study ranged from 08/10/2010 to 04/15/2011.

454 Approximately 60 percent of respondents indicated "gas tank low" as the primary reason for the refueling trip in question.

the given model year). TPMS survey data indicate that drivers who indicated the primary reason for their refueling trips was a low reading on the gas gauge typically refuel when their tanks are 35 percent full (*i.e.* as shown in Table VIII-8, with 7.0 gallons in reserve, and purchasing 13 gallons in the refueling trip). By this measure, a typical driver would have an effective driving range of 312 miles (= 13.0 gallons x 24 mpg) before he or she is likely to refuel. Increasing this model's actual on-road fuel economy from 24 to 25 mpg would therefore extend its effective driving range to 325 miles (= 13.0 gallons x 25 mpg). Assuming that the truck is driven 12,000 miles/year,[455] this 1 mpg improvement in actual on-road fuel economy reduces the expected number of refueling trips per year from 38.5 (= 12,000 miles per year / 312 miles per refueling) to 36.9 (= 12,000 miles per year / 325 miles per refueling), or by 1.6 refuelings per year. If a typical fueling cycle for a light truck requires a total of 6.83 minutes, then the annual value of time saved due to that 1 mpg improvement would amount to $3.97 (= (6.83/60) x $21.81 x 1.6).

In the central analysis, this calculation was repeated for each future calendar year that light-duty vehicles of each model year affected by the CAFE standards considered in this rule would remain in service. The resulting cumulative lifetime valuations of time savings account for both the reduction over time in the number of vehicles of a given model year that remain in service and the reduction in the number of miles (VMT) driven by those that stay in service. We also adjust the value of time savings that will occur in future years both to account for expected annual growth in real wages[456] and to apply a discount rate to determine the net present value of time saved.[457] A further adjustment is made to account for evidence from the interview-based portion of the TPMS study which suggests that 40 percent of refueling trips are for reasons other than a low reading on the gas gauge; it is therefore assumed that only 60 percent of the theoretical refueling time savings will be realized, as it was assumed that owners who refuel on a fixed schedule will continue to do. NHTSA sought feedback from peer reviewers regarding the

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[455] Source of annual vehicle mileage: U.S. Department of Transportation, Federal Highway Administration, 2009 National Household Travel Survey (NHTS). See http://nhts.ornl.gov/2009/pub/stt.pdf (table 22, p.48). 12,000 miles/year is an approximation of a light duty vehicle's annual mileage during its initial decade of use (the period in which the bulk of benefits are realized). The VOLPE model estimates VMT by model year and vehicle age, taking into account the rebound effect, secular growth rates in VMT, and fleet survivability; these complexities are omitted in the above example for simplicity.

[456] A 1.1 percent annual rate of growth in real wages is used to adjust the value of travel time per vehicle ($/hour) for future years for which a given model is expected to remain in service. This rate is supported by a BLS analysis of growth in real wages from 2000 – 2009. See http://www.bls.gov/opub/ted/2011/ted_20110224.htm (last accessed August 1, 2012)

[457] Note that here, as elsewhere in the analysis, discounting is applied on a mid-year basis. For example, at a 3% discount rate, the sequence of discount factors is calculated as: {1/((1+0.03)^(0.5)), 1/((1+0.03)^(1.5)), … , 1/((1+0.03)^(T – 0.5))}. NHTSA utilized mid-year discounting to reflect the fact that a given model year's vehicles are sold over the course of one or more years, therefore costs and benefits do not begin to fully accrue on January 1st of the model year.

NPRM analysis of refueling time savings and has updated its analysis and discussion to address peer reviewers' comments.[458]

Manufacturers' decisions regarding vehicles' fuel tank sizes are integral to the realized value of this benefit. At vehicle redesign, manufacturers typically redesign fuel tanks based on a variety of considerations including driving range, cargo and passenger space (utility), mass targets, safety, and other factors. As fuel economy increases, manufacturers may opt at the time of vehicle redesign to downsize vehicles' fuel tanks. Downsizing the fuel tanks of more fuel-efficient vehicles offers a number of advantages:

- Reduced vehicle mass[459]
  - May improve vehicle performance
  - Improves fuel economy, thereby reducing CAFE compliance costs
- Reduced vehicle manufacturing costs
  - Lower material costs in fuel tank manufacturing
  - Lower material costs in evaporative emissions canisters
- May allow additional space for cargo and/or passengers
- May allow additional space for other vehicle equipment and/or more crush space for safety

Manufacturers need not wait until vehicle redesign to reduce the effective size of fuel tanks; by changing the length of the fill tube, effective tank volume may be adjusted during model refresh years, thereby allowing the realization of some of the above listed benefits.

In the NPRM, the agency stated that manufacturers might resize fuel tanks at redesign to maintain similar range; however, in the quantitative valuation of refueling time savings benefit, the agency did not integrate this assumption. Rather, NHTSA included in the NPRM a request for manufacturer comment on this assumption. No comments were received on this issue in response to the NPRM. However, in the peer review of the study, a commenter suggested that the quality of NHTSA's analysis of refueling time savings benefits could be improved by the inclusion of analysis of the relationship between fuel economy and vehicle range among the

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[458] Peer review materials, peer reviewer backgrounds, comments, and NHTSA responses are available at Docket NHTSA-2012-0001.

[459] For example, for a vehicle with a 15 gallon fuel tank and a 400 mile range, increasing fuel economy from 40 to 60 mpg (an increase of 50%), downsizing the fuel tank to maintain a range of 400 miles would enable a mass reduction of approximately 51 pounds based on the reduction in the amount of fuel alone (based on an 8.3 gallon reduction in fuel tank volume and a gasoline density of 6.073 lbs/gallon). If the fuel tank was not downsized, the range of the vehicle would increase to 600 miles.

baseline fleets upon which the agency developed the 2017-2025 CAFE standards, and (if appropriate) the integration of the results of the suggested analysis into the estimation of the value of the refueling time savings benefit. NHTSA performed such a study based on the 2010 baseline fleet data, discussed further below.

NHTSA also consulted with engineering experts at EDAG in the context of the NHTSA-funded lightweight future vehicle study[460] regarding expectations of the volume of the fuel tanks of future vehicles affected by this rule. The EDAG engineers involved in this study expressed the joint opinion that fuel tank downsizing is certain to occur as fuel economy increases, for reasons consistent with those stated above. The future lightweight Honda Accord designed by EDAG features a 14.6 percent decrease in fuel tank size relative to the baseline 2011 model. Recent redesigns of the MY 2013 Ford Fusion and MY 2012 Toyota Camry show evidence that manufacturers are downsizing fuel tanks. The MY 2013 Ford Fusion has a 16.5 gallon tank, versus the 17.5 gallon tank in the MY 2012 Fusion. Similarly the MY 2012 Toyota Camry has a 17.0 gallon tank, versus the 18.5 gallon tank in the MY 2011 Camry.

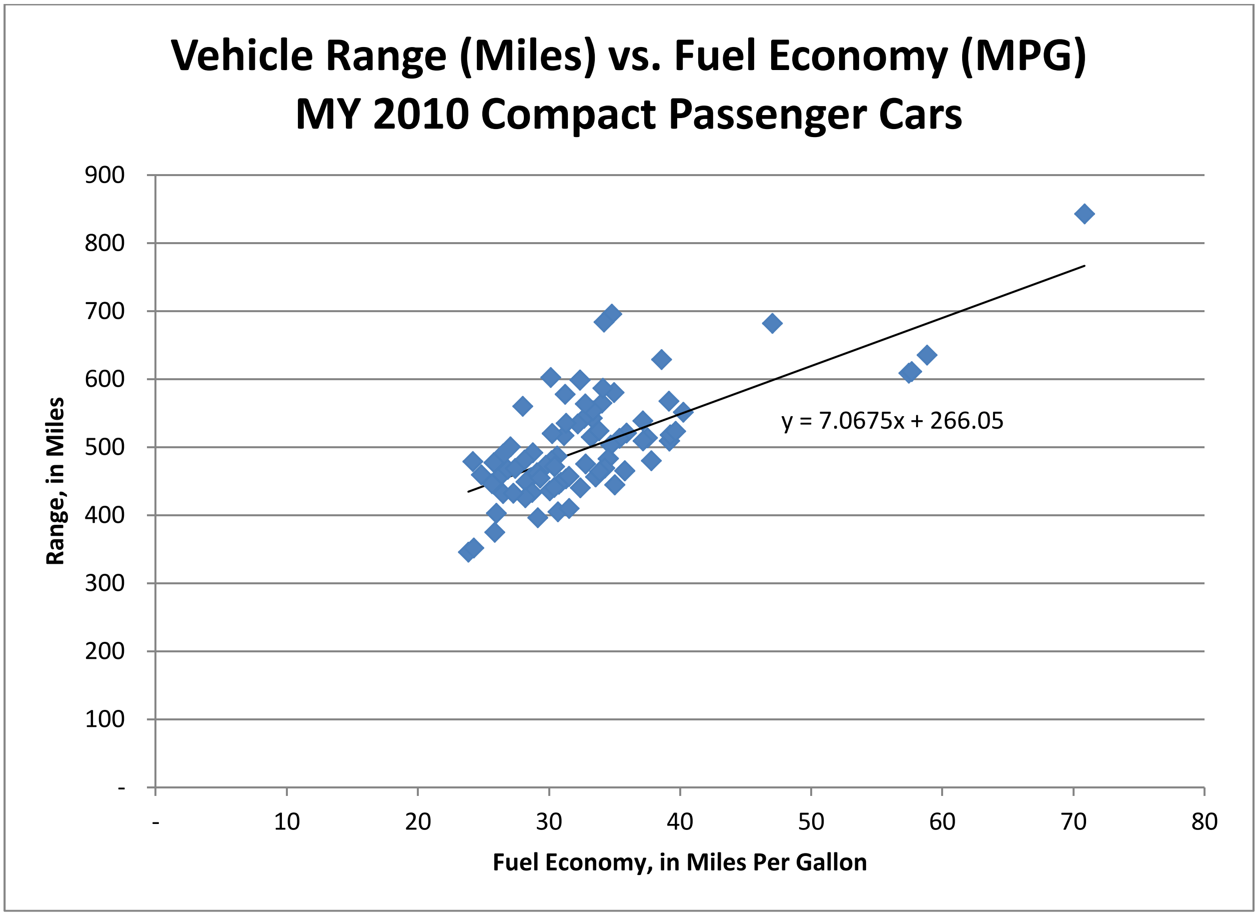
If manufacturers elect to reduce fuel tank size in response to improved fuel economy to maintain range, the value of the refueling time savings benefit will be reduced because the number of trips to fueling stations will not be reduced as much as estimated assuming no fuel tank downsizing. It is important to note that NHTSA recognizes and (discussed in detail later in this analysis) accounts for the fact that reductions to fuel tank volume – even if to the point that average vehicle range remains unchanged while fuel economy rises – will not eliminate the value of the refueling time savings benefit, as there remains a time savings due to the reduction in time required to pump fuel into smaller tanks. The agency believes that annual refreshes of fuel tank size during the years in-between model redesigns are unlikely; therefore, while the downsizing of fuel tanks would decrease the realized value of the refueling time savings benefit, it would not eliminate it.

NHTSA performed a quantitative analysis based on manufacturers' 2010 vehicle market data, regressing vehicle range (in miles) against fuel economy (measured in miles per gallon). Regressions were performed for each regulatory subclass of vehicles, and limited to exclude diesel, E85, and compressed natural gas vehicles, though hybrid gasoline-electric vehicles were

[460] See Docket No. NHTSA-2010-0131 for the lightweight future vehicle study and peer review feedback of that study.

included in the sample. As an illustration, figure VIII-1 presents the scatter plot and trend line for MY 2010 compact passenger cars.

Figure VIII-1



NHTSA's analysis of range versus fuel economy across each regulatory subclass within the MY 2010 fleet indicate that vehicles of a given subclass tend to cluster together within a narrow bound; in the above example, the driving ranges of compact passenger cars are mostly clustered between 400 and 600 miles. Across all subclasses of the 2010 fleet, vehicles exhibit a minimum 300 mile range in all cases, which NHTSA assumed to be the minimum level of driving range acceptable to owners.

NHTSA assumed that the relationship between fuel economy and range exhibited in the MY 2010 data is indicative of that of future fleets. Consumers are increasingly prioritizing fuel economy in vehicle purchasing decisions[461]; NHTSA assumes that consumers also place some value on vehicle range such that all other things equal, a consumer would prefer a vehicle of greater range. NHTSA is unaware of studies suggesting vehicle owners' future preferences for vehicle range. Therefore, NHTSA assumed that automakers will manufacture vehicles of MYs 2017-2025 with ranges that are consistent with the subclass-specific regression equations as shown below in Table VIII-9.[462]

Table VIII-9
Regression-based Predictive Functions of Vehicle Range
Based on MY 2010 Fleet

Regulatory Class	Technology Class	Predicted Range (miles) as Function of Fuel Economy (mpg)	Sample Size
PC	Subcompact	= 365.63 + 2.6121*(FE)	95
PC	Subcompact Perf	= 295.48 + 5.6996*(FE)	100
PC	Compact	= 266.05 + 7.0675*(FE)	105
PC	Compact Perf	= 242.18 + 7.9258*(FE)	56
PC	Midsize	= 24.427 + 16.877*(FE)	92
PC	Midsize Perf	= 133.41 + 13.22*(FE)	58
PC	Large	= 93.157 + 15.099*(FE)	46
PC	Large Perf	= 149.85 + 14.037*(FE)	71
PC	Small LT	= 189.81 + 9.867*(FE)	42
PC	Midsize LT	= 211.45 + 11.421*(FE)	32
LT	Small LT	= 200.39 + 9.6627*(FE)	41
LT	Midsize	= 190.38 + 12.295*(FE)	169
LT	Large	= 294.16 + 11.76*(FE)	108
LT	Minivan	= 458.19 + 1.8684*(FE)	14

For example, the average range of the MY 2010 compact passenger cars depicted in Figure VIII-1 is 501.93 miles, with average fuel economy of 33.38 mpg, which implies a representative vehicle's fuel tank size of 15.04 gallons. If this representative vehicle's fuel economy rises by

[461] See "High gas prices motivate drivers to change direction" (Consumer Reports, May 2012). *Available at:* http://www.consumerreports.org/content/cro/en/cars/fuel-economy-survey-high-gas-prices-impact-drivers.html (last accessed August 1, 2012)

[462] The study of the relationship between range and fuel economy has not been peer reviewed. Peer reviewers requested its inclusion and offered suggestions on methods; however, it was developed only recently and as such the approach and results have not been peer reviewed.

10% to 36.71 mpg while holding the fuel tank size constant, range would grow to 552.12 miles, an increase of 50.19 miles. However, the linear trend equation shown in Figure VIII-1 offers an alternate prediction of the vehicle's range that implicitly includes tank downsizing as follows: predicted range = 266.05 + 7.0675*(33.38 mpg) = 525.5 miles, or an increase of 23.57 miles. Vehicle range of 525.5 miles with fuel economy of 36.71 mpg implies a fuel tank size of 14.31 gallons, a 4.82 percent reduction in fuel volume. Of the 50.19 mile increase in vehicle range that would occur if the fuel tank size remained constant, only 23.57 miles of this increase are expected to be achieved due to the relationship between fuel economy and range seen in the sample of vehicles included in the regression. Thus, 26.62 miles (= 50.19 miles – 23.57 miles), or 53.0% of the *possible* range increase for compact passenger cars is not expected to be achieved.

NHTSA repeated the calculations expressed in the example of the preceding paragraph across all vehicle regulatory subclasses to estimate the percentage of *possible* range increase that is not expected to be achieved due to reduction in fuel tank volume. This percentage varies greatly by regulatory subclass, as shown in Table VIII-10. Note that in each class, improvements to fuel economy led to gains in vehicle range; it is only the *amount* of increase that was the subject of this analysis. The values presented in Table VIII-10 should be interpreted as "although this vehicle's range is expected to increase in response to gains in fuel economy, NHTSA anticipates it will grow by X percent less than it otherwise would if the manufacturer were to hold constant the volume of the fuel tank."

Table VIII-10
Potential Vehicle Range Increase "Lost"
Due to Fuel Tank Downsizing

Regulatory Class	Technology Class	% of Possible Range Gain Not Expected to be Achieved due to Fuel Tank Downsizing
PC	Subcompact	80.1%
PC	Subcompact Perf.	65.5%
PC	Compact	53.0%
PC	Compact Perf.	55.7%
PC	Midsize	4.6%
PC	Midsize Perf.	31.5%
PC	Large	19.6%
PC	Large Perf.	34.1%
PC	Small LT	38.6%
PC	Midsize LT	41.0%
LT	Small LT	42.2%
LT	Midsize	40.1%
LT	Large	55.0%
LT	Minivan	90.5%

NHTSA then created a composite sales-weighted estimate using data from each of the above subclasses across model years 2017 – 2025. These values ranged from a low of 40.45 percent to a high of 41.71 percent, for an overall average of 40.91 percent across all nine model years. In the CAFE model, the refueling time savings benefits are initially calculated without any adjustment for the expected reductions in fuel tank size. The above analysis led NHTSA to conclude that those initial calculations overestimate the value of this benefit by up to 40.91 percent, and that some downward adjustment to the refueling time savings benefit calculation is therefore necessary.

In addition to considering the downward adjustment in refueling benefits that result from fuel tank resizing, it is also necessary to account for the refueling time savings benefit resulting from less time is required to pump fuel into smaller tanks. NHTSA researched the magnitude of this time savings as follows.

Taking a MY 2025 passenger car as representative of the future fleet (note that of the model years affected by this rule, MY 2025 vehicles are projected to see the greatest reduction in fuel tank volume, and therefore is the model year that would see the maximum time savings benefit) NHTSA proceeded as follows. If the average tank size of the MY 2025 passenger cars remains the same (16.71 gallons) as that of the total MY 2010 passenger car sample utilized in the regression analysis discussed earlier, NHTSA assumed that refueling trips would continue to require 6.38 minutes as shown in Table VIII-8. The projected difference in fuel economy between the MY 2025 baseline and preferred alternative levels is 14.05 mpg (= 52.87 mpg – 38.82 mpg).[463] If fuel tank volume remains constant at 16.71 gallons, range will increase by 234.78 miles (= 14.05 mpg x 16.71 gallons). As discussed above, NHTSA's regression analysis projects that 40.91 percent (96.05 miles) of this increase in range will not occur as a result of fuel tank downsizing. The projected increase in vehicle range is 138.73 miles (= 234.78 miles – 96.05 miles), resulting in a vehicle with range of 787.41 miles (= baseline range of 648.68 miles + 138.73 miles). The implied volume of this vehicle's fuel tank is 14.89 gallons (= 787.41 miles / 52.87 mpg). Assuming that all refueling trips occur when the remaining volume of fuel tank capacity reaches 35 percent[464], the typical volume of fuel pumped in the baseline case is 10.86 gallons, versus 9.68 gallons when accounting for the expected decrease in fuel tank volume. At an assumed fuel flow rate of 5 gallons per minute, this expected reduction of 1.18 gallons of fuel pumped per refueling cycle saves 14.2 seconds. Note that this particular benefit accrues to *all* refueling cycles, which NHTSA subsequently accounted for in aggregation of this benefit to fleet-wide levels.

To account for this additional time savings across the lifetimes of all nine model years affected by this rule, NHTSA assumed that on average, one-half (or 7.1 seconds) of the 14.2 seconds of time saved (estimated above using an MY 2025 vehicle) would be realized by each vehicle affected by this rule, due to the fact that the required standards in MYs 2017 through 2024 are below those of MY 2025. Accounting for the additional time savings resulting from pumping fuel into smaller fuel tanks increases the estimated refueling time savings benefits. This increase partially offsets the 40.91 percent downward adjustment mentioned above, equivalent to a reduction in this downward adjustment from 40.91 to 30 percent. Therefore, NHTSA applied a 30 percent downward adjustment to the calculation of refueling time savings benefits to address the net loss to the refueling time savings benefit stemming from expected reductions in fuel tank volume.

[463] 2008 market baseline values. Fuel economy values cited in this example are not adjusted for the on-road fuel economy gap.
[464] Average percentage of fuel remaining in the tank at the time of refueling, derived from TPMS study data.

Tables VIII-15, VIII-16, and VIII-17 provide an illustration of the derivation of the lifetime net present value of refueling time savings for the MY 2025 fleet of passenger cars, assuming the rate of increase in fuel economy as per the preferred alternative relative to the baseline for the same model year. Tables VIII-15 and VIII-16 present the underlying assumptions behind the results presented in Table VIII-13. This example is illustrative only; the CAFE model calculates this benefit at a combined (passenger car and light truck) level using the average of VMT-weighted parameters, after which the results are prorated to passenger car and light truck fleets, respectively. The VMT schedule used in this example assumes that all vehicles sold in the given model year rely on internal combustion engines; in the CAFE model, the fleet contains a mix of vehicles utilizing alternate engine technologies that result in a variety of individualized VMT schedules. Due to these simplifications that were made to allow an empirical example, the results of this example cannot be compared to the actual CAFE model output of this benefit's value.

Table VIII-11
Economic Values Used in Example of Estimation of Lifetime Net Present Value
of MY 2025 Passenger Car Refueling Time Savings

Sales of MY 2025 Passenger Cars:	10,403,216	Discount Rate:	7%
Achieved MPG, Preferred Alternative (with AC adjustment):	52.87	Achieved MPG, Baseline (with AC adjustment):	38.82
Actual On-Road MPG, Preferred Alternative:	42.30	Actual On-Road MPG, Baseline:	31.06
Average Fuel Tank Size (gallons):	15	Refueling Occurs When Tank Reaches (% capacity):	35%
Effective (pre-refueling) Driving Range, Preferred Alternative:	412.4	Effective (pre-refueling) Driving Range, Baseline:	302.8
Refueling Trips Due To Low Fuel Tank:	60%	Average Length of Refueling Trip (minutes):	6.38
Value of Passenger Car Vehicle-Hour Travel Time (2010$):	$21.45	Annual Real Wage Growth:	1.1%
Downward Adjustment (Fuel Tank Downsizing)	30%		

Table VIII-12
Vehicle Survival Rates and VMT Schedules for MY 2025 Passenger Cars,
Preferred Alternative vs. Baseline Scenario

Year	Vehicle Survival Rate	# of Surviving Vehicles	Annual VMT, Baseline (per-vehicle)	Annual VMT, Preferred Alternative (per-vehicle)	Fleetwide VMT, Baseline	Fleetwide VMT, Preferred Alternative
2025	1.0000	10,403,216	17,724	18,423	184,387,678,460	191,657,976,381
2026	0.9878	10,276,729	17,374	18,057	178,550,547,046	185,563,005,391
2027	0.9766	10,159,648	16,984	17,657	172,551,611,407	179,384,465,403
2028	0.9614	10,002,032	16,465	17,133	164,683,094,482	171,368,925,896
2029	0.9450	9,831,518	15,936	16,590	156,672,716,399	163,102,588,141
2030	0.9298	9,673,212	15,472	16,095	149,668,308,257	155,690,761,683
2031	0.9113	9,480,433	14,802	15,400	140,327,351,991	145,996,762,371
2032	0.8912	9,271,226	14,134	14,699	131,043,042,530	136,273,478,975
2033	0.8689	9,039,106	13,405	13,942	121,164,982,564	126,020,813,260
2034	0.8397	8,735,700	12,620	13,116	110,248,033,165	114,577,073,354
2035	0.7999	8,321,437	11,631	12,097	96,789,557,953	100,668,514,534
2036	0.7556	7,860,995	10,666	11,086	83,841,922,242	87,147,640,829
2037	0.7055	7,339,528	9,612	9,997	70,544,136,903	73,371,277,040
2038	0.6527	6,789,723	8,571	8,920	58,194,584,700	60,564,684,003
2039	0.5946	6,185,596	7,546	7,850	46,677,776,167	48,556,027,723
2040	0.5311	5,524,792	6,507	6,766	35,951,650,655	37,380,791,547
2041	0.4585	4,769,646	5,428	5,639	25,891,022,963	26,895,142,492
2042	0.3832	3,986,365	4,384	4,549	17,474,865,697	18,132,961,005
2043	0.3077	3,201,267	3,397	3,522	10,874,793,876	11,275,665,401
2044	0.2414	2,511,309	2,562	2,658	6,434,927,545	6,674,183,168
2045	0.1833	1,906,752	1,881	1,948	3,585,715,105	3,715,050,194
2046	0.1388	1,443,739	1,384	1,431	1,998,341,807	2,065,405,996
2047	0.1066	1,108,644	1,048	1,076	1,161,337,021	1,193,232,839
2048	0.0820	853,341	782	803	667,085,947	685,009,777
2049	0.0629	654,799	587	601	384,215,034	393,631,876
2050	0.0514	534,886	469	480	250,655,802	256,507,046
2051	0.0420	436,421	377	385	164,581,433	168,020,813
2052	0.0337	350,469	298	304	104,330,170	106,510,435
2053	0.0281	292,844	246	251	72,021,805	73,526,898
2054	0.0235	244,693	205	209	50,045,382	51,091,218

Table VIII-13
Estimation of Lifetime Net Present Value of Refueling Time Savings for MY 2025 Passenger Cars, Preferred Alternative vs. Baseline Scenario

Year	# of Refueling Trips, Baseline	# of Refueling Trips, Preferred Alternative	# of Fewer Refueling Trips Due To Higher CAFE Standard (x 60% adjustment)	# of Fewer Hours Spent Refueling	Value of Vehicle-hour travel time in given year (2010$)[465]	Value of Time Saved (2010$, 7% Discount Rate)
2025	464,718,653	144,191,805	86,515,083	9,199,437	$25.14	$223,557,075
2026	449,940,000	139,694,276	83,816,566	8,912,495	$25.41	$204,641,557
2027	434,958,715	134,865,047	80,919,028	8,604,390	$25.69	$186,673,215
2028	415,523,204	128,316,055	76,989,633	8,186,564	$25.98	$167,815,076
2029	395,479,575	121,906,707	73,144,024	7,777,648	$26.26	$150,641,612
2030	377,507,904	116,747,454	70,048,472	7,448,488	$26.55	$136,311,391
2031	354,002,583	109,405,779	65,643,467	6,980,089	$26.84	$120,695,860
2032	330,426,256	102,322,177	61,393,306	6,528,155	$27.14	$106,656,975
2033	305,566,320	94,561,419	56,736,852	6,033,019	$27.44	$93,132,411
2034	277,818,352	86,257,929	51,754,758	5,503,256	$27.74	$80,270,002
2035	244,093,866	75,537,979	45,322,788	4,819,323	$28.04	$66,418,182
2036	211,309,412	65,564,963	39,338,978	4,183,045	$28.35	$54,470,432
2037	177,905,463	55,055,129	33,033,077	3,512,517	$28.66	$43,216,955
2038	146,852,945	45,325,249	27,195,150	2,891,751	$28.98	$33,617,387
2039	117,735,208	36,410,591	21,846,354	2,322,996	$29.30	$25,516,368
2040	90,638,289	28,086,217	16,851,730	1,791,901	$29.62	$18,597,380
2041	65,213,432	20,287,480	12,172,488	1,294,341	$29.95	$12,692,699
2042	43,967,516	13,740,399	8,244,239	876,637	$30.28	$8,122,554
2043	27,340,433	8,571,813	5,143,088	546,882	$30.61	$4,787,771
2044	16,183,085	5,067,221	3,040,333	323,289	$30.95	$2,674,225
2045	9,007,990	2,833,254	1,699,952	180,762	$31.29	$1,412,801
2046	5,008,050	1,591,150	954,690	101,515	$31.63	$749,677
2047	2,893,266	941,861	565,117	60,091	$31.98	$419,292
2048	1,660,963	541,980	325,188	34,578	$32.33	$227,972
2049	954,451	314,357	188,614	20,056	$32.68	$124,936
2050	621,960	205,790	123,474	13,129	$33.04	$77,278
2051	407,405	136,099	81,659	8,683	$33.41	$48,290
2052	258,259	86,275	51,765	5,504	$33.78	$28,923
2053	178,283	59,558	35,735	3,800	$34.15	$18,866
2054	123,882	41,384	24,831	2,640	$34.52	$12,386
Lifetime Net Present Value of Refueling Time Savings (2010$):						$1,743,629,547
Adjusted for Expected Fuel Tank Downsizing and Resulting Secondary Time Savings (2010$):						$1,220,540,683

[465] Value of refueling time is adjusted upward from 2010 level of $21.45 to account for annual real wage growth of 1.1%.

Table VIII-13 demonstrates the progressive decrease over time in the value of future years' benefits due to the decline in the number of surviving vehicles, the reduction in miles that those vehicles are driven, and discounting of future benefits. Over the 30-year lifetime of the passenger car fleet in this example, the net present value of discounted benefits is about $1,221 million. About 84 percent of that benefit is realized by the end of the fleet's first decade of service. Again, the preceding example of Tables VIII-15, VIII-16, and VIII-17 is intended to be illustrative only of the logic applied in the CAFE model's estimation of refueling time savings; due to simplifications made for the sake of allowing this empirical example, this value differs somewhat from the value of refueling time savings calculated within the CAFE model.

Since a reduction in the expected number of annual refueling trips leads to a decrease in miles driven to and from fueling stations, we can also calculate the value of consumers' fuel savings associated with this decrease. As shown in Table VIII-8, the typical incremental round-trip mileage per refueling cycle is 1.08 miles for light trucks and 0.97 miles for passenger cars. Going back to the earlier example of a light truck model, a decrease of 1.6 in the number of refuelings per year leads to a reduction of 1.73 miles driven per year (= 1.6 refuelings x 1.08 miles driven per refueling). Again, if this model's actual on-road fuel economy was 24 mpg, the reduction in miles driven yields an annual savings of approximately 0.07 gallons of fuel (= 1.73 miles / 24 mpg), which at $3.77/gallon[466] results in a savings of $0.27 per year to the owner. Note that this example is illustrative only of the approach NHTSA uses to quantify this benefit; in practice, the societal value of this benefit must exclude fuel taxes (as they are transfer payments) from the calculation, and must be modeled using fuel price forecasts specific to each year the given fleet will remain in service.

The annual savings to each consumer shown in the above example may seem like a small amount, but the reader should recognize that the valuation of the cumulative lifetime benefit of this savings to owners is determined separately for passenger car and light truck fleets and then aggregated to show the net benefit across all light-duty vehicles – which is much more significant at the macro level. Calculations of benefits realized in future years are adjusted for expected real growth in the price of gasoline, for the decline in the number of vehicles of a given model year that remain in service as they age, for the decrease in the number of miles (VMT) driven by those that stay in service, and for the percentage of refueling trips that occur for

[466] Estimate of $3.77/gallon is in 2010$. This figure is an average of forecasted cost per gallon (including taxes, as individual consumers consider reduced tax expenditures to be savings) for motor gasoline for years 2017 to 2027. Source of price forecasts: U.S. Energy Information Administration, Annual Energy Outlook Early Release 2012 (see Table VIII-5a).

reasons other than a low reading on the gas gauge; a discount rate is also applied in the valuation of future benefits. NHTSA considered using this direct estimation approach to quantify the value of this benefit by model year, however concluded that the value of this benefit is implicitly captured in the separate measure of overall valuation of fuel savings. Therefore direct estimates of this benefit are not added to net benefits calculations.

We note that there are other benefits resulting from the reduction in miles driven to and from fueling stations, such as a reduction in greenhouse gas emissions – CO_2 in particular – which, as per the case of fuel savings discussed in the preceding paragraph are implicitly accounted for elsewhere in the CAFE model.

Special mention must be made with regard to the value of refueling time savings benefits to owners of electric and plug-in electric (both referred to here as EV) vehicles. EV owners who routinely drive daily distances that do not require recharging on-the-go may eliminate the need for trips to fueling or charging stations. It is likely that early adopters of EVs will factor this benefit into their purchasing decisions and maintain driving patterns that require once-daily at-home recharging (a process which takes two to six hours for a full charge). However, EV owners who regularly or periodically need to drive distances further than the fully-charged EV range may need to recharge at fixed locations. A distributed network of charging stations (e.g., in parking lots, at parking meters) may allow some EV owners to recharge their vehicles while at work or while shopping, yet the lengthy charging cycles of current charging technology may pose a cost to owners due to the value of time spent waiting for EVs to charge. Moreover, EV owners who primarily recharge their vehicles at home will still experience some level of inconvenience due to their vehicle being either unavailable for unplanned use, or to its range being limited during this time should they interrupt the charging process. Therefore, at present EVs hold potential in offering significant time savings to owners with driving patterns optimally suited for EV characteristics. If fast-charging technologies emerge and a widespread network of fast-charging stations is established, it is expected that a larger segment of EV vehicle owners will fully realize the potential refueling time savings benefits that EVs offer. This is an area of significant uncertainty. Although one peer reviewer requested NHTSA elaborate quantitatively on refueling time savings in relation to EVs, the particular characteristics of EVs and the synergy or lack thereof with regard to EV uptake by owners for whom driving patterns are optimally suited to the realization of refueling time savings limit NHTSA from rigorously addressing this topic within the scope of this analysis.

C. Other Economic Benefits from Reducing U.S. Petroleum Use

Reducing fuel use by requiring cars and light trucks to attain higher fuel economy also produces wider benefits to the U.S. economy by lowering the cost of economic externalities that result from U.S. petroleum consumption and imports, including reducing the price of petroleum, lowering the potential costs from disruption in the flow of oil imports, and possibly reducing outlays to support U.S. military activities to secure the flow of oil imports and to cushion the economy against their possible interruption by maintaining the Strategic Petroleum Reserve. Reducing fuel consumption also lowers the economic costs of environmental externalities resulting from fuel production and use, including reducing the impacts on human health impacts from emissions of criteria air pollutants, and reducing future economic damages from potential changes in the global climate caused by greenhouse gas emissions.

Economic Externalities from U.S. Petroleum Imports

U.S. consumption and imports of petroleum products imposes costs on the domestic economy that are not reflected in the market price for crude petroleum, or in the prices paid by consumers of petroleum products such as gasoline. These costs include (1) higher prices for petroleum products resulting from the effect of U.S. oil import demand on the world oil price; (2) the risk of disruptions to the U.S. economy caused by sudden reductions in the supply of imported oil to the U.S.; and (3) expenses for maintaining a U.S. military presence to secure imported oil supplies from unstable regions, and for maintaining the strategic petroleum reserve (SPR) to cushion against resulting price increases.[467]

Higher U.S. consumption and imports of crude oil or refined petroleum products can raise the magnitude of these external economic costs, thus increasing the true economic cost of supplying transportation fuels above the resource costs of producing them. Conversely, *reducing* fuel consumption by requiring motor vehicles to achieve higher fuel economy will lower U.S. consumption and imports of crude petroleum and refined fuels, thus lowering the values of these external costs. Any reduction in their value that results from requiring improved vehicle fuel

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[467] *See, e.g.*, Bohi, Douglas R. and W. David Montgomery (1982). Oil Prices, Energy Security, and Import Policy Washington, DC: Resources for the Future, Johns Hopkins University Press; Bohi, D. R., and M. A. Toman (1993). "Energy and Security: Externalities and Policies," Energy Policy 21:1093-1109; and Toman, M. A. (1993) (Docket NHTSA-2009-0062-24). "The Economics of Energy Security: Theory, Evidence, Policy," in A. V. Kneese and J. L. Sweeney, eds. (1993) (Docket NHTSA-2009-0062-23). Handbook of Natural Resource and Energy Economics, Vol. III. Amsterdam: North-Holland, pp. 1167-1218.

economy represents an additional economic benefit of raising CAFE standards, over and above the economic value of saving fuel itself.

Increased U.S. petroleum consumption can impose higher costs on all purchasers of petroleum products, because the U.S. is a sufficiently large purchaser of foreign oil supplies that changes in U.S. demand can affect the world petroleum price. The effect of U.S. petroleum demand on world oil prices is determined by the degree of OPEC monopoly power over global oil supplies, and the degree of monopsony power over world oil demand that the U.S. exercises. The importance of these two factors means that increases in domestic demand for petroleum products that are met through higher oil imports can cause the price of oil in the world market to rise, which imposes economic costs on all other purchasers in the global petroleum market in excess of the higher prices paid by U.S. consumers.[468] Conversely, reducing U.S. oil imports can lower the world petroleum price, and thus generate benefits to other oil purchasers by reducing these "monopsony costs."

Although the degree of current OPEC monopoly power is subject to considerable debate, the consensus appears to be that OPEC remains able to exercise some degree of control over the response of world oil supplies to variation in world oil prices, so that the world oil market does not behave competitively.[469] The extent of U.S. monopsony power is determined by a complex set of factors including the relative importance of U.S. imports in the world oil market, and the sensitivity of petroleum supply and demand to its world price among other participants in the international oil market. Most evidence appears to suggest that variation in U.S. demand for imported petroleum continues to exert some influence on world oil prices, although this influence appears to be limited.[470]

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[468] For example, if the U.S. imports 10 million barrels of petroleum per day at a world oil price of $80 per barrel, its total daily import bill is $800 million. If increasing imports to 11 million barrels per day causes the world oil price to rise to $81 per barrel, the daily U.S. import bill rises to $891 million. The resulting increase of $91 million per day ($891 million minus $800 million) is attributable to increasing daily imports by only 1 million barrels. This means that the incremental cost of importing each additional barrel is $91, or $10 more than the newly-increased world price of $81 per barrel. This additional $10 per barrel represents a cost imposed on all other purchasers in the global petroleum market by U.S. buyers, in excess of the price they pay to obtain those additional imports.

[469] For a summary see Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997, at 17. *Available at* http://www.esd.ornl.gov/eess/energy_analysis/files/ORNL6851.pdf (last accessed August 1, 2012)
[470] *Id.*, at 18-19.

In analyzing benefits from increased light truck CAFE standards for model years 2005-07 and 2008-11, NHTSA relied on a 1997 study by Oak Ridge National Laboratories (ORNL) to estimate the value of reduced economic externalities from petroleum consumption and imports.[471] ORNL subsequently updated its estimates of the value of these externalities, using the analytic framework developed in its original 1997 study in conjunction with recent estimates of the variables and parameters that determine their value.[472] These include world oil prices, current and anticipated future levels of OPEC petroleum production, U.S. oil import levels, the estimated responsiveness of regional oil supplies and demands to prices in different regions of the world, and the likelihood of oil supply disruptions. ORNL prepared its updated estimates of oil import externalities for use by EPA in evaluating the benefits of reductions in U.S. oil consumption and imports expected to result from its Renewable Fuel Standard Rule of 2007 (RFS)[473].

The updated ORNL study was subjected to a detailed peer review, and was subsequently revised by ORNL to reflect the reviewers' comments and recommendations. Specifically, reviewers recommended that ORNL increase its estimates of the sensitivity of oil supply by non-OPEC producers and oil demand by nations other than the U.S. to changes in the world oil price, as well as reduce its estimate of the sensitivity of U.S. gross domestic product (GDP) to potential sudden increases in world oil prices.[474] These revisions significantly changed ORNL's estimates of some components of the external costs of U.S. petroleum imports, and NHTSA used the revised values in its evaluation of proposed CAFE standards for MY 2012-16 passenger cars and light trucks.[475]

At the request of EPA, ORNL provided further revisions to its earlier estimates of external costs from U.S. oil imports to reflect changes in the outlook for world petroleum prices (using various editions of EIA's *Annual Energy Outlook*), as well as continuing changes in the structure and characteristics of global petroleum supply and demand. ORNL provided updates of its earlier

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[471] Leiby, Paul N., Donald W. Jones, T. Randall Curlee, and Russell Lee, *Oil Imports: An Assessment of Benefits and Costs*, ORNL-6851, Oak Ridge National Laboratory, November 1, 1997. *Available at* http://www.esd.ornl.gov/eess/energy_analysis/files/ORNL6851.pdf (last accessed August 1, 2012)

[472] Leiby, Paul N. "Estimating the Energy Security Benefits of Reduced U.S. Oil Imports," Oak Ridge National Laboratory, ORNL/TM-2007/028, Revised July 23, 2007. *Available at* http://www.esd.ornl.gov/eess/energy_analysis/files/Leiby2007%20Estimating%20the%20Energy%20Security%20Benefits%20of%20Reduced%20U.S.%20Oil%20Imports%20ornl-tm-2007-028%20rev2007Jul25.pdf (last accessed August 1, 2012).

[473] Federal Register Vol.72, #83, May 1, 2007 pp.23,900-24,014

[474] *Peer Review Report Summary: Estimating the Energy Security Benefits of Reduced U.S. Oil Imports*, ICF, Inc., September 2007. Docket NHTSA-2009-0059-0160.

[475] Leiby, Paul N. "Estimating the Energy Security Benefits of Reduced U.S. Oil Imports," Oak Ridge National Laboratory, ORNL/TM-2007/028, Final Report, 2008.

estimates to EPA in 2010 and 2011, and NHTSA used these estimates in its evaluations of final CAFE standards for MY 2012-16, and proposed standards for MY 2017-25 cars and light trucks.[476] More recently, ORNL has once again supplied revised estimates of external costs from U.S. petroleum imports to EPA, and NHTSA has elected to use these most recently updated values in evaluating alternative CAFE standards for this final rule.[477]

These most recent revisions increase ORNL's estimates of the monopsony cost associated with U.S. oil imports in the year 2025 to \$3.25 to \$16.69 per barrel, with a most likely estimate of \$9.77 per barrel of petroleum imported into the U.S. (expressed in 2010 dollars). These estimates imply that each gallon of fuel saved as a result of adopting higher CAFE standards that is reflected in lower U.S. imports of crude petroleum (or, presumably, refined petroleum products) will reduce the monopsony costs imposed by U.S. oil imports by \$0.077 to \$0.397 per gallon, with the actual value most likely to be \$0.233 per gallon saved (again in 2010 dollars).

These figures represent the reduced value of payments from U.S. oil purchasers to foreign oil suppliers that results when lower U.S. oil demand reduces the world price of petroleum, beyond the savings from reduced purchases of petroleum itself.[478] Consistency with NHTSA's use of estimates of the *global* benefits from reducing emissions of CO_2 and other greenhouse gases in this analysis, however, requires the use of a global perspective for assessing their net value. From this perspective, reducing these payments simply results in a transfer of resources from foreign oil suppliers to U.S. purchasers (or more properly, in a savings in the value of resources previously transferred from U.S. purchasers to foreign producers), and provides no real savings in resources to the global economy. Thus NHTSA's analysis of the benefits from adopting the higher CAFE standards it proposed for MY 2017-2025 cars and light trucks excluded the reduced value of monopsony payments by U.S. oil consumers that might result from lower fuel consumption by these vehicles.

In comments on those proposed standards, ACEEE stated that not including an estimate for monopsony value was a "departure from previous rules," and argued that monopsony effects should be counted among the final rule's economic benefits, because (1) reduction in the price of

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[476] Paul N. Leiby, "Energy Security Estimate Updated to AEO 2009," Oak Ridge National Laboratory, undated; and Paul N. Leiby, "Approach to Estimating the U.S. Oil Security Premium for the Proposed 2017-2025 Light -Duty Vehicle GHG/Fuel Economy Rule," Oak Ridge National Laboratory, October 14, 2011.
[477] Paul N. Leiby, "Estimating the U.S. Oil Security Premium for the 2017-2025 Light -Duty Vehicle GHG/Fuel Economy Rule", Oak Ridge National Laboratory (ORNL), July 15, 2012.
[478] The reduction in payments from U.S. oil purchasers to domestic petroleum producers is not included as a benefit, since it represents a transfer that occurs entirely within the U.S. economy.

petroleum would bring a net benefit in terms of job creation due to the low labor intensity of the energy sector, and (2) reduced demand means that the most expensive sources of petroleum are not used, which also reduces the price of all petroleum.[479] CFA commented simply that the monopsony effect is a true consumption externality, and should be included for the final rule at a value of $0.30/gallon.[480] SAFE suggested that even if reducing domestic demand for oil does not necessarily lead to lower fuel prices, it might lead to production levels that are adjusted downward based on expectations that increased fuel economy will reduce aggregate demand.[481] UCS argued that if the purpose of the CAFE program is conserve energy and improve energy security by raising fuel economy standards, NHTSA must include a value for the monopsony effect in the final rule or risk "abdication of [its] statutory responsibility."[482]

In fact, NHTSA previously excluded any reduction in these monopsony costs resulting from lower U.S. fuel consumption in its analyses of CAFE standards for MY 2008-11 light trucks, MY 2011 passenger cars and light trucks, and MY 2012-16 cars and light trucks. The rationale for doing so – namely that these costs represent a financial transfer rather than a use of real economic resources, and that reducing them does not provide a savings in the use of economic resources – is thus well-established, remains sound, and is consistent with the global perspective of NHTSA's analysis of this final rule. The agency also notes that job "creation" is not among the economic benefits attributable to higher CAFE standards (and in any case increased employment represents the consumption of additional economic resources, which is an economic *cost*), and that any reduction in the price of petroleum that continues to be purchased after a decline in total demand also represents a financial transfer rather than a true economic benefit.

In response to the assertion by CFA, the monopsony effect does not meet the definition of a consumption externality, because it is transmitted completely through the price mechanism and does not directly affect the welfare of individuals or the production functions of firms. Further, the economic benefit resulting from any decline in production levels of crude petroleum is already accounted for in the agency's estimates of the (pre-tax) value of fuel savings. Finally, by excluding any reduction in monopsony payments from its analysis of benefits from higher fuel economy, the agency is simply being consistent with the usual principles of economic analysis and with OMB guidelines for conducting regulatory analysis, and is thus in no way failing to meet its statutory responsibilities. Thus NHTSA has continued to do so in its analysis of the alternative CAFE standards considered in this final rule.

[479] ACEEE, Docket No. NHTSA-2010-0131-0062, at 1-2.
[480] CFA, Docket No. NHTSA-2010-0131-0073, at 16, 54-55.
[481] SAFE, Docket No. NHTSA-2010-0131-0259, at 4.
[482] UCS, Docket No. EPA-HQ-OAR-2010-0799-9567, at 6-7.

The second component of external economic costs imposed by U.S. petroleum imports arises partly because an increase in oil prices triggered by a disruption in the supply of imported oil reduces the level of output that the U.S. economy can produce. The reduction in potential U.S. economic output depends on the extent and duration of the increases in petroleum product prices that result from a disruption in the supply of imported oil, as well as on whether and how rapidly these prices return to pre-disruption levels. Even if prices for imported oil return completely to their original levels, however, economic output will be at least temporarily reduced from the level that would have been possible without a disruption in oil supplies.

Because supply disruptions and resulting price increases tend to occur suddenly rather than gradually, they can also impose costs on businesses and households for adjusting their use of petroleum products more rapidly than if the same price increase had occurred gradually over time. These adjustments impose costs because they temporarily reduce economic output even below the level that would ultimately be reached once the U.S. economy completely adapted to higher petroleum prices. The additional costs to businesses and households reflect their inability to adjust prices, output levels, and their use of energy and other resources quickly and smoothly in response to rapid changes in prices for petroleum products.

Since future disruptions in foreign oil supplies are an uncertain prospect, each of these disruption costs must be adjusted by the probability that the supply of imported oil to the U.S. will actually be disrupted. The “expected value” of these costs – the product of the probability that an oil import disruption will occur and the costs of reduced economic output and abrupt adjustment to sharply higher petroleum prices – is the appropriate measure of their magnitude. Any reduction in the expected value of these costs resulting from a measure that lowers U.S. oil imports represents an additional benefit to the U.S. economy *beyond* the direct value of savings from reduced purchases of petroleum products.

While the vulnerability of the U.S. economy to oil price shocks is widely believed to depend on *total* petroleum consumption rather than on the level of oil imports, variation in imports is still likely to have some effect on the magnitude of price increases resulting from a disruption of import supply. In addition, changing the quantity of petroleum imported into the U.S. may also affect the probability that such a disruption will occur. If either the size of the likely price increase or the probability that U.S. oil supplies will be disrupted is affected by the volume of

U.S. oil imports, the expected value of the economic costs resulting from potential supply disruptions will also depend on the level of imports.[483]

Businesses and households use a variety of market mechanisms, including oil futures markets, energy conservation measures, and technologies that permit rapid fuel switching to "insure" against higher petroleum prices and reduce their costs for adjusting to sudden price increases. While the availability of these market mechanisms has probably reduced the potential costs of disruptions to the supply of imported oil over time, consumers of petroleum products are unlikely to take account of costs they impose on others, so these costs are probably not fully reflected in the price of imported oil. Thus changes in oil import levels probably continue to affect the expected cost to the U.S. economy from potential oil supply disruptions, although this component of oil import costs is likely to be significantly smaller than estimated by studies conducted in the wake of the oil supply disruptions that occurred during the 1970s.

In its analysis of benefits from the higher CAFE standards it previously proposed for MY 2017-25, NHTSA employed ORNL's 2011 estimates of costs from potential disruptions in global oil supplies and resulting price increases for petroleum products. These ranged from $0.081 to $0.278 for each gallon of fuel saved that ultimately results in a reduction in U.S. petroleum imports, with a most likely value of $0.174 per gallon (these figures are in 2009 dollars for consistency with those reported in the agency's preliminary RIA). The agency noted that unlike the reduction in monopsony payments, lowering these expected disruption costs by reducing petroleum imports represents a real savings in the use of economic resources. Thus it contributes economic benefits in addition to the savings in resource costs for producing fuel itself that results from higher fuel economy.

In response, several environmental groups and other NGOs commented that the standards would have significant energy security benefits in terms of avoiding macroeconomic disruption. UCS stated that "No other federal policy has delivered greater oil savings, energy security benefits, or greenhouse gas emissions reductions to the country," and requested that we monetize improved energy security through reduced oil consumption and lower carbon emissions for the final rule analysis.[484] EDF described a study by Jamie Fine that found "that cost savings from avoided

[483] Leiby, Paul N. "Estimating the Energy Security Benefits of Reduced U.S. Oil Imports," Oak Ridge National Laboratory, ORNL/TM-2007/028, Final Report, 2008. The exact dependence of disruption costs on the volume of U.S. petroleum imports is demonstrated in equations (12) and (13), p. 38, and the accompanying discussion on pp. 37-39.

[484] UCS, Docket No. EPA-HQ-OAR-2010-0799-9567, at 5-6.

gasoline and diesel use in the event of an energy price shock in 2020 could be in the range of $2.4 to $5.2 billion for the state of California alone" under California's plan to reduce GHGs to 1990 levels by 2020, and requested that the agencies at least report a range of estimates for benefits associated with energy security.[485] EDF suggested that the agencies "consider cost estimation proposals such as that included in Sen. Richard Lugar's (R-Ind.) Practical Energy and Climate Plan, S. 3464," which "included both an extensive list of potential impacts of energy security to be considered and an alternative approximation valuation methodology for the "external cost of petroleum use" (i.e. this does not include the actual fuel savings)."[486] EDF stated that "For inputs that the agencies cannot quantify, the final rule should include a list and explain that the benefits of the rule are likely undervalued due to such factors."[487] SAFE commented simply that electrification of the fleet is good for energy security because it reduces the risk of macroeconomic disruptions, as a domestic fuel source.[488]

In response to these comments, the agency notes that its estimate of benefits from reducing U.S. petroleum consumption and imports incorporates *both* the potential economic cost of oil supply disruptions and the reduced probability that such disruptions will occur, exactly as advocated by UCS and other commenters. In addition, the agency analyzes the sensitivity of its benefit estimates to plausible variation in the per-gallon value of reduced macroeconomic disruption costs that result from lowering U.S. petroleum consumption and imports. Thus NHTSA feels that it has anticipated and responded fully to the comments it received on this issue.

ORNL's most recently updated and revised estimates of the increase in expected costs associated with oil supply disruptions to the U.S. and the resulting rapid increase in prices for petroleum products amount to $4.03 to $11.92 per barrel of oil imported into the U.S. in the year 2025, with a most likely estimate of $8.26 per barrel of imports (all figures are in 2010 dollars).[489] According to these estimates, each gallon of fuel saved that results in a reduction in U.S. petroleum imports (either crude petroleum or refined fuel) will reduce the expected costs of oil supply disruptions to the U.S. economy by $0.096 to $0.284, with the actual value most likely to be $0.197 per gallon (again in 2010 dollars). Unlike the reduction in monopsony payments that results from lower U.S. petroleum imports, however, the reduction in these expected disruption costs represents a real savings in resources, and thus contributes economic benefits in addition to the savings in resource costs for fuel production that would result from increasing fuel economy.

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[485] EDF, Docket No. NHTSA-2010-0131-0302, at 3-4, 15.
[486] *Id*. at 15.
[487] *Id*.
[488] SAFE, Docket No. NHTSA-2010-0131-0259, at 6-7.
[489] Paul N. Leiby, "Estimating the U.S. Oil Security Premium for the 2017-2025 Light -Duty Vehicle GHG/Fuel Economy Rule", Oak Ridge National Laboratory (ORNL), July 15, 2012.

NHTSA employs these values in its evaluation of the economic benefits from adopting higher CAFE standards for MY 2017-2025 cars and light trucks.

The third component of the external economic costs of importing oil into the U.S. includes government outlays for maintaining a military presence to secure the supply of oil imports from potentially unstable regions of the world and protect against their interruption. Some analysts also include outlays for maintaining the U.S. Strategic Petroleum Reserve (SPR) as an additional cost of U.S. dependence on oil imports, since the SPR is intended to cushion the U.S. economy against the consequences of disruption in the supply of imported oil.

NHTSA believes that while costs for U.S. military security may vary over time in response to long-term changes in the actual level of oil imports into the U.S., these costs are unlikely to decline in response to any reduction in U.S. oil imports resulting from raising future CAFE standards for light-duty vehicles. U.S. military activities in regions that represent vital sources of oil imports also serve a broader range of security and foreign policy objectives than simply protecting oil supplies, and as a consequence are unlikely to vary significantly in response to changes in the level of oil imports prompted by higher standards.

Neither the Congress nor the Executive Branch has ever attempted to calibrate U.S. military expenditures, force levels, or deployments to any oil market variable, or to some calculation of the projected economic consequences of hostilities in the Persian Gulf. Instead, changes in U.S. force levels, deployments, and thus military spending in that region have been largely governed by political events, emerging threats, and other military and political considerations, rather than by shifts in U.S. oil consumption or imports. NHTSA thus concluded that the levels of U.S. military activity and expenditures are likely to remain unaffected by even relatively large changes in light duty vehicle fuel consumption. As a consequence, the agency's analysis of this rule does not include savings in budgetary outlays to support U.S. military activities among the benefits of higher fuel economy and the resulting fuel savings.

However, the agency conducted a sensitivity analysis of the potential effect of assuming that some reduction in military spending would result from fuel savings and reduced petroleum imports in order to investigate its impacts on the standards and fuel savings. Using estimates of total U.S. military costs for securing Persian Gulf oil supplies and the volume of imports from that region in 2004 reported by Delucchi and Murphy, the agency estimated the potential savings in military outlays under the assumption that those would decline in exact proportion to any reduction in U.S. petroleum imports. Under that assumption, the estimated savings in military spending would range from \$0.03 to \$0.17 (in 2010 dollars) for each gallon of fuel saved as a result of higher CAFE standards that in turn resulted in lower U.S. imports of petroleum from the Persian Gulf.[490] If the Persian Gulf region is assumed to be the marginal source of supply for U.S. imports of crude petroleum and refined products, then each gallon of fuel saved might reduce U.S. military outlays by some amount within the above range. NHTSA selected a value of \$0.12 per gallon for its sensitivity analysis involving the military security component, slightly above the midpoint of the range identified by Delucchi and Murphy.

In both written comments and at the agencies' public hearings, many commenters expressed their beliefs that these standards will have significant benefits for U.S. energy and national security. A number of commenters, including consumer advocacy and environmental organizations, organizations representing labor, and state and local governments, as well as energy security advocates and numerous private individuals, urged NHTSA to quantify to the extent possible, a military component of the energy security benefits associated with this rulemaking. Some commenters recognized that deriving a single estimate of the energy security benefits from reduced military costs as a result of the rule would be difficult, and suggested that even providing a range of potential savings would be useful. The American Petroleum Institute commented that military expenditures will not likely change with a reduction in U.S. oil imports, and therefore should not be included in the assessment of this rulemaking.

NHTSA examined possible approaches to estimating the military component of energy security benefits from this final rule, and found that research addressing this question faces two major challenges. The first is the difficulty of correctly attributing specific military programs and expenditures to oil the goal of protecting petroleum supplies, rather than to other objectives. The second challenge arises in estimating whether and how extensively these costs would be likely to vary if U.S petroleum consumption or imports could be reduced.

Recent studies commonly estimate that there are substantial U.S. military costs associated with the mission of securing oil supplies, but do not identify specific cost reductions that would be likely to result from reductions in U.S. oil consumption or imports. At one extreme, the Council on Foreign Relations noted that substantial foreign policy-related military missions will continue over the next 20 years even in the absence of any need to secure imported petroleum supplies for the U.S. From this perspective, even eliminating U.S. petroleum consumption and imports would not result in significant reductions in military spending. In their previously cited study, Delucchi and Murphy deducted costs they attributed to missions other than securing petroleum

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[490] Mark A. Delucchi and James J. Murphy. "US Military Expenditures to Protect the Use of Persian Gulf Oil for Motor Vehicles." Energy Policy, Volume 36, Issue 6, June 2008, pages 2253-2264. *Available at* http://www.sciencedirect.com/science/article/pii/S0301421508001262 (last accessed August 1, 2012). The estimates reported here were converted to 2010 dollars using the change in the GDP price deflator.

supplies from the total cost of Persian Gulf military programs, and arrived at estimates of military spending to secure U.S. oil interests ranging from \$18 to \$59 billion in 2004 (expressed in 2010 dollars).[491]

In another recent study, RAND considered force reductions and cost savings that could be achieved if oil security were no longer a consideration.[492] Using two different approaches and guided by the history of post Cold-War force reductions and a detailed examination of the current U.S. allocation of defense resources, RAND concluded that \$75–\$91 billion, or 12–15 per cent of the U.S. defense budget in 2009, could be reduced if U.S. dependence on imported oil were eliminated entirely. However, the study also concluded that the reduction in military costs from a partial reduction in the U.S. dependence on imported oil would be minimal. In another study, Stern developed an estimate of military cost for Persian Gulf force projection using an activity-based allocation method to distinguish costs related to securing oil imports.[493] He used information on actual naval force deployments rather than budgets to guide his cost allocation, focusing on the costs of aircraft carrier deployment. For the 1976–2007 period, Stern estimated average military costs for securing U.S. petroleum imports of \$212 billion annually and \$500 billion for 2007 alone, and argued that these costs could potentially be reduced as a consequence of lower U.S. oil imports.

Although these recent studies provide useful insights into the military components of U.S. energy security, they do not provide an estimate of potential savings in military spending from reduced U.S. petroleum imports that the agency regards as sufficiently reliable for use in this rulemaking. Even studies that carefully attribute specific missions to the objective of securing international oil production and distribution offer little guidance about the degree to which incremental reductions in U.S. dependence on imported oil would reduce or eliminate those missions or programs. While NHTSA will continue to review newer studies in an attempt to estimate a military spending component of U.S. energy security benefits, the agency continues to exclude military cost savings from its estimate of energy security benefits used to analyze the impacts of this final rule.

Similarly, while the ideal size of the Strategic Petroleum Reserve from the standpoint of its potential influence on domestic oil prices during a supply disruption may be related to the level of U.S. oil consumption and imports, its *actual* size has not appeared to vary in response to recent changes in oil imports. Thus while the budgetary costs for maintaining the Reserve are

[491] Mark A. Delucchi and James J. Murphy. "US Military Expenditures to Protect the Use of Persian Gulf Oil for Motor Vehicles." Energy Policy, Volume 36, Issue 6, June 2008, pages 2253-2264. The estimates reported by the authors were converted to 2010 dollars using the change in the GDP price deflator.
[492] Keith Crane et al., "Does Imported Oil Threaten U.S. National Security?" Santa Monica, CA, The RAND Corporation, 2009. Research brief available at http://www.rand.org/pubs/research_briefs/2009/RAND_RB9448.pdf (last accessed August 1, 2012)
[493] R.J. Stern, "United States cost of military force projection in the Persian Gulf, 1976–2007", *Energy Policy*, 2010.

similar to other external costs in that they are not likely to be reflected in the market price for imported oil, these costs do not appear to have varied in response to changes in oil import levels. As a result, the agency's analysis of benefits from these final CAFE standards for MY 2017-2025 does not include cost savings from maintaining a smaller SPR among the external benefits of reducing gasoline consumption and petroleum imports. This view concurs with that of the recent ORNL study of economic costs from U.S. oil imports, which concludes that savings in government outlays to maintain the U.S. petroleum reserves are unlikely to result from reductions in consumption of petroleum products and oil imports on the scale of those resulting from the increases in CAFE standards considered for MY 2017-25.

The Impact of Fuel Savings on U.S. Petroleum Imports

Based on a detailed analysis of differences in fuel consumption, petroleum imports, and imports of refined petroleum products among the Reference Case, High Economic Growth, and Low Economic Growth Scenarios presented in the Energy Information Administration's Annual Energy Outlook 2009, NHTSA estimates that approximately 50 percent of the reduction in fuel consumption resulting from adopting higher CAFE standards is likely to be reflected in reduced U.S. imports of refined fuel, while the remaining 50 percent would be expected to be reflected in reduced domestic fuel refining.[494] Of this latter figure, 90 percent is anticipated to reduce U.S. imports of crude petroleum for use as a refinery feedstock, while the remaining 10 percent is expected to reduce U.S. domestic production of crude petroleum.[495] Thus on balance, each gallon of fuel saved as a consequence of higher CAFE standards is anticipated to reduce total U.S. imports of crude petroleum or refined fuel by 0.95 gallons.[496]

The Economic Value of Reducing CO_2 Emissions

NHTSA has taken the economic benefits of reducing CO_2 emission into account in this rulemaking, both in developing alternative CAFE standards and in assessing the economic benefits of each alternative that was considered. Since direct estimates of the economic benefits from reducing CO_2 or other GHG emissions are generally not reported in published literature on

[494] Differences in forecasted annual U.S. imports of crude petroleum and refined products among the Reference, High Oil Price, and Low Oil Price scenarios analyzed in EIA's Annual Energy Outlook 2011 range from 35-74 percent of differences in projected annual gasoline and diesel fuel consumption in the U.S. These differences average 53 percent over the forecast period spanned by AEO 2011.

[495] Differences in forecasted annual U.S. imports of crude petroleum among the Reference, High Oil Price, and Low Oil Price scenarios analyzed in EIA's Annual Energy Outlook 2011 range from 67-104 percent of differences in total U.S. refining of crude petroleum, and average 90 percent over the forecast period spanned by AEO 2011.

[496] This figure is calculated as $0.50 + 0.50*0.9 = 0.50 + 0.45 = 0.95$.

the impacts of climate change, these benefits are typically assumed to be the "mirror image" of the estimated incremental *costs* resulting from an increase in those emissions. Thus, the benefits from reducing CO_2 emissions are usually measured by the savings in estimated economic damages that an equivalent *increase* in emissions would otherwise have caused.

The "social cost of carbon" (SCC) is intended to be a monetary measure of the incremental damage resulting from increased carbon dioxide (CO_2) emissions, including losses in agricultural productivity, the economic damages caused by adverse effects on human health, property losses and damages resulting from sea level rise, and changes in the economic value of ecosystem services. The SCC is usually expressed in dollars per additional metric ton of CO_2 emissions occurring during a specified year, and is higher for more distant future years because the damages caused by an additional ton of emissions increase with larger existing concentrations of CO_2 in the earth's atmosphere. Reductions in CO_2 emissions that are projected to result from lower fuel consumption, refining, and distribution during each future year are multiplied by the estimated SCC appropriate for that year, which is used to represent the value of eliminating each ton of CO_2 emissions, to determine the total economic benefit from reduced emissions during that year. These benefits are then discounted to their present value as usual, using a discount rate that is consistent with that used to develop the estimate of the SCC itself.

For these final MY 2017-2021 and augural MY 2022-2025 standards, NHTSA has relied on estimates of the SCC developed by a federal interagency working group convened for the specific purpose of developing new estimates to be used by U.S. federal agencies in regulatory evaluations. Under Executive Order 12866, federal agencies are required, to the extent permitted by law, "to assess both the costs and the benefits of the intended regulation and, recognizing that some costs and benefits are difficult to quantify, propose or adopt a regulation only upon a reasoned determination that the benefits of the intended regulation justify its costs." The group's purpose in developing new estimates of the SCC was to allow federal agencies to incorporate the social benefits of reducing carbon dioxide (CO_2) emissions into cost-benefit analyses of regulatory actions that have small, or "marginal," impacts on cumulative global emissions, as most federal regulatory actions can be expected to have.

The interagency group convened on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key inputs and assumptions in order to generate SCC estimates. Agencies that actively participated in the interagency process included the Environmental Protection Agency, and the Departments of Agriculture, Commerce, Energy, Transportation, and Treasury. This process was convened by the Council of Economic Advisers and the Office of Management and Budget, with active participation and regular input from the

Council on Environmental Quality, National Economic Council, Office of Energy and Climate Change, and Office of Science and Technology Policy. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions that are grounded in the existing literature. In this way, key uncertainties and model differences can more transparently and consistently inform the range of SCC estimates used in the rulemaking process.

The interagency group developed its estimates of the SCC estimates while clearly acknowledging the many uncertainties involved, and with a clear understanding that they should be updated over time to reflect increasing knowledge of the science and economics of climate impacts. Technical experts from numerous agencies met on a regular basis to consider public comments, explore the technical literature in relevant fields, and discuss key model inputs and assumptions. The main objective of this process was to develop a range of SCC values using a defensible set of input assumptions grounded in the existing scientific and economic literature. In this way, key uncertainties and model differences transparently and consistently can inform the range of SCC estimates used in the rulemaking process.

The group ultimately selected four SCC values for use in regulatory analyses. Three values are based on the average SCC from three integrated assessment models, using discount rates of 2.5, 3, and 5 percent. The fourth value, which represents the 95th percentile SCC estimate across all three models at a 3 percent discount rate, is included to represent the possibility of higher-than-expected impacts from temperature change that lie further out in the tails of the distribution of SCC estimates. Table VIII-14 summarizes the interagency group’s estimates of the SCC during various future years. The SCC estimates reported in the table assume that the marginal damages from increased emissions are constant for small departures from the baseline emissions path, an approximation that is reasonable for policies that have effects on emissions that are small relative to cumulative global carbon dioxide emissions.

Table VIII-14
Social Cost of CO_2 Emissions, 2010 – 2050 (2007 dollars)

Discount Rate	5%	3%	2.5%	3%
Source	Average	Average	Average	95th Percentile
2010	$4.7	$21.4	$35.1	$64.9
2015	$5.7	$23.8	$38.4	$72.8
2020	$6.8	$26.3	$41.7	$80.7
2025	$8.2	$29.6	$45.9	$90.4
2030	$9.7	$32.8	$50.0	$100.0
2035	$11.2	$36.0	$54.2	$109.7
2040	$12.7	$39.2	$58.4	$119.3
2045	$14.2	$42.1	$61.7	$127.8
2050	$15.7	$44.9	$65.0	$136.2

As Table VIII-14 shows the four SCC estimates selected by the interagency group for use in regulatory analyses are $5, $21, $35, and $65 (in 2007 dollars) for emissions occurring in the year 2010. The first three estimates are based on the average SCC across models and socio-economic and emissions scenarios at the 5, 3, and 2.5 percent discount rates, respectively. The fourth value is included to represent the higher-than-expected impacts from temperature change further out in the tails of the SCC distribution. For this purpose, the group elected to use the SCC value for the 95th percentile at a 3 percent discount rate.

Table VIII-14 cites values in 2007 dollars to maintain consistency with the interagency group's reported estimates, as well as with the values reported in NHTSA's final CAFE rulemaking for MYs 2012-2016 and in the agency's analysis of proposed CAFE standards for MY 2017-25. However, the agency updated these values to 2010 dollars for the current rulemaking; to illustrate the results, the SCC estimates for emissions occurring in the year 2020 used in this final regulatory analysis are $7, $27, $43, and $84.

The central value identified by the interagency group is the average SCC across models at the 3 percent discount rate. For example, the $27 per metric ton value reported immediately above represents this central value for emissions occurring in the year 2020 (in 2010 dollars). To capture the uncertainties involved in regulatory impact analysis, however, the group emphasized the importance of considering the full range of estimated SCC values. As the table also shows, the SCC estimates also rise over time; for example, the central value increases to $34 per ton of CO_2 in 2030 and to $41 per ton of CO_2 by 2040 when expressed in 2007 dollars.

Details of the process used by the interagency group to develop its SCC estimates, complete results including year-by-year estimates of each of the four values, and a thorough discussion of their intended use and limitations is provided in the document *Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866*, Interagency Working Group on Social Cost of Carbon, United States Government, February 2010.[497]

The agencies received a number of lengthy, detailed comments on the SCC values recommended by the interagency group and the process it used to develop them. Most of these comments addressed the topics of incorporating updated knowledge about climate impacts, more fully considering the potential for catastrophic impacts, valuing the population's presumed aversion to the risk of significant climate impacts on economic well-being, and the discount rate used to convert distant future economic impacts to their present values. EDF, NRDC, and IPI each urged the agency to revise its estimates of the SCC to incorporate recent improvements in understanding the range and severity of economic impacts from climate change.

NRDC and EDF noted that the three integrated assessment models used by the federal interagency group to develop the SCC estimates used to analyze the proposed rule have been updated to reflect recent estimates of climate sensitivity to GHG accumulations and to expand the range of monetized economic damages resulting from climate change, and encouraged the agency to update its estimates of the SCC using these newest versions of these models. NRDC further recommended that these models be updated to reflect recent research identifying adverse climate impacts on agricultural productivity. EDF and IPI recommended that the agency provide a complete listing of known and potential economic damages resulting from climate change, identify which of these were monetized in the interagency group's estimates of the SCC, and explicitly note which of them were excluded. NRDC urged NHTSA to develop "multipliers" that could be applied to reductions in the use value of natural resources and ecosystem services to account for accompanying reductions in their non-use values.

All three commenters urged the agency to revise its SCC estimates to more fully reflect the potential for catastrophic economic damages resulting from future climate change. NRDC recommended doing so by integrating such damages directly into the three integrated assessment

[497] This document is available at http://www2.eere.energy.gov/buildings/appliance_standards/commercial/pdfs/sem_finalrule_appendix15a.pdf (last accessed August 1, 2012) or Docket No. NHTSA-2010-0131.

models used by the interagency group, while IPI recommended adjusting those models' estimates of benefits from reducing GHG emissions to account for their undervaluation of the risk and magnitude of catastrophic damages. EDF urged revisions to the mathematical form of the models' functions relating GHG accumulations to changes in global climate indicators and resulting economic damages, in order to remedy what EDF views as their underestimation of the probability that such damages will result.

NRDC also recommended that the agency report the magnitude of extremely low-probability economic damages in order to inform the public and decision-makers about the impact of catastrophic scenarios. NRDC further urged the agency to conduct sensitivity analysis of the SCC using various "equity weights," which would increase the value of climate damages likely to be experienced by lower-income regions of the world.

IPI, EDF, and NRDC each urged the agency to incorporate the economic value of the population's aversion to the risk of large losses in welfare in its SCC estimates. Specifically, the commenters recommended that the SCC be revised to include a measure of the typical consumer's willingness to sacrifice current consumption to avoid being exposed to the risk of a large welfare loss from potential climate change. Including such a "risk premium," which would be in addition to the conventional expected value of damages from different degrees of potential climate change, could increase the agency's estimates of the SCC significantly. IPI noted that such a risk premium could be approximated by reducing the discount rate applied to future climate-related economic damages if it could not be estimated directly, while NRDC referred the agency to published research describing a recently-developed alternative method for incorporating the value of risk aversion.

All three of the same commenters urged NHTSA to base its estimates of the SCC on lower discount rates than those the interagency group applied to future economic damages, which would increase the agency's SCC values. NRDC noted that OMB Circular A-4 recommends a 1% rate as a lower bound for discounting where future benefits or costs will be experienced by future generations, and also pointed out that short-term interest rates are currently well below this figure. As an alternative, NRDC recommended using declining future discount rates to account for more fully for long-run uncertainty about interest rates than the procedure used by the interagency group. EDF similarly encouraged the agency to reduce the discount rates incorporated in the interagency group's SCC estimates below 3%, and also to consider using declining discount rates to account more appropriately for scientific and economic uncertainty surrounding the correct social discount rate for use over long time periods.

Finally, NRDC noted than an alternative to using the SCC to value reductions in GHG emissions would be to estimate the cost of achieving the final reduction in emissions necessary to reach a target emissions level (or "marginal abatement cost") that is consistent with the maximum acceptable degree of climate change. While NRDC acknowledged that the determination of what constitutes an acceptable degree of climate change would ultimately be a political decision, the associated level of emissions and the marginal cost of reducing emissions to that level from today's baseline could be determined scientifically with reasonable accuracy and allowing some margin for error.

The agency appreciates the careful thought and detailed analyses that are reflected in the extensive comments it received on the SCC. In the time frame for evaluating and adopting this final rule, however, NHTSA judged that it would be impractical to replicate the detailed process the federal interagency group used to produce its recommended values for the SCC, and to develop the updated input assumptions and revised modeling procedures advocated by the commenters. Recognizing this, the agency has elected to continue using the interagency group's recommended SCC values to estimate the economic benefits stemming from the reductions in GHG emissions that are projected to result from this final rule.

Benefits from Reducing Emissions of Criteria Air Pollutants

Car and light truck use, fuel refining, and fuel distribution and retailing also generate emissions of certain criteria air pollutants, including carbon monoxide (CO), hydrocarbon compounds (usually referred to as "volatile organic compounds," or VOC), nitrogen oxides (NO_x), fine particulate matter (PM2.5), and sulfur dioxide (SO_2). While reductions in fuel refining and distribution that result from lower fuel consumption will reduce emissions of criteria pollutants, additional vehicle use associated with the rebound effect from higher fuel economy will increase emissions of these pollutants. Thus the net effect of stricter CAFE standards on total emissions of each criteria pollutant depends on the relative magnitudes of reduced emissions in fuel refining and distribution, and increases in emissions from vehicle use. Because the relationship between emission rates (emissions per gallon refined of fuel or mile driven) in fuel refining and vehicle use is different for each criteria pollutant, the net effect of fuel savings from increased CAFE standards on total emissions of each pollutant is likely to differ.

NHTSA estimates the increase in emissions of each criteria air pollutant from additional vehicle use by multiplying the increase in total miles driven by cars and light trucks of each model year and age by their estimated emission rates per vehicle-mile of each pollutant. These emission rates differ between cars and light trucks as well as between gasoline and diesel vehicles, and both their values for new vehicles and the rates at which they increase with age and accumulated mileage can vary among model years. With the exception of SO_2, NHTSA calculated the increase in emissions of these criteria pollutants from added car and light truck use by multiplying the estimated increases in their vehicles' use during each year over their expected lifetimes by per-mile emission rates appropriate to each vehicle type, fuel used, model year, and age as of that future year.

These emission rates were developed by U.S. EPA using its recently-developed Motor Vehicle Emission Simulator (MOVES 2010). The MOVES model assumes that the per-mile rates at which these pollutants are emitted are determined by EPA regulations and the effectiveness of catalytic after-treatment of engine exhaust emissions, and are thus unaffected by changes in car and light truck fuel economy. As a consequence, the effects of required increases in fuel economy emissions of these pollutants from car and light truck use are determined entirely by the increases in driving that result from the fuel economy rebound effect.

Emission factors in the MOVES database are expressed in the form of grams per vehicle-hour of operation. To convert these emission factors to grams per mile for use in NHTSA's calculations, MOVES was run for the year 2050, and was programmed to report aggregate emissions from vehicle start and running exhaust. EPA analysts selected the year 2050 in order to generate emission factors that were representative of lifetime average emission rates for vehicles meeting the agency's Tier 2 emission standard.[498] Separate estimates were developed for each vehicle type and model year, as well as for each state and month, in order to reflect the effects of regional and temporal variation in temperature and other relevant variables on emissions.

The MOVES emissions estimates were then summed to the model year level and divided by average distance traveled in order to produce per-mile emission factors for each

[498] Because all light-duty emission rates in MOVES 2010 are assumed to be invariant after MY 2010, a calendar-year 2050 run produced a full set of emission rates that reflect anticipated deterioration in the effectiveness of vehicles' emission control systems with increasing age and accumulated mileage for post-MY 2010 vehicles.

pollutant. The resulting emission rates represent average values across the nation, and incorporate typical temperature variations over an entire calendar year. These national average rates also reflect county-specific differences in fuel composition, as well as in the presence and type of vehicle inspection and maintenance programs.[499]

Emission rates for the criteria pollutant SO_2 were calculated by NHTSA using average fuel sulfur content estimates supplied by EPA, together with the assumption that the entire sulfur content of fuel is emitted in the form of SO_2. These calculations assumed that national average gasoline and diesel sulfur levels would remain at current levels.[500] Total SO_2 emissions under each alternative CAFE standard were calculated by applying the resulting emission rates directly to annual gasoline and diesel fuel use by cars and light trucks that is projected to occur under that alternative. As with other impacts, the *changes* in emissions of criteria air pollutants resulting from alternative increases in CAFE standards for MY 2017-2025 cars and light trucks were calculated as the difference between emissions under each alternative that would increase CAFE standards and emissions under the baseline alternative, which would extend the MY 2016 CAFE and EPA GHG emissions standards to apply to future model years.

Emissions of criteria air pollutants also occur during each phase of fuel production and distribution, including crude oil extraction and transportation, fuel refining, and fuel storage and transportation. The reduction in emissions during each of these phases depends on the extent to which fuel savings result in lower imports of refined fuel, or in reduced domestic fuel refining. To a lesser extent, they also depend on whether reductions in domestic gasoline refining are reflected in reduced imports of crude oil or in reduced domestic extraction of petroleum. NHTSA's analysis assumes that reductions in imports of refined fuel would reduce criteria pollutant emissions during fuel storage and distribution only. Reductions in domestic fuel refining using imported crude oil as a feedstock are assumed to reduce emissions during fuel refining, storage, and distribution, because each of these activities would be reduced. Finally,

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[499] The national mix of fuel types includes county-level market shares of conventional and reformulated gasoline, as well as county-level variation in sulfur content, ethanol fractions, and other fuel properties. Inspection/maintenance programs at the county level account for detailed program design elements such as test type, inspection frequency, and program coverage by vehicle type and age.

[500] These are 30 and 15 parts per million (ppm, measured on a mass basis) for gasoline and diesel respectively, which produces emission rates of 0.17 grams of SO_2 per gallon of gasoline and 0.10 grams per gallon of diesel.

reduced domestic fuel refining using domestically-produced crude oil is assumed to reduce emissions during all four phases of fuel production and distribution.[501]

NHTSA estimated the reductions in criteria pollutant emissions from producing and distributing fuel that would occur with alternative CAFE standards using emission rates obtained by EPA from Argonne National Laboratories' Greenhouse Gases and Regulated Emissions in Transportation (GREET) model.[502] The GREET model provides separate estimates of air pollutant emissions that occur in four phases of fuel production and distribution: crude oil extraction, crude oil transportation and storage, fuel refining, and fuel distribution and storage.[503] EPA modified the GREET model to change certain assumptions about emissions during crude petroleum extraction and transportation, as well as to update its emission rates to reflect adopted and pending EPA emission standards. The agency converted these emission rates from the mass per fuel energy content basis on which GREET reports them to mass per gallon of fuel supplied using the estimates of fuel energy content reported by GREET. The resulting emission rates were applied to the agency's estimates of fuel consumption under each alternative CAFE standard to develop estimates of total emissions of each criteria pollutant during fuel production and distribution. The assumptions about the effects of *changes* in fuel consumption on domestic and imported sources of fuel supply discussed above were then employed to calculate the effects of reductions in fuel use from alternative CAFE standards on changes in domestic emissions of each criteria pollutant.

Finally, NHTSA calculated the *net* changes in domestic emissions of each criteria pollutant by summing the increases in its emissions projected to result from increased vehicle use, and the reductions in emissions anticipated to result from lower domestic fuel refining and distribution.[504] As indicated previously, the effect of adopting higher CAFE standards on total emissions of each criteria pollutant depends on the relative magnitudes of the resulting reduction in emissions from fuel refining and distribution, and the increase in emissions from additional

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[501] In effect, this assumes that the distances crude oil travels to U.S. refineries are approximately the same regardless of whether it travels from domestic oilfields or import terminals, and that the distances that gasoline travels from refineries to retail stations are approximately the same as those from import terminals to gasoline stations.

[502] Argonne National Laboratories, *The Greenhouse Gas and Regulated Emissions from Transportation (GREET) Model*, *available at* http://greet.es.anl.gov/ (last accessed August 1, 2012).

[503] Emissions that occur during vehicle refueling at retail gasoline stations (primarily evaporative emissions of volatile organic compounds, or VOCs) are already accounted for in the "tailpipe" emission factors used to estimate the emissions generated by increased light truck use. GREET estimates emissions in each phase of gasoline production and distribution in mass per unit of gasoline energy content; these factors are then converted to mass per gallon of gasoline using the average energy content of gasoline.

[504] All emissions from increased vehicle use are assumed to occur within the U.S., since CAFE standards would apply only to vehicles produced for sale in the U.S.

vehicle use. Although these net changes vary significantly among individual criteria pollutants, the agency projects that on balance, adopting higher CAFE standards would reduce emissions of all criteria air pollutants except carbon monoxide (CO).

The net changes in domestic emissions of fine particulates (PM2.5) and its chemical precursors (such as NOx, SOx, and VOCs) are converted to economic values using estimates of the reductions in health damage costs per ton of emissions of each pollutant that is avoided, which were developed and recently revised by EPA. These savings represent the estimated reductions in the value of damages to human health resulting from lower atmospheric concentrations and population exposure to air pollution that occur when emissions of each pollutant that contributes to atmospheric PM2.5 concentrations are reduced. The value of reductions in the risk of premature death due to exposure to fine particulate pollution (PM2.5) account for a majority of EPA's estimated values of reducing PM2.5 related emissions, although the value of avoiding other health impacts related to PM2.5 exposure is also included in these estimates.

These values do not include a number of unquantified benefits, such as reduction in the welfare and environmental impacts of PM2.5 pollution, or reductions in health and welfare impacts related to other criteria pollutants (ozone, NO2, and SO2) and air toxics. EPA estimates different PM-related per-ton values for reducing emissions from vehicle use than for reductions in emissions of that occur during fuel production and distribution. NHTSA applies these separate values to its estimates of changes in emissions from vehicle use and fuel production and distribution to determine the net change in total economic damages from emissions of these pollutants.

EPA projects that the per-ton values for reducing emissions of criteria pollutants from both mobile sources (including motor vehicles) and stationary sources such as fuel refineries and storage facilities will increase over time. These projected increases reflect rising income levels, which are assumed to increase affected individuals' willingness to pay for reduced exposure to health threats from air pollution, as well as future population growth, which increases population exposure to future levels of air pollution.

D. Added Costs from Congestion, Crashes, and Noise

While it provides some benefits to drivers, increased vehicle use associated with the fuel economy rebound effect can also contribute to increased traffic congestion, motor vehicle crashes, and highway noise. Additional vehicle use can contribute to traffic congestion and delays by increasing recurring congestion on heavily-traveled roadways during peak travel periods, depending on how the additional travel is distributed over the day and on where it occurs. By increasing the number of crashes and disabled vehicles, added driving can also increase the delays that often result from these incidents, although the extent to which it actually does so again depends on when and where the added travel occurs.

In either case, added delays impose higher costs on drivers and other vehicle occupants in the form of increased travel time and operating expenses, and these should be considered as an additional economic cost associated with the rebound effect. Because drivers do not take these added costs into account in deciding when to make trips or where they travel, they must be accounted for separately as a cost of the added driving associated with the rebound effect.

Increased passenger car and light truck use due to the rebound effect may also increase the costs associated with traffic crashes. Drivers presumably take account of the potential costs they (and the other occupants of their vehicles) face from the possibility of being involved in a crash when they decide to make additional trips. However, they probably do not consider all of the potential costs they impose on occupants of other vehicles and on pedestrians when crashes occur, so any increase in these "external" crash costs must be considered as another cost of additional rebound-effect driving.

Like increased delay costs, any increase in these external crash costs caused by added driving is likely to depend on the traffic conditions under which it takes place, since crashes are more frequent in heavier traffic, but their severity may be reduced by the slower speeds at which heavier traffic typically moves. Thus estimates of the increase in external crash costs from the rebound effect also need to account for when and where the added driving occurs.

Finally, added vehicle use from the rebound effect may also increase traffic noise. Noise generated by vehicles causes inconvenience, irritation, and potentially even discomfort to occupants of other vehicles, to pedestrians and other bystanders, and to residents or occupants of surrounding property. Because none of these effects are likely to be taken into account by the drivers whose vehicles contribute to traffic noise, they represent additional externalities associated with motor vehicle use.

Although there is considerable uncertainty in estimating its value, the added inconvenience and irritation caused by increased traffic noise imposes some economic costs on those it affects, and these added costs are unlikely to be taken into account by drivers of the vehicles that cause it. Thus any increase in noise costs resulting from added vehicle use must be included together with other increases in external costs of additional rebound-effect driving.

NHTSA's analysis uses estimates of the congestion, crash, and noise costs caused by increased travel in automobiles, pickup trucks, and vans developed by the Federal Highway Administration.[505] These estimates are intended to measure the *increases* in external costs – that is, the "marginal" external costs – from added congestion, property damages and injuries in traffic crashes, and noise levels caused by additional usage of cars and light trucks that are borne by persons other than their drivers. FHWA's "Middle" estimates for congestion, accident, and noise costs imposed by passenger cars are 5.6 cents, 2.4 cents and 0.1 cents per additional vehicle mile when expressed in 2010 dollars.[506] For light trucks, FHWA's estimates correspond to 5.0 cents, 2.7 cents, and 0.1 cents per additional vehicle-mile.

The Federal Highway Administration's estimates of these costs agree closely with some other recent estimates. For example, recent published research conducted by Resources for the Future (RFF) estimates marginal congestion and external crash costs for increased light-duty vehicle use in the U.S. to be 4.0 and 3.5 cents per vehicle-mile when converted to 2010 dollars.[507] These estimates incorporate careful adjustments of congestion and crash costs that are intended to reflect the traffic conditions under which additional driving is likely to take place, as well as its likely effects on both the frequency and severity of motor vehicle crashes.

FHWA's estimates of added costs for congestion, crashes , and noise are multiplied by the estimated increases in passenger car and light truck use due during each year of the affected model years' lifetimes to yield the estimated increases in congestion, crash, and noise externality

[505] These estimates were developed by FHWA for use in its 1997 *Federal Highway Cost Allocation Study*, available at http://www.fhwa.dot.gov/policy/hcas/final/index.htm. (last accessed on March 15, 2010)

[506] Federal Highway Administration, 1997 *Federal Highway Cost Allocation Study*, Tables V-22, V-23, and V-24, http://www.fhwa.dot.gov/policy/hcas/final/index.htm (last accessed on August 1, 2012). The higher congestion cost for automobiles than for light trucks reflects the larger fraction of auto than of light truck use that occurs within congested urban areas.

[507] Ian W.H. Parry and Kenneth A. Small, "Does Britain or the U.S. Have the Right Gasoline Tax?" Discussion Paper 02-12, Resources for the Future, March 2002, pp. 19 and Table 1, http://www.rff.org/rff/Documents/RFF-DP-02-12.pdf. (last accessed on August 1, 2012) or Docket No. NHTSA-2010-0131.

costs. The resulting yearly estimates are then summed to obtain their lifetime values. The value of these increased costs varies among model years and the alternative increases in CAFE standards considered in this analysis, because the increases in vehicle use depend on the improvements in fuel economy that would result in specific model years under each alternative.

Minimum Sound Requirements for Hybrid and Electric Vehicles

NHTSA analyses have found that hybrid vehicles strike pedestrians and bicyclists more often at low speed than vehicles with internal combustion engines (ICEs).[508] Testing has shown that electric and hybrid electric vehicles emit less sound and are quieter at low speeds than vehicles with internal combustion engines.[509] The Pedestrian Safety Enhancement Act (PSEA) requires NHTSA to conduct a rulemaking to require an alert sound for pedestrians to be emitted by all types of motor vehicles that are electric vehicles (EVs) or hybrid vehicles (HVs).[510] NHTSA is in the process of developing a Notice of Proposed Rulemaking to propose sound requirements.

NHTSA estimates that EVs and HVs are 22 percent more likely to be involved in a crash with a pedestrian and 38 percent more likely to be involved in a crash with a pedal cyclist than vehicles with internal combustion engines.[511] Statistically significant results were found for injuries, but not for fatalities. NHTSA's analysis of the final CAFE standards assumes total fleet penetration of strong HEVs, PHEVs, and EVs (the vehicles designated in the minimum sound requirements rulemaking as "EVs" and "HVs") of only 3 percent in MY 2021, and only up to 5 percent in MY 2025. At this time NHTSA assumes that sound is the only difference between EVs and HVs and internal combustion engines causing this increase in pedestrian and pedal cyclist injuries. Assuming our eventual sound requirements work as intended, any increase in pedestrian and

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[508] Wu et al. (2011) Incidence Rates of Pedestrian And Bicyclist Crashes by Hybrid Electric Passenger Vehicles: An Update, Report No. DOT HS 811 526. Dept. of Transportation, Washington, DC. Available at http://www-nrd.nhtsa.dot.gov/Pubs/811526.pdf (last accessed July 10, 2012)

[509] Garay-Vega et al.(2010) Quieter Cars and the Safety of Blind Pedestrians: Phase I, Report No. DOT HS 811 304, U.S. Dept. of Transportation, Washington, DC. Available at http://www.nhtsa.gov/DOT/NHTSA/NVS/Crash%20Avoidance/Technical%20Publications/2010/811304rev.pdf. (last accessed July 10, 2012).

[510] Pub. L. 111-373, 124 Stat. 4086 (Jan. 4, 2011).

[511] Wu et al. (2011) Incidence Rates of Pedestrian And Bicyclist Crashes by Hybrid Electric Passenger Vehicles: An Update, Report No. DOT HS 811 526. Dept. of Transportation, Washington, DC. Available at http://www-nrd.nhtsa.dot.gov/Pubs/811526.pdf (last accessed July 10, 2012).

pedal cyclist injuries brought about by an increase in hybrid or electric vehicle sales to meet CAFE standards should likely be neutralized.

E. Additional Maintenance and Repair Costs

The NPRM analysis of this rule noted areas where increases and decreases in maintenance costs were possible, but did not quantify these costs and requested comment on this topic. One example of an area of potential cost savings is the lack of need for oil changes in electric vehicles. Separately, increased use of low rolling resistance tires to improve fuel economy may result in an increase in maintenance costs, as such tires are more expensive to replace.

The National Automobile Dealers Association (NADA) offered comment on the issue of maintenance and other costs, stating that the final rule should evaluate the potential impact on a vehicle's total cost of ownership, to include maintenance costs. In response, NHTSA identified a select list of technologies for which sufficient data on periodicity and cost exist to support quantification of changes in vehicle maintenance costs within the central analysis. This list includes costs associated with low rolling resistance tires, diesel fuel filters, and benefits resulting from electric vehicle characteristics that eliminate the need for oil changes as well as engine air filter changes.

To estimate maintenance costs, NHTSA looked at vehicle models for which there exists a version with fuel-efficiency-improving technology and a version with the corresponding baseline technology. The difference between maintenance costs for the two models represent a cost which the agencies assumed to be attributable to this rulemaking. By comparing the manufacturer recommended maintenance schedule of the items being compared, we were able to estimate the differences in maintenance intervals for the two. With estimates of the costs per maintenance event, we are able to put together a picture of the maintenance cost differences associated with the "new" technology.

The full list of technologies considered is shown in Chapter 3 of the joint TSD, along with the maintenance interval comparisons, and costs per maintenance event. A summary of the costs is shown in Table VIII-15 below.

Table VIII-15
Maintenance Event Costs and Intervals (2010 dollars)[512]

New Technology	Reference Case	Cost per Maintenance Event	Maintenance Interval (miles)
Low rolling resistance tires (level 1)	Standard tires	$6.44	40,000
Low rolling resistance tires (level 2)	Standard tires	$43.52	40,000
Diesel fuel filter replacement	Gasoline vehicle	$49.25	20,000
EV oil change	Gasoline vehicle	-$38.67	7,500
EV air filter replacement	Gasoline vehicle	-$28.60	30,000
EV engine coolant replacement	Gasoline vehicle	-$51.20	100,000
EV spark plug replacement	Gasoline vehicle	-$83.00	105,000
EV battery coolant replacement	Gasoline vehicle	$93.20	150,000
EV battery health check	Gasoline vehicle	$38.67	15,000

The maintenance intervals are used along with yearly VMT tables to determine which year(s) maintenance events occur (note: the VMT schedule will vary depending on the vehicle class). The cost of maintenance events applied to a vehicle is also a function of the survival rate of that vehicle class. Once all of the maintenance event costs are tabulated, they are multiplied by the survival rate of that vehicle class to determine the average cost per vehicle in that class. Lastly, the net present value of the average costs is calculated based on the year they occurred and the discount rate chosen (e.g., 3% or 7%).

Repair costs during the warranty period that are identifiably different for new technologies were included in the central analysis for the final rule. In the final rule, as in the NPRM, repair costs during the warranty period that are common for all vehicles remain a component of the indirect cost multiplier. A sensitivity analysis was added to this FRIA to examine repair costs in the post-warranty period, discussed further in Chapter X.

F. The Discount Rate

[512] All maintenance interval, hours required, and part(s) cost differentials between reference and control cases were sourced from the ALLDATA subscription database (www.alldatapro.com) in January through February of 2012, unless noted otherwise in the text. Note: negative values represent savings resulting from forms of maintenance required by gasoline vehicles that are not required by EVs.

Discounting future fuel savings and other benefits is intended to account for the reduction in their value to society when they are deferred until some future date, rather than received immediately. The discount rate expresses the percent decline in the value of these benefits – as viewed from today's perspective – for each year they are deferred into the future. In evaluating the benefits from alternative increases in CAFE standards for MY 2017-2025 passenger cars and light trucks, NHTSA separately estimated benefits at both 3% and 7% discount rates per year. Inclusion of the 7% discount rate in this rulemaking's central analysis is a departure from the previous rulemaking, in which the 7% discount rate was treated as a separate sensitivity analysis.

The primary reason that NHTSA selected 3 percent as the appropriate rate for discounting future benefits from increased CAFE standards is that most or all of vehicle manufacturers' costs for complying with higher CAFE standards are likely to be reflected in higher sales prices for their new vehicle models. By increasing sales prices for new cars and light trucks, CAFE regulation will thus primarily affect vehicle purchases and other private consumption decisions. Both economic theory and OMB guidance on discounting indicate that the future benefits and costs of regulations that mainly affect private consumption should be discounted at the social rate of time preference.[513] Also of note is that OMB guidance indicates that savers appear to discount future consumption at an average real (that is, adjusted to remove the effect of inflation) rate of about 3 percent when they face little risk about its likely level, which makes it a reasonable estimate of the social rate of time preference.[514]

One important exception to the 3 percent discount rate matches the rates used to discount benefits from reducing CO_2 emissions from the years in which reduced emissions occur, which span the lifetimes of MY 2017-2025 cars and light trucks, to their present values. In order to ensure consistency in the derivation and use of the interagency group's estimates of the unit values of reducing CO_2 emissions, the benefits from reducing those emissions during each future year are discounted using the *same* "intergenerational" discount rates that were used to derive each of the alternative unit values of reducing CO_2 emissions. As Table VIII-14 above shows, these rates are 5 percent for the interagency group's lowest estimate of the SCC, 3 percent for its central and highest estimates, and 2.5 percent for the estimate lying between the group's central and highest estimates.

[513] *Id.*
[514] Office of Management and Budget, Circular A-4, "Regulatory Analysis," September 17, 2003, 33. *Available at* http://www.whitehouse.gov/sites/default/files/omb/assets/regulatory_matters_pdf/a-4.pdf (last accessed August 1, 2012) or Docket No. NHTSA-2010-0131.

Because there is some uncertainty about the extent to which vehicle manufacturers will be able to recover their costs for complying with higher CAFE standards by increasing vehicle sales prices, however, NHTSA elected to include a 7 percent discount rate in the central analysis, whereas historically variation of the discount rate has been reserved for sensitivity analyses. OMB guidance indicates that the real economy-wide opportunity cost of capital is the appropriate discount rate to apply to future benefits and costs when the primary effect of a regulation is "…to displace or alter the use of capital in the private sector," and estimates that this rate currently averages about 7 percent.[515] NHTSA received comment from the Union of Concerned Scientists supporting the use of 3 and 7 percent discount rates in the NPRM central analysis, while the American Petroleum Institute noted that were NHTSA to utilize a higher discount rate of 15 percent[516] that the estimated net present value of lifetime fuel savings would be substantially lower.

All costs and benefits are discounted to the time that the vehicle is purchased or the model year. Thus from a consumer perspective, costs occur when the vehicle is purchased, while fuel savings occur throughout the lifetime of the vehicle and are discounted back to the time the vehicle was purchased. From the manufacturers' perspective, the costs are assigned to the model year that the countermeasure is added to the vehicle. Thus, all costs and benefits are assumed to occur either in the model year or are discounted back to the model year for which the vehicle is produced. When we accumulate MY 2017-2025 total costs or benefits, we simply add together the present discounted values for each model year. We do not further discount those model year values to any set year (e.g. we do not discount all the values to 2017 or to 2012). All costs and benefits are in 2010 dollars.

This is the first CAFE rulemaking wherein the agency has included operating costs other than outlays for fuel purchases in its analysis of the costs and benefits of new standards. In past CAFE rulemakings, reported monetized costs of new standards included only the costs (on an MSRP basis) of technology estimated to be added in response to the new standards. All other monetized impacts occur as incremental changes to social costs between the baseline and regulatory alternatives, and were reported as benefits and, if negative, as negative benefits (*i.e.*, disbenefits).

[515] *Id.*
[516] Suggested as a potential discount rate due to the use of a 15 percent discount rate in the *Annual Energy Outlook 2011* evaluation of the cost-effectiveness of fuel-efficiency-improving technologies in new vehicles.

In considering how to report monetized impacts on different costs to own and operate a new vehicle, the agency has more generally revisited its approach to categorizing different monetized effects as either costs or benefits. Noting that OMB guidance generally calls for agencies to treat positive monetized impacts as benefits, and negative monetized impacts as costs, NHTSA revised its reporting of costs and benefits to follow this approach. Thus, for example, while we have previously treated monetized damages related to additional congestion, accidents, and noise attributable to the rebound effect as negative benefits, we now report those impacts as social costs. This change in reporting in no way changes the agency's resultant calculations of net benefits which has always correctly accounted for the sign of monetized impacts.

However, NHTSA notes that, while straightforward in principle, the concept of categorizing negative monetized impacts as costs and positive negative monetized impacts as benefits is subject to considerable practical complications. For example, in NHTSA's current analysis, monetized impacts on highway fatalities change sign between model years and between passenger car and light truck fleets. Also, disaggregation of criteria pollutant emissions would lead increased tailpipe emissions to be treated as costs, and reduced upstream emissions to be treated as benefits. For future fuel economy rulemaking analysis, NHTSA plans to further consider how best to report monetized impacts as either costs or benefits.

As noted in the Executive Summary, the following conventions pertaining to the presentation of costs are consistent throughout the FRIA, including the subsequent tables in Chapter VIII:

- Tables that exclusively present costs display all costs as positive values.
- Tables that contain a mix of costs and benefits that are aggregated to a net or total value display costs as parenthesized values to aid the reader in following the summation logic.

F. Summary of Values used to Estimate Benefits

Table VIII-16 summarizes the economic values used to estimate benefits.

Table VIII-16
Economic Values Used for Benefits Computations (2010 dollars)

Fuel Economy Rebound Effect	10%
"Gap" between Test and On-road MPG for liquid-fueled Vehicles	20%
"Gap" between Test and On-road Wall Electricity Consumption for Electric and Plug-in Hybrid Electric Vehicles	30%
Value of refueling time per ($ per vehicle-hour)	$ 21.62
Average Percentage of Tank Refilled During Refueling Stop	65%
Annual growth in average vehicle use (through 2030)	0.6%
Fuel Prices (2017-2061 average, $/gallon)	
Retail gasoline price	$3.76
Pre-tax gasoline price	$3.42
Economic Benefits from Reducing Oil Imports ($/gallon)	
"Monopsony" Component	$ 0.00
Price Shock Component	$ 0.197 in 2025
Military Security Component	$ 0.00
Total Economic Costs ($/gallon)	$ 0.197 in 2025
Emission Damage Costs (weighted, $/ton or $/metric ton)	
Carbon monoxide	$ 0
Volatile organic compounds (VOC)	$ 1,700
Nitrogen oxides (NOx)	$ 6,700
Particulate matter ($PM_{2.5}$)	$ 306,500
Sulfur dioxide (SO_2)	$ 39,600
Carbon dioxide (CO_2) emissions in 2010	$ 22
Annual Increase in CO_2 Damage Cost	Variable
External Costs from Additional Automobile Use ($/vehicle-mile)	
Congestion	$ 0.056
Accidents	$ 0.024
Noise	$ 0.001
Total External Costs	$ 0.081
External Costs from Additional Light Truck Use ($/vehicle-mile)	
Congestion	$0.050
Accidents	$0.027
Noise	$0.001
Total External Costs	$0.078
Discount Rates Applied to Future Benefits[517]	3%, 7%

[517] Future benefits from reducing CO_2 emissions are discounted using the *same* "intergenerational" discount rates that were used to derive each of the alternative SCC estimates used to value reductions in those emissions. As Table VIII-14 shows, these rates are 5 percent for the interagency group's lowest estimate of the SCC, 3 percent for its central and highest estimates, and 2.5 percent for the estimate lying between the group's central and highest estimates.

G. Benefits Estimates

Benefits were calculated separately for passenger cars and light trucks under each alternative CAFE requirement for each model year covered by this rule. In Tables VIII-17 and VIII-18, the societal costs and benefits for passenger car and light truck CAFE standards under the preferred alternative are shown for model years 2011 - 2025. These tables include undiscounted values (where available) as well as their net present values discounted to the given model year at 3 percent and 7 percent. Positive values in these tables reflect net reductions in fuel consumption or emissions and their resulting economic impacts, which represent benefits from the proposal, while negative values represent increasing emissions, congestion, noise or crash severity and their added costs. The net social benefit from these societal impacts is shown on the Total line in each table.

The preferred alternative for passenger cars would save 107.9 or 108.3 (2010 and 2008 baseline fleets, respectively) billion gallons of fuel and prevent 2,341 or 2,317 (2010 and 2008 baseline fleets, respectively) million metric tons of CO_2 emissions over the lifetimes of the passenger cars sold during model years 2011 through 2025, compared to the fuel savings and emissions reductions that would occur if the standards remained at the adjusted baseline for MYs 2017-2025. The preferred alternative for light trucks would save 61.5 or 62.8 (2010 and 2008 baseline fleets, respectively) billion gallons of fuel and prevent 1,323 or 1,369 (2010 and 2008 baseline fleets, respectively) million metric tons of CO_2 emissions over the lifetimes of the light trucks sold during those model years, compared to the fuel savings and emissions reductions that would occur if the standards remained at the adjusted baseline for MYs 2017-2025.

The sum of the net present values of societal benefits resulting from the implementation of the preferred alternative for passenger cars and light trucks is \$595.6 and \$604.7 (2010 and 2008 baseline fleets, respectively) billion[518] over the lifetimes of MY 2011-25 fleets. This estimate of societal benefits includes direct impacts from lower fuel consumption as well as externalities, and also reflects offsetting societal costs resulting from the rebound effect. This estimate does not include technology costs. Fuel savings account for 80.8 percent and CO_2 emissions account for 8.3 percent of net societal benefits.

[518] The estimates of \$595.6 and \$604.7 billion are based on a 3% discount rate for valuing future impacts. In the case of a 7% discount rate, the sum of the net present are estimated at \$476.1 and \$483.4 (2010 and 2008 baseline fleets, respectively) billion.

Tables VIII-19 and VIII-20 summarize the net societal costs and benefits, excluding technology costs, for all alternatives for passenger cars and light trucks for each model year at the 3 percent and 7 percent discount rates, respectively. Benefit levels parallel the increasing stringency of the various alternatives that were examined. Tables VIII-19 and 20 demonstrate that the 7 percent annual increase scenario produces net societal benefits that exceed the other alternatives; this is due to the fact that this scenario requires the highest achieved levels of fuel economy. However, as technology costs are not included in these tables, this result masks the high compliance costs associated with achieving the fuel economy levels required by this scenario. Tables VIII-21 and VIII-22 demonstrate the impact of the inclusion of technology costs, after which the Max Net Benefits and Total Cost = Total Benefits scenarios are estimated to exceed all other scenarios' total net benefits. Note that the "Max Net Benefits" scenario optimizes to maximize the total net benefits of each individual model year, not all model years as a whole, therefore while it generally exhibits greater total net benefits across the sum of all model years in relation to other scenarios, this is not required by the model. The Total Costs = Total Benefits scenario is estimated to achieve total net benefits very similar to those of the Max Net Benefits scenario, as it allows technologies that are cost effective to pay for some technologies that are not cost effective.

Table VIII-23 summarizes the fuel savings, in gallons, from all alternatives for passenger cars and light trucks. Similarly, Table VIII-24 presents the net change in electricity consumption from all alternatives for passenger cars and light trucks. Both Tables VIII-23 and VIII-24 separate the Max Net Benefits and Total Cost = Total Benefit alternatives into their 3 and 7 percent discount rate counterparts, as the choice of the discount rate can produce differing results for these two alternatives.

Note that under several of the alternatives, a net decrease in electricity consumption is projected for the passenger car fleet in MY 2017. This result may seem counterintuitive due to trends that suggest increased use of HEV, PHEV, and EV technologies. This result can be explained by several factors. For certain alternatives, the stringency increases were gradual enough that the CAFE model did not add any EVs in this model year. Also, there were two EVs in the MY 2008 fleet, on which the baseline fleet was developed, that were not in the MY 2010 baseline fleet.[519] Application of the AC adjustment in the baseline scenario and the greater application of the AC adjustment in the alternative scenarios decreased vehicle energy consumption, therefore reducing electricity consumption in the various alternatives relative to the baseline.

[519] BMW's Mini-E and Tesla's Roadster were both part of the MY 2008 fleet.

Table VIII-17[520]
Lifetime Benefits for Preferred Alternative by Model Year
(2010 dollars, in millions)
MY 2011 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$0 - $271	$0 - $218	$0 - $171
Consumer Surplus from Additional Driving	2010 2008	$0 - $36	$0 - $29	$0 - $23
Refueling Time Value	2010 2008	$0 - $2	$0 - $2	$0 - $1
Petroleum Market Externalities	2010 2008	$0 - $14	$0 - $11	$0 - $9
Maintenance Costs	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
Congestion Costs	2010 2008	$0 - ($14)	$0 - ($11)	$0 - ($9)
Accident Costs	2010 2008	$0 - ($6)	$0 - ($5)	$0 - ($4)
Noise Costs	2010 2008	$0 - ($0)	$0 - ($0)	$0 - ($0)
Value of Reduced Fatalities	2010 2008	$0 - ($0)	$0 - ($0)	$0 - ($0)
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$0 - $25	$0 - $20	$0 - $20
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$0 - $0	$0 - $0	$0 - $0
NOX	2010 2008	$0 - $1	$0 - $1	$0 - $1
PM	2010 2008	$0 - $4	$0 - $3	$0 - $3
SOX	2010 2008	$0 - $4	$0 - $3	$0 - $2
Total	2010 2008	$0 - $337	$0 - $271	$0 - $217

[520] The CAFE model estimates maintenance costs and relative value losses in discounted terms only. In the "undiscounted value" column of Tables VIII-17 and VIII-18, the 3% discounted values for these categories are substituted. Discounted CO2 benefits are presented at the 3% discount rate only, in keeping with the application of inter-generational discounting.

MY 2012 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$580 - $941	$464 - $754	$363 - $590
Consumer Surplus from Additional Driving	2010 2008	$61 - $104	$49 - $83	$38 - $65
Refueling Time Value	2010 2008	$23 - $36	$18 - $29	$15 - $23
Petroleum Market Externalities	2010 2008	$33 - $53	$27 - $43	$22 - $34
Maintenance Costs	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
Congestion Costs	2010 2008	($27) - ($44)	($22) - ($36)	($17) - ($28)
Accident Costs	2010 2008	($12) - ($19)	($9) - ($15)	($7) - ($12)
Noise Costs	2010 2008	($0) - ($1)	($0) - ($1)	($0) - ($1)
Value of Reduced Fatalities	2010 2008	$0 - ($0)	$0 - ($0)	$0 - ($0)
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$54 - $87	$42 - $69	$42 - $69
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$1 - $1	$1 - $1	$0 - $1
NOX	2010 2008	$2 - $3	$1 - $2	$1 - $2
PM	2010 2008	$9 - $15	$8 - $12	$6 - $10
SOX	2010 2008	$8 - $13	$7 - $11	$5 - $8
Total	2010 2008	$731 - $1,189	$586 - $953	$468 - $761

MY 2013 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$1,347 - $2,088	$1,080 - $1,670	$846 - $1,305
Consumer Surplus from Additional Driving	2010 2008	$141 - $221	$113 - $177	$88 - $138
Refueling Time Value	2010 2008	$53 - $84	$43 - $68	$34 - $54
Petroleum Market Externalities	2010 2008	$77 - $117	$62 - $95	$49 - $75
Maintenance Costs	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
Congestion Costs	2010 2008	($64) - ($93)	($51) - ($75)	($41) - ($59)
Accident Costs	2010 2008	($27) - ($41)	($22) - ($33)	($17) - ($26)
Noise Costs	2010 2008	($1) - ($2)	($1) - ($1)	($1) - ($1)
Value of Reduced Fatalities	2010 2008	($11) - ($1)	($9) - ($1)	($7) - ($1)
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$125 - $195	$99 - $154	$99 - $154
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$2 - $3	$1 - $2	$1 - $2
NOX	2010 2008	$4 - $6	$3 - $5	$3 - $4
PM	2010 2008	$21 - $33	$18 - $27	$14 - $22
SOX	2010 2008	$19 - $29	$15 - $23	$12 - $19
Total	2010 2008	$1,685 - $2,639	$1,352 - $2,110	$1,081 - $1,685

MY 2014 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$3,522 - $3,331	$2,819 - $2,669	$2,206 - $2,090
Consumer Surplus from Additional Driving	2010 2008	$339 - $351	$271 - $281	$212 - $220
Refueling Time Value	2010 2008	$134 - $137	$108 - $111	$86 - $87
Petroleum Market Externalities	2010 2008	$198 - $186	$160 - $150	$127 - $119
Maintenance Costs	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
Congestion Costs	2010 2008	($154) - ($150)	($124) - ($121)	($98) - ($96)
Accident Costs	2010 2008	($68) - ($66)	($55) - ($53)	($43) - ($42)
Noise Costs	2010 2008	($3) - ($3)	($2) - ($2)	($2) - ($2)
Value of Reduced Fatalities	2010 2008	($13) - ($1)	($10) - ($1)	($8) - ($1)
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$330 - $312	$261 - $247	$261 - $247
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$4 - $4	$4 - $3	$3 - $3
NOX	2010 2008	$10 - $9	$8 - $7	$6 - $6
PM	2010 2008	$55 - $52	$45 - $42	$36 - $34
SOX	2010 2008	$49 - $46	$39 - $37	$31 - $29
Total	2010 2008	$4,402 - $4,208	$3,523 - $3,371	$2,816 - $2,695

MY 2015 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$6,053 - $4,978	$4,846 - $3,990	$3,795 - $3,127
Consumer Surplus from Additional Driving	2010 2008	$590 - $517	$473 - $415	$370 - $326
Refueling Time Value	2010 2008	$234 - $210	$189 - $170	$150 - $134
Petroleum Market Externalities	2010 2008	$335 - $275	$271 - $222	$214 - $176
Maintenance Costs	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
Congestion Costs	2010 2008	($262) - ($222)	($212) - ($179)	($167) - ($142)
Accident Costs	2010 2008	($117) - ($98)	($94) - ($79)	($74) - ($62)
Noise Costs	2010 2008	($5) - ($4)	($4) - ($3)	($3) - ($3)
Value of Reduced Fatalities	2010 2008	($15) - ($1)	($12) - ($1)	($10) - ($1)
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$572 - $471	$452 - $372	$452 - $372
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$7 - $6	$6 - $5	$5 - $4
NOX	2010 2008	$16 - $13	$13 - $11	$11 - $9
PM	2010 2008	$93 - $76	$76 - $63	$61 - $50
SOX	2010 2008	$82 - $68	$67 - $55	$53 - $43
Total	2010 2008	$7,585 - $6,289	$6,071 - $5,040	$4,856 - $4,034

MY 2016 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$9,149 - $6,925	$7,333 - $5,556	$5,748 - $4,357
Consumer Surplus from Additional Driving	2010 2008	$875 - $693	$702 - $557	$551 - $437
Refueling Time Value	2010 2008	$352 - $300	$285 - $243	$225 - $192
Petroleum Market Externalities	2010 2008	$500 - $380	$404 - $307	$320 - $243
Maintenance Costs	2010 2008	($8) - ($0)	($8) - ($0)	($6) - ($0)
Congestion Costs	2010 2008	($400) - ($311)	($323) - ($251)	($256) - ($199)
Accident Costs	2010 2008	($177) - ($136)	($143) - ($110)	($113) - ($87)
Noise Costs	2010 2008	($7) - ($6)	($6) - ($5)	($5) - ($4)
Value of Reduced Fatalities	2010 2008	($27) - ($12)	($22) - ($10)	($17) - ($8)
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$875 - $662	$692 - $524	$692 - $524
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$11 - $8	$9 - $7	$7 - $6
NOX	2010 2008	$24 - $18	$20 - $15	$16 - $12
PM	2010 2008	$139 - $105	$114 - $87	$92 - $69
SOX	2010 2008	$123 - $94	$100 - $76	$79 - $60
Total	2010 2008	$11,431 - $8,722	$9,158 - $6,996	$7,334 - $5,604

MY 2017 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$12,247 - $10,194	$9,816 - $8,178	$7,696 - $6,415
Consumer Surplus from Additional Driving	2010 2008	$1,138 - $969	$913 - $778	$718 - $611
Refueling Time Value	2010 2008	$472 - $435	$382 - $352	$302 - $278
Petroleum Market Externalities	2010 2008	$665 - $556	$537 - $449	$425 - $355
Maintenance Costs	2010 2008	($9) - ($62)	($9) - ($62)	($7) - ($46)
Congestion Costs	2010 2008	($532) - ($453)	($430) - ($366)	($341) - ($290)
Accident Costs	2010 2008	($236) - ($198)	($190) - ($160)	($151) - ($127)
Noise Costs	2010 2008	($10) - ($8)	($8) - ($7)	($6) - ($5)
Value of Reduced Fatalities	2010 2008	($18) - ($14)	($15) - ($12)	($12) - ($9)
Relative Value Loss (EVs)	2010 2008	($0) - ($1)	($0) - ($1)	($0) - ($1)
CO2	2010 2008	$1,185 - $985	$937 - $780	$937 - $780
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$15 - $12	$12 - $10	$10 - $8
NOX	2010 2008	$32 - $27	$27 - $22	$22 - $18
PM	2010 2008	$184 - $154	$151 - $126	$121 - $101
SOX	2010 2008	$164 - $137	$132 - $111	$105 - $88
Total	2010 2008	$15,296 - $12,731	$12,254 - $10,198	$9,818 - $8,177

MY 2018 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$17,751 - $17,633	$14,240 - $14,148	$11,171 - $11,100
Consumer Surplus from Additional Driving	2010 2008	$1,687 - $1,696	$1,355 - $1,363	$1,065 - $1,071
Refueling Time Value	2010 2008	$658 - $706	$532 - $571	$421 - $452
Petroleum Market Externalities	2010 2008	$953 - $953	$770 - $771	$609 - $610
Maintenance Costs	2010 2008	($12) - ($138)	($12) - ($138)	($9) - ($103)
Congestion Costs	2010 2008	($783) - ($783)	($634) - ($634)	($502) - ($502)
Accident Costs	2010 2008	($344) - ($343)	($278) - ($278)	($220) - ($220)
Noise Costs	2010 2008	($14) - ($14)	($11) - ($11)	($9) - ($9)
Value of Reduced Fatalities	2010 2008	($43) - ($34)	($35) - ($28)	($28) - ($22)
Relative Value Loss (EVs)	2010 2008	($0) - ($5)	($0) - ($5)	($0) - ($2)
CO2	2010 2008	$1,740 - $1,724	$1,377 - $1,365	$1,377 - $1,365
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$21 - $21	$17 - $17	$14 - $14
NOX	2010 2008	$46 - $45	$38 - $37	$31 - $30
PM	2010 2008	$264 - $263	$217 - $216	$174 - $173
SOX	2010 2008	$235 - $223	$190 - $180	$150 - $143
Total	2010 2008	$22,157 - $21,946	$17,765 - $17,574	$14,244 - $14,099

MY 2019 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$27,442 - $26,327	$21,997 - $21,123	$17,250 - $16,574
Consumer Surplus from Additional Driving	2010 2008	$2,531 - $2,457	$2,032 - $1,974	$1,596 - $1,552
Refueling Time Value	2010 2008	$989 - $1,009	$799 - $816	$632 - $646
Petroleum Market Externalities	2010 2008	$1,463 - $1,416	$1,182 - $1,145	$935 - $906
Maintenance Costs	2010 2008	($203) - ($316)	($203) - ($316)	($152) - ($237)
Congestion Costs	2010 2008	($1,189) - ($1,162)	($961) - ($940)	($761) - ($744)
Accident Costs	2010 2008	($526) - ($509)	($425) - ($412)	($336) - ($326)
Noise Costs	2010 2008	($21) - ($21)	($17) - ($17)	($14) - ($13)
Value of Reduced Fatalities	2010 2008	($81) - ($85)	($67) - ($69)	($53) - ($55)
Relative Value Loss (EVs)	2010 2008	($0) - ($12)	($0) - ($12)	($0) - ($5)
CO2	2010 2008	$2,723 - $2,602	$2,154 - $2,061	$2,154 - $2,061
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$32 - $32	$26 - $26	$21 - $21
NOX	2010 2008	$70 - $62	$58 - $52	$47 - $42
PM	2010 2008	$405 - $398	$332 - $326	$267 - $261
SOX	2010 2008	$361 - $326	$291 - $264	$230 - $208
Total	2010 2008	$33,995 - $32,523	$27,200 - $26,020	$21,817 - $20,889

MY 2020 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	\$34,179 - \$36,444	\$27,388 - \$29,219	\$21,473 - \$22,915
Consumer Surplus from Additional Driving	2010 2008	\$3,169 - \$3,396	\$2,543 - \$2,726	\$1,997 - \$2,142
Refueling Time Value	2010 2008	\$1,232 - \$1,394	\$996 - \$1,127	\$787 - \$891
Petroleum Market Externalities	2010 2008	\$1,807 - \$1,951	\$1,460 - \$1,577	\$1,154 - \$1,247
Maintenance Costs	2010 2008	(\$221) - (\$370)	(\$221) - (\$370)	(\$165) - (\$276)
Congestion Costs	2010 2008	(\$1,475) - (\$1,589)	(\$1,192) - (\$1,285)	(\$943) - (\$1,017)
Accident Costs	2010 2008	(\$653) - (\$701)	(\$528) - (\$566)	(\$418) - (\$448)
Noise Costs	2010 2008	(\$27) - (\$29)	(\$22) - (\$23)	(\$17) - (\$18)
Value of Reduced Fatalities	2010 2008	(\$77) - (\$79)	(\$63) - (\$64)	(\$50) - (\$51)
Relative Value Loss (EVs)	2010 2008	(\$0) - (\$40)	(\$0) - (\$40)	(\$0) - (\$18)
CO2	2010 2008	\$3,434 - \$3,638	\$2,718 - \$2,880	\$2,718 - \$2,880
CO	2010 2008	\$0 - \$0	\$0 - \$0	\$0 - \$0
VOC	2010 2008	\$40 - \$45	\$33 - \$36	\$26 - \$29
NOX	2010 2008	\$87 - \$83	\$72 - \$69	\$58 - \$56
PM	2010 2008	\$499 - \$541	\$410 - \$443	\$329 - \$355
SOX	2010 2008	\$446 - \$398	\$360 - \$322	\$285 - \$254
Total	2010 2008	\$42,441 - \$45,082	\$33,954 - \$36,049	\$27,236 - \$28,941

MY 2021 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$42,652 - $42,927	$34,184 - $34,414	$26,802 - $26,986
Consumer Surplus from Additional Driving	2010 2008	$3,897 - $3,943	$3,125 - $3,163	$2,453 - $2,484
Refueling Time Value	2010 2008	$1,542 - $1,655	$1,247 - $1,338	$987 - $1,059
Petroleum Market Externalities	2010 2008	$2,243 - $2,282	$1,813 - $1,845	$1,434 - $1,459
Maintenance Costs	2010 2008	($453) - ($327)	($453) - ($327)	($337) - ($244)
Congestion Costs	2010 2008	($1,849) - ($1,874)	($1,495) - ($1,515)	($1,183) - ($1,199)
Accident Costs	2010 2008	($816) - ($824)	($659) - ($666)	($521) - ($527)
Noise Costs	2010 2008	($33) - ($34)	($27) - ($27)	($21) - ($22)
Value of Reduced Fatalities	2010 2008	($113) - ($82)	($93) - ($67)	($74) - ($53)
Relative Value Loss (EVs)	2010 2008	($4) - ($50)	($4) - ($50)	($2) - ($22)
CO2	2010 2008	$4,336 - $4,339	$3,435 - $3,439	$3,435 - $3,439
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$50 - $52	$41 - $42	$33 - $34
NOX	2010 2008	$104 - $97	$86 - $81	$70 - $66
PM	2010 2008	$626 - $630	$513 - $516	$412 - $414
SOX	2010 2008	$542 - $464	$438 - $375	$346 - $297
Total	2010 2008	$52,721 - $53,198	$42,152 - $42,562	$33,833 - $34,171

MY 2022 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$47,359 - $49,330	$37,949 - $39,532	$29,745 - $30,987
Consumer Surplus from Additional Driving	2010 2008	$4,324 - $4,483	$3,466 - $3,593	$2,719 - $2,819
Refueling Time Value	2010 2008	$1,714 - $1,908	$1,387 - $1,543	$1,097 - $1,221
Petroleum Market Externalities	2010 2008	$2,473 - $2,606	$2,000 - $2,107	$1,582 - $1,667
Maintenance Costs	2010 2008	($573) - ($429)	($573) - ($429)	($427) - ($319)
Congestion Costs	2010 2008	($2,057) - ($2,148)	($1,662) - ($1,736)	($1,315) - ($1,373)
Accident Costs	2010 2008	($906) - ($945)	($732) - ($763)	($579) - ($603)
Noise Costs	2010 2008	($37) - ($39)	($30) - ($31)	($24) - ($25)
Value of Reduced Fatalities	2010 2008	($121) - ($63)	($99) - ($52)	($79) - ($42)
Relative Value Loss (EVs)	2010 2008	($6) - ($59)	($6) - ($59)	($3) - ($26)
CO2	2010 2008	$4,873 - $5,044	$3,863 - $3,999	$3,863 - $3,999
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$55 - $59	$45 - $48	$36 - $39
NOX	2010 2008	$114 - $110	$95 - $92	$77 - $75
PM	2010 2008	$688 - $717	$565 - $587	$453 - $471
SOX	2010 2008	$595 - $511	$481 - $413	$380 - $326
Total	2010 2008	$58,496 - $61,085	$46,748 - $48,845	$37,528 - $39,215

MY 2023 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$54,131 - $53,933	$43,369 - $43,216	$33,988 - $33,869
Consumer Surplus from Additional Driving	2010 2008	$4,945 - $4,936	$3,962 - $3,955	$3,106 - $3,101
Refueling Time Value	2010 2008	$1,924 - $2,048	$1,557 - $1,656	$1,232 - $1,310
Petroleum Market Externalities	2010 2008	$2,801 - $2,826	$2,265 - $2,285	$1,791 - $1,808
Maintenance Costs	2010 2008	($731) - ($479)	($731) - ($479)	($545) - ($357)
Congestion Costs	2010 2008	($2,353) - ($2,354)	($1,901) - ($1,902)	($1,503) - ($1,504)
Accident Costs	2010 2008	($1,035) - ($1,034)	($836) - ($835)	($661) - ($660)
Noise Costs	2010 2008	($42) - ($42)	($34) - ($34)	($27) - ($27)
Value of Reduced Fatalities	2010 2008	($143) - ($70)	($117) - ($58)	($93) - ($46)
Relative Value Loss (EVs)	2010 2008	($7) - ($71)	($7) - ($71)	($3) - ($31)
CO2	2010 2008	$5,632 - $5,572	$4,467 - $4,420	$4,467 - $4,420
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$62 - $64	$51 - $53	$41 - $42
NOX	2010 2008	$129 - $119	$108 - $99	$88 - $81
PM	2010 2008	$778 - $777	$639 - $636	$513 - $510
SOX	2010 2008	$675 - $538	$546 - $435	$432 - $344
Total	2010 2008	$66,766 - $66,762	$53,335 - $53,376	$42,826 - $42,861

MY 2024 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$62,329 - $61,299	$49,915 - $49,111	$39,105 - $38,484
Consumer Surplus from Additional Driving	2010 2008	$5,658 - $5,594	$4,529 - $4,479	$3,549 - $3,511
Refueling Time Value	2010 2008	$2,186 - $2,300	$1,768 - $1,861	$1,399 - $1,472
Petroleum Market Externalities	2010 2008	$3,208 - $3,200	$2,594 - $2,588	$2,052 - $2,048
Maintenance Costs	2010 2008	($834) - ($483)	($834) - ($483)	($621) - ($359)
Congestion Costs	2010 2008	($2,697) - ($2,678)	($2,178) - ($2,164)	($1,722) - ($1,711)
Accident Costs	2010 2008	($1,189) - ($1,175)	($959) - ($949)	($758) - ($750)
Noise Costs	2010 2008	($49) - ($48)	($39) - ($39)	($31) - ($31)
Value of Reduced Fatalities	2010 2008	($137) - ($57)	($113) - ($48)	($90) - ($38)
Relative Value Loss (EVs)	2010 2008	($32) - ($110)	($32) - ($110)	($14) - ($48)
CO2	2010 2008	$6,531 - $6,368	$5,182 - $5,055	$5,182 - $5,055
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$72 - $74	$59 - $60	$47 - $48
NOX	2010 2008	$144 - $129	$120 - $107	$98 - $87
PM	2010 2008	$887 - $873	$728 - $715	$584 - $572
SOX	2010 2008	$688 - $487	$556 - $393	$440 - $311
Total	2010 2008	$76,765 - $75,771	$61,294 - $60,578	$49,219 - $48,652

MY 2025 Passenger Cars

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$66,899 - $68,186	$53,557 - $54,598	$41,946 - $42,764
Consumer Surplus from Additional Driving	2010 2008	$6,091 - $6,171	$4,872 - $4,937	$3,815 - $3,867
Refueling Time Value	2010 2008	$2,276 - $2,461	$1,841 - $1,991	$1,457 - $1,575
Petroleum Market Externalities	2010 2008	$3,418 - $3,578	$2,763 - $2,894	$2,186 - $2,289
Maintenance Costs	2010 2008	($931) - ($418)	($931) - ($418)	($698) - ($313)
Congestion Costs	2010 2008	($2,893) - ($2,968)	($2,335) - ($2,396)	($1,846) - ($1,894)
Accident Costs	2010 2008	($1,275) - ($1,304)	($1,029) - ($1,052)	($813) - ($831)
Noise Costs	2010 2008	($52) - ($53)	($42) - ($43)	($33) - ($34)
Value of Reduced Fatalities	2010 2008	($123) - ($8)	($101) - ($8)	($81) - ($7)
Relative Value Loss (EVs)	2010 2008	($42) - ($221)	($42) - ($221)	($18) - ($96)
CO2	2010 2008	$7,068 - $7,055	$5,611 - $5,602	$5,611 - $5,602
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$78 - $87	$64 - $71	$51 - $56
NOX	2010 2008	$145 - $132	$121 - $108	$99 - $86
PM	2010 2008	$957 - $987	$783 - $801	$627 - $636
SOX	2010 2008	$708 - $137	$573 - $110	$453 - $87
Total	2010 2008	$82,324 - $83,820	$65,703 - $66,972	$52,756 - $53,787

MY 2011 – 2025 Passenger Cars Combined

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$385,638 - $384,807	$308,958 - $308,396	$242,134 - $241,733
Consumer Surplus from Additional Driving	2010 2008	$35,445 - $35,567	$28,403 - $28,510	$22,279 - $22,367
Refueling Time Value	2010 2008	$13,789 - $14,684	$11,151 - $11,877	$8,821 - $9,397
Petroleum Market Externalities	2010 2008	$20,173 - $20,391	$16,308 - $16,490	$12,899 - $13,045
Maintenance Costs	2010 2008	($3,976) - ($3,022)	($3,976) - ($3,022)	($2,966) - ($2,254)
Congestion Costs	2010 2008	($16,735) - ($16,844)	($13,521) - ($13,612)	($10,693) - ($10,766)
Accident Costs	2010 2008	($7,380) - ($7,398)	($5,960) - ($5,976)	($4,712) - ($4,726)
Noise Costs	2010 2008	($302) - ($303)	($244) - ($245)	($193) - ($194)
Value of Reduced Fatalities	2010 2008	($922) - ($507)	($756) - ($418)	($603) - ($334)
Relative Value Loss (EVs)	2010 2008	($91) - ($570)	($91) - ($570)	($40) - ($247)
CO2	2010 2008	$39,479 - $39,078	$31,291 - $30,987	$31,291 - $30,987
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$448 - $469	$368 - $383	$295 - $306
NOX	2010 2008	$926 - $854	$770 - $707	$628 - $574
PM	2010 2008	$5,607 - $5,624	$4,599 - $4,600	$3,690 - $3,680
SOX	2010 2008	$4,694 - $3,473	$3,795 - $2,806	$3,001 - $2,219
Total	2010 2008	$476,792 - $476,302	$381,093 - $380,914	$305,831 - $305,789

Table VIII-18[521]
Lifetime Benefits for Preferred Alternative by Model Year
(2010 dollars, in millions)
MY 2011 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$0 - $0	$0 - $0	$0 - $0
Consumer Surplus from Additional Driving	2010 2008	$0 - $0	$0 - $0	$0 - $0
Refueling Time Value	2010 2008	$0 - $0	$0 - $0	$0 - $0
Petroleum Market Externalities	2010 2008	$0 - $0	$0 - $0	$0 - $0
Maintenance Costs	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
Congestion Costs	2010 2008	$0 - $0	$0 - $0	$0 - $0
Accident Costs	2010 2008	$0 - $0	$0 - $0	$0 - $0
Noise Costs	2010 2008	$0 - $0	$0 - $0	$0 - $0
Value of Reduced Fatalities	2010 2008	$0 - $0	$0 - $0	$0 - $0
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$0 - $0	$0 - $0	$0 - $0
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$0 - $0	$0 - $0	$0 - $0
NOX	2010 2008	$0 - $0	$0 - $0	$0 - $0
PM	2010 2008	$0 - $0	$0 - $0	$0 - $0
SOX	2010 2008	$0 - $0	$0 - $0	$0 - $0
Total	2010 2008	$0 - $0	$0 - $0	$0 - $0

[521] The CAFE model estimates maintenance costs and relative value losses in discounted terms only. In the "undiscounted value" column of Tables VIII-17 and VIII-18, the 3% discounted values for these categories are substituted. Discounted CO2 benefits are presented at the 3% discount rate only, in keeping with the application of inter-generational discounting.

MY 2012 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$104 - $109	$83 - $85	$65 - $65
Consumer Surplus from Additional Driving	2010 2008	$6 - $10	$5 - $8	$4 - $6
Refueling Time Value	2010 2008	$4 - $4	$3 - $3	$2 - $3
Petroleum Market Externalities	2010 2008	$6 - $6	$5 - $5	$4 - $4
Maintenance Costs	2010 2008	($1) - ($0)	($1) - ($0)	($1) - ($0)
Congestion Costs	2010 2008	($3) - ($3)	($2) - ($3)	($2) - ($2)
Accident Costs	2010 2008	($2) - ($2)	($1) - ($1)	($1) - ($1)
Noise Costs	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
Value of Reduced Fatalities	2010 2008	$3 - ($0)	$2 - ($0)	$2 - ($0)
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$10 - $10	$8 - $8	$8 - $8
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$0 - $0	$0 - $0	$0 - $0
NOX	2010 2008	$0 - $0	$0 - $0	$0 - $0
PM	2010 2008	$2 - $2	$1 - $1	$1 - $1
SOX	2010 2008	$1 - $2	$1 - $1	$1 - $1
Total	2010 2008	$130 - $138	$104 - $108	$83 - $85

MY 2013 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$513 - $156	$402 - $122	$311 - $94
Consumer Surplus from Additional Driving	2010 2008	$57 - $14	$44 - $11	$34 - $8
Refueling Time Value	2010 2008	$13 - $6	$10 - $5	$8 - $4
Petroleum Market Externalities	2010 2008	$28 - $9	$22 - $7	$18 - $5
Maintenance Costs	2010 2008	($2) - ($0)	($2) - ($0)	($1) - ($0)
Congestion Costs	2010 2008	($16) - ($5)	($13) - ($4)	($10) - ($3)
Accident Costs	2010 2008	($9) - ($3)	($7) - ($2)	($5) - ($2)
Noise Costs	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
Value of Reduced Fatalities	2010 2008	$8 - ($0)	$6 - ($0)	$5 - ($0)
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$48 - $15	$37 - $11	$37 - $11
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$1 - $0	$1 - $0	$0 - $0
NOX	2010 2008	$1 - $0	$1 - $0	$1 - $0
PM	2010 2008	$8 - $2	$6 - $2	$5 - $2
SOX	2010 2008	$7 - $2	$6 - $2	$4 - $1
Total	2010 2008	$657 - $198	$515 - $154	$407 - $121

MY 2014 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$1,125 - $128	$889 - $100	$691 - $77
Consumer Surplus from Additional Driving	2010 2008	$122 - $9	$97 - $7	$75 - $6
Refueling Time Value	2010 2008	$33 - $5	$27 - $4	$21 - $3
Petroleum Market Externalities	2010 2008	$62 - $7	$49 - $6	$39 - $4
Maintenance Costs	2010 2008	($3) - ($0)	($3) - ($0)	($3) - ($0)
Congestion Costs	2010 2008	($40) - ($4)	($32) - ($3)	($25) - ($2)
Accident Costs	2010 2008	($20) - ($2)	($16) - ($2)	($13) - ($1)
Noise Costs	2010 2008	($1) - ($0)	($1) - ($0)	($0) - ($0)
Value of Reduced Fatalities	2010 2008	$13 - $0	$10 - $0	$8 - $0
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$106 - $12	$83 - $9	$83 - $9
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$1 - $0	$1 - $0	$1 - $0
NOX	2010 2008	$3 - $0	$2 - $0	$2 - $0
PM	2010 2008	$17 - $2	$14 - $2	$11 - $1
SOX	2010 2008	$15 - $2	$12 - $1	$10 - $1
Total	2010 2008	$1,433 - $161	$1,132 - $125	$899 - $98

MY 2015 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$2,148 - $760	$1,695 - $595	$1,316 - $459
Consumer Surplus from Additional Driving	2010 2008	$211 - $83	$167 - $65	$130 - $50
Refueling Time Value	2010 2008	$69 - $18	$55 - $14	$43 - $11
Petroleum Market Externalities	2010 2008	$118 - $40	$94 - $32	$74 - $25
Maintenance Costs	2010 2008	($3) - ($0)	($3) - ($0)	($2) - ($0)
Congestion Costs	2010 2008	($71) - ($24)	($57) - ($19)	($45) - ($15)
Accident Costs	2010 2008	($37) - ($13)	($29) - ($10)	($23) - ($8)
Noise Costs	2010 2008	($1) - ($0)	($1) - ($0)	($1) - ($0)
Value of Reduced Fatalities	2010 2008	$13 - $44	$11 - $35	$8 - $27
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$205 - $73	$159 - $56	$159 - $56
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$3 - $1	$2 - $1	$2 - $1
NOX	2010 2008	$6 - $2	$5 - $2	$4 - $1
PM	2010 2008	$32 - $11	$26 - $9	$21 - $7
SOX	2010 2008	$29 - $10	$23 - $8	$18 - $6
Total	2010 2008	$2,719 - $1,006	$2,145 - $787	$1,702 - $622

MY 2016 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$3,055 - $1,401	$2,408 - $1,098	$1,869 - $849
Consumer Surplus from Additional Driving	2010 2008	$315 - $144	$249 - $113	$193 - $88
Refueling Time Value	2010 2008	$91 - $38	$72 - $30	$57 - $23
Petroleum Market Externalities	2010 2008	$165 - $75	$132 - $59	$103 - $47
Maintenance Costs	2010 2008	($3) - ($0)	($3) - ($0)	($2) - ($0)
Congestion Costs	2010 2008	($100) - ($43)	($80) - ($34)	($63) - ($27)
Accident Costs	2010 2008	($52) - ($23)	($42) - ($19)	($33) - ($14)
Noise Costs	2010 2008	($2) - ($1)	($2) - ($1)	($1) - ($1)
Value of Reduced Fatalities	2010 2008	$17 - $23	$14 - $18	$11 - $14
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$294 - $135	$228 - $104	$228 - $104
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$4 - $2	$3 - $1	$2 - $1
NOX	2010 2008	$8 - $4	$6 - $3	$5 - $2
PM	2010 2008	$45 - $20	$36 - $16	$29 - $13
SOX	2010 2008	$41 - $19	$32 - $15	$25 - $12
Total	2010 2008	$3,877 - $1,794	$3,055 - $1,405	$2,424 - $1,111

MY 2017 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$4,222 - $3,312	$3,328 - $2,602	$2,584 - $2,016
Consumer Surplus from Additional Driving	2010 2008	$432 - $329	$341 - $259	$265 - $201
Refueling Time Value	2010 2008	$113 - $88	$90 - $70	$71 - $55
Petroleum Market Externalities	2010 2008	$224 - $177	$179 - $140	$140 - $110
Maintenance Costs	2010 2008	($4) - ($17)	($4) - ($17)	($3) - ($12)
Congestion Costs	2010 2008	($137) - ($102)	($109) - ($81)	($85) - ($63)
Accident Costs	2010 2008	($72) - ($55)	($57) - ($44)	($45) - ($34)
Noise Costs	2010 2008	($3) - ($2)	($2) - ($2)	($2) - ($1)
Value of Reduced Fatalities	2010 2008	$30 - $32	$24 - $25	$19 - $20
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$412 - $323	$320 - $250	$320 - $250
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$5 - $4	$4 - $3	$3 - $3
NOX	2010 2008	$11 - $8	$9 - $7	$7 - $6
PM	2010 2008	$61 - $48	$50 - $39	$40 - $31
SOX	2010 2008	$55 - $44	$44 - $35	$35 - $27
Total	2010 2008	$5,351 - $4,189	$4,216 - $3,287	$3,348 - $2,606

MY 2018 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$5,724 - $7,758	$4,510 - $6,098	$3,501 - $4,726
Consumer Surplus from Additional Driving	2010 2008	$483 - $687	$381 - $540	$296 - $419
Refueling Time Value	2010 2008	$136 - $195	$108 - $155	$85 - $122
Petroleum Market Externalities	2010 2008	$301 - $413	$240 - $329	$188 - $258
Maintenance Costs	2010 2008	($0) - ($90)	($0) - ($90)	($0) - ($66)
Congestion Costs	2010 2008	($182) - ($238)	($145) - ($189)	($114) - ($148)
Accident Costs	2010 2008	($96) - ($129)	($77) - ($102)	($60) - ($80)
Noise Costs	2010 2008	($4) - ($5)	($3) - ($4)	($2) - ($3)
Value of Reduced Fatalities	2010 2008	$60 - $85	$47 - $67	$37 - $52
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$565 - $765	$439 - $592	$439 - $592
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$7 - $9	$5 - $7	$4 - $6
NOX	2010 2008	$14 - $19	$12 - $16	$10 - $13
PM	2010 2008	$82 - $111	$67 - $90	$53 - $72
SOX	2010 2008	$75 - $102	$59 - $81	$47 - $64
Total	2010 2008	$7,163 - $9,684	$5,644 - $7,591	$4,483 - $6,025

MY 2019 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$14,720 - $14,453	$11,573 - $11,354	$8,971 - $8,795
Consumer Surplus from Additional Driving	2010 2008	$1,311 - $1,298	$1,031 - $1,021	$800 - $792
Refueling Time Value	2010 2008	$309 - $363	$246 - $289	$193 - $226
Petroleum Market Externalities	2010 2008	$753 - $764	$599 - $607	$469 - $476
Maintenance Costs	2010 2008	($34) - ($172)	($34) - ($172)	($25) - ($128)
Congestion Costs	2010 2008	($455) - ($441)	($362) - ($350)	($284) - ($275)
Accident Costs	2010 2008	($245) - ($239)	($194) - ($190)	($152) - ($149)
Noise Costs	2010 2008	($9) - ($9)	($7) - ($7)	($6) - ($5)
Value of Reduced Fatalities	2010 2008	($1) - $106	($1) - $84	($1) - $66
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$1,477 - $1,442	$1,143 - $1,115	$1,143 - $1,115
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$17 - $17	$13 - $14	$11 - $11
NOX	2010 2008	$36 - $35	$30 - $29	$24 - $24
PM	2010 2008	$207 - $205	$168 - $166	$134 - $133
SOX	2010 2008	$188 - $188	$150 - $150	$117 - $117
Total	2010 2008	$18,274 - $18,010	$14,355 - $14,109	$11,396 - $11,198

MY 2020 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$19,530 - $20,909	$15,363 - $16,435	$11,913 - $12,736
Consumer Surplus from Additional Driving	2010 2008	$1,742 - $1,857	$1,370 - $1,460	$1,063 - $1,133
Refueling Time Value	2010 2008	$385 - $547	$307 - $436	$241 - $341
Petroleum Market Externalities	2010 2008	$982 - $1,095	$782 - $872	$613 - $683
Maintenance Costs	2010 2008	$11 - ($222)	$11 - ($222)	$8 - ($165)
Congestion Costs	2010 2008	($600) - ($634)	($477) - ($504)	($374) - ($395)
Accident Costs	2010 2008	($323) - ($343)	($257) - ($273)	($201) - ($214)
Noise Costs	2010 2008	($12) - ($13)	($10) - ($10)	($7) - ($8)
Value of Reduced Fatalities	2010 2008	$29 - $184	$23 - $146	$18 - $114
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$1,987 - $2,110	$1,540 - $1,634	$1,540 - $1,634
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$22 - $24	$18 - $20	$14 - $16
NOX	2010 2008	$46 - $51	$39 - $42	$32 - $34
PM	2010 2008	$273 - $294	$222 - $239	$177 - $191
SOX	2010 2008	$247 - $270	$196 - $215	$154 - $168
Total	2010 2008	$24,321 - $26,129	$19,127 - $20,489	$15,190 - $16,270

MY 2021 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$27,045 - $28,495	$21,244 - $22,380	$16,459 - $17,333
Consumer Surplus from Additional Driving	2010 2008	$2,495 - $2,520	$1,958 - $1,978	$1,517 - $1,533
Refueling Time Value	2010 2008	$475 - $750	$378 - $597	$296 - $468
Petroleum Market Externalities	2010 2008	$1,360 - $1,480	$1,082 - $1,178	$848 - $923
Maintenance Costs	2010 2008	($97) - ($213)	($97) - ($213)	($72) - ($158)
Congestion Costs	2010 2008	($829) - ($860)	($658) - ($683)	($516) - ($535)
Accident Costs	2010 2008	($447) - ($466)	($355) - ($370)	($278) - ($290)
Noise Costs	2010 2008	($17) - ($17)	($13) - ($14)	($10) - ($11)
Value of Reduced Fatalities	2010 2008	$117 - $169	$93 - $134	$73 - $105
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$2,777 - $2,910	$2,150 - $2,255	$2,150 - $2,255
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$34 - $33	$27 - $26	$22 - $21
NOX	2010 2008	$46 - $69	$40 - $57	$34 - $46
PM	2010 2008	$416 - $396	$334 - $322	$264 - $258
SOX	2010 2008	$343 - $365	$273 - $291	$214 - $228
Total	2010 2008	$33,718 - $35,632	$26,455 - $27,940	$20,999 - $22,177

MY 2022 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$29,963 - $32,550	$23,527 - $25,555	$18,220 - $19,783
Consumer Surplus from Additional Driving	2010 2008	$2,779 - $2,890	$2,179 - $2,267	$1,686 - $1,755
Refueling Time Value	2010 2008	$550 - $858	$438 - $683	$343 - $536
Petroleum Market Externalities	2010 2008	$1,500 - $1,677	$1,193 - $1,335	$935 - $1,046
Maintenance Costs	2010 2008	($157) - ($260)	($157) - ($260)	($117) - ($193)
Congestion Costs	2010 2008	($917) - ($981)	($728) - ($779)	($570) - ($610)
Accident Costs	2010 2008	($495) - ($531)	($393) - ($422)	($308) - ($330)
Noise Costs	2010 2008	($18) - ($20)	($15) - ($16)	($11) - ($12)
Value of Reduced Fatalities	2010 2008	$132 - $173	$105 - $138	$82 - $108
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$3,111 - $3,363	$2,412 - $2,608	$2,412 - $2,608
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$37 - $37	$30 - $30	$23 - $24
NOX	2010 2008	$52 - $77	$45 - $64	$38 - $52
PM	2010 2008	$453 - $448	$365 - $365	$289 - $292
SOX	2010 2008	$377 - $414	$300 - $329	$235 - $258
Total	2010 2008	$37,366 - $40,696	$29,299 - $31,897	$23,257 - $25,317

MY 2023 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	\$33,986 - \$35,146	\$26,664 - \$27,581	\$20,636 - \$21,344
Consumer Surplus from Additional Driving	2010 2008	\$3,222 - \$3,157	\$2,523 - \$2,474	\$1,951 - \$1,914
Refueling Time Value	2010 2008	\$626 - \$914	\$498 - \$728	\$390 - \$570
Petroleum Market Externalities	2010 2008	\$1,688 - \$1,795	\$1,342 - \$1,429	\$1,052 - \$1,120
Maintenance Costs	2010 2008	(\$215) - (\$276)	(\$215) - (\$276)	(\$159) - (\$205)
Congestion Costs	2010 2008	(\$1,040) - (\$1,059)	(\$826) - (\$840)	(\$646) - (\$658)
Accident Costs	2010 2008	(\$562) - (\$574)	(\$446) - (\$456)	(\$349) - (\$357)
Noise Costs	2010 2008	(\$21) - (\$21)	(\$16) - (\$17)	(\$13) - (\$13)
Value of Reduced Fatalities	2010 2008	\$154 - \$169	\$123 - \$135	\$96 - \$106
Relative Value Loss (EVs)	2010 2008	(\$0) - (\$0)	(\$0) - (\$0)	(\$0) - (\$0)
CO2	2010 2008	\$3,567 - \$3,668	\$2,766 - \$2,847	\$2,766 - \$2,847
CO	2010 2008	\$0 - \$0	\$0 - \$0	\$0 - \$0
VOC	2010 2008	\$41 - \$39	\$33 - \$32	\$26 - \$26
NOX	2010 2008	\$61 - \$83	\$52 - \$68	\$44 - \$56
PM	2010 2008	\$502 - \$479	\$404 - \$390	\$320 - \$312
SOX	2010 2008	\$424 - \$443	\$337 - \$352	\$264 - \$276
Total	2010 2008	\$42,432 - \$43,963	\$33,239 - \$34,446	\$26,378 - \$27,337

MY 2024 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$37,829 - $39,348	$29,665 - $30,870	$22,949 - $23,883
Consumer Surplus from Additional Driving	2010 2008	$3,558 - $3,507	$2,783 - $2,746	$2,151 - $2,123
Refueling Time Value	2010 2008	$737 - $1,032	$586 - $822	$460 - $644
Petroleum Market Externalities	2010 2008	$1,868 - $1,993	$1,486 - $1,586	$1,164 - $1,244
Maintenance Costs	2010 2008	($367) - ($318)	($367) - ($318)	($273) - ($236)
Congestion Costs	2010 2008	($1,158) - ($1,182)	($919) - ($938)	($719) - ($734)
Accident Costs	2010 2008	($624) - ($641)	($495) - ($508)	($387) - ($398)
Noise Costs	2010 2008	($23) - ($24)	($18) - ($19)	($14) - ($15)
Value of Reduced Fatalities	2010 2008	$190 - $185	$151 - $147	$119 - $116
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$4,008 - $4,145	$3,110 - $3,219	$3,110 - $3,219
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$44 - $44	$36 - $35	$28 - $28
NOX	2010 2008	$70 - $91	$60 - $76	$50 - $62
PM	2010 2008	$546 - $530	$441 - $432	$350 - $346
SOX	2010 2008	$468 - $491	$372 - $391	$292 - $307
Total	2010 2008	$47,145 - $49,203	$36,891 - $38,542	$29,279 - $30,589

MY 2025 Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$39,253 - $43,879	$30,768 - $34,404	$23,792 - $26,605
Consumer Surplus from Additional Driving	2010 2008	$3,714 - $3,926	$2,902 - $3,069	$2,240 - $2,370
Refueling Time Value	2010 2008	$765 - $1,133	$609 - $902	$478 - $708
Petroleum Market Externalities	2010 2008	$1,921 - $2,200	$1,529 - $1,751	$1,198 - $1,373
Maintenance Costs	2010 2008	($372) - ($349)	($372) - ($349)	($276) - ($259)
Congestion Costs	2010 2008	($1,202) - ($1,317)	($953) - ($1,044)	($745) - ($817)
Accident Costs	2010 2008	($648) - ($714)	($514) - ($566)	($402) - ($443)
Noise Costs	2010 2008	($24) - ($26)	($19) - ($21)	($15) - ($16)
Value of Reduced Fatalities	2010 2008	$199 - $69	$159 - $56	$124 - $44
Relative Value Loss (EVs)	2010 2008	($0) - ($0)	($0) - ($0)	($0) - ($0)
CO2	2010 2008	$4,198 - $4,665	$3,259 - $3,624	$3,259 - $3,624
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$45 - $48	$37 - $39	$29 - $31
NOX	2010 2008	$73 - $100	$62 - $83	$52 - $68
PM	2010 2008	$558 - $585	$451 - $476	$358 - $382
SOX	2010 2008	$481 - $543	$383 - $432	$300 - $339
Total	2010 2008	$48,962 - $54,741	$38,302 - $42,857	$30,394 - $34,009

MY 2011 – 2025 Combined Light Trucks

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	$219,216 - $228,405	$172,120 - $179,279	$133,273 - $138,764
Consumer Surplus from Additional Driving	2010 2008	$20,449 - $20,433	$16,030 - $16,018	$12,405 - $12,398
Refueling Time Value	2010 2008	$4,304 - $5,951	$3,428 - $4,738	$2,688 - $3,715
Petroleum Market Externalities	2010 2008	$10,975 - $11,731	$8,734 - $9,336	$6,845 - $7,318
Maintenance Costs	2010 2008	($1,248) - ($1,917)	($1,248) - ($1,917)	($926) - ($1,423)
Congestion Costs	2010 2008	($6,749) - ($6,890)	($5,359) - ($5,470)	($4,196) - ($4,283)
Accident Costs	2010 2008	($3,632) - ($3,734)	($2,884) - ($2,965)	($2,257) - ($2,321)
Noise Costs	2010 2008	($134) - ($138)	($107) - ($109)	($84) - ($86)
Value of Reduced Fatalities	2010 2008	$963 - $1,239	$766 - $985	$600 - $772
Relative Value Loss (EVs)	2010 2008	$0 - $0	$0 - $0	$0 - $0
CO2	2010 2008	$22,766 - $23,636	$17,653 - $18,333	$17,653 - $18,333
CO	2010 2008	$0 - $0	$0 - $0	$0 - $0
VOC	2010 2008	$259 - $258	$209 - $209	$167 - $167
NOX	2010 2008	$427 - $540	$362 - $447	$301 - $364
PM	2010 2008	$3,201 - $3,133	$2,584 - $2,550	$2,053 - $2,041
SOX	2010 2008	$2,751 - $2,893	$2,189 - $2,303	$1,716 - $1,805
Total	2010 2008	$273,547 - $285,542	$214,478 - $223,738	$170,238 - $177,564

Table VIII-19a
Present Value of Lifetime Net Social Benefits by Alternative
(Millions of 2010 Dollars)
(3 percent discount rate)

Passenger Cars	Baseline Fleet	MYs 2011-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$20,689 - $18,741	$12,254 - $10,198	$17,765 - $17,574	$27,200 - $26,020	$33,954 - $36,049	$42,152 - $42,562	$46,748 - $48,845	$53,335 - $53,376	$61,294 - $60,578	$65,703 - $66,972	$381,093 - $380,914
2% Annual Increase	2010 2008	$8,977 - $12,014	$5,525 - $6,520	$8,826 - $10,731	$13,448 - $14,799	$19,114 - $20,410	$23,513 - $24,251	$26,074 - $27,443	$29,865 - $31,598	$35,085 - $36,958	$37,248 - $39,981	$207,676 - $224,705
3% Annual Increase	2010 2008	$24,685 - $25,764	$9,411 - $8,909	$13,796 - $15,743	$21,259 - $22,170	$28,868 - $31,031	$33,284 - $35,691	$37,424 - $40,899	$43,259 - $44,670	$51,543 - $48,973	$56,180 - $53,060	$319,710 - $326,912
4% Annual Increase	2010 2008	$35,934 - $36,252	$13,198 - $12,645	$18,531 - $20,818	$28,210 - $28,082	$37,660 - $38,050	$45,900 - $44,835	$50,547 - $50,544	$56,353 - $55,744	$62,491 - $63,132	$69,183 - $69,771	$418,007 - $419,874
5% Annual Increase	2010 2008	$27,421 - $30,279	$16,484 - $15,203	$23,022 - $23,965	$34,714 - $32,163	$44,452 - $44,194	$51,999 - $52,721	$57,119 - $57,897	$63,662 - $63,191	$72,174 - $71,913	$80,757 - $78,912	$471,802 - $470,438
6% Annual Increase	2010 2008	$30,860 - $36,489	$19,113 - $18,564	$26,126 - $27,731	$39,433 - $35,730	$47,135 - $47,522	$56,275 - $55,973	$61,102 - $64,028	$68,802 - $69,833	$78,978 - $78,885	$86,962 - $88,750	$514,785 - $523,507
7% Annual Increase	2010 2008	$39,545 - $43,870	$22,902 - $21,974	$30,384 - $31,536	$42,841 - $40,099	$50,331 - $51,105	$57,772 - $58,897	$65,569 - $67,765	$71,624 - $73,017	$80,680 - $81,827	$89,822 - $88,758	$551,469 - $558,851
Max Net Benefits	2010 2008	$49,287 - $59,360	$26,396 - $26,838	$30,389 - $31,817	$41,694 - $37,807	$48,303 - $46,399	$53,834 - $52,907	$57,936 - $56,548	$62,893 - $60,247	$69,743 - $66,726	$75,119 - $71,524	$515,593 - $510,173
Total Cost = Total Benefit	2010 2008	$51,454 - $69,971	$27,167 - $32,162	$30,950 - $36,121	$42,444 - $40,770	$49,441 - $49,708	$55,375 - $55,967	$60,272 - $61,113	$66,907 - $66,126	$74,689 - $72,764	$79,661 - $78,539	$538,360 - $563,242

Table VIII-19b
Present Value of Lifetime Net Social Benefits by Alternative
(Millions of 2010 Dollars)
(3 percent discount rate)

Light Trucks	Baseline Fleet	MYs 2011-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$6,949 - $2,578	$4,216 - $3,287	$5,644 - $7,591	$14,355 - $14,109	$19,127 - $20,489	$26,455 - $27,940	$29,299 - $31,897	$33,239 - $34,446	$36,891 - $38,542	$38,302 - $42,857	$214,478 - $223,738
2% Annual Increase	2010 2008	$20,274 - $12,537	$9,556 - $7,238	$10,313 - $10,031	$14,786 - $14,251	$16,731 - $18,222	$18,586 - $21,708	$20,354 - $24,188	$22,641 - $25,620	$24,879 - $27,473	$25,596 - $28,664	$183,716 - $189,932
3% Annual Increase	2010 2008	$24,025 - $15,272	$11,518 - $9,812	$12,786 - $13,491	$18,916 - $20,460	$23,617 - $26,553	$28,471 - $31,656	$31,222 - $34,518	$34,985 - $36,868	$37,241 - $39,487	$39,511 - $41,759	$262,291 - $269,877
4% Annual Increase	2010 2008	$24,385 - $17,953	$11,941 - $12,561	$14,500 - $17,254	$21,825 - $25,977	$27,850 - $33,036	$34,141 - $38,954	$37,014 - $42,103	$40,909 - $45,336	$44,851 - $48,155	$49,328 - $50,791	$306,744 - $332,119
5% Annual Increase	2010 2008	$24,820 - $20,811	$13,062 - $14,325	$15,664 - $20,232	$24,698 - $30,367	$31,408 - $39,429	$38,261 - $45,100	$41,514 - $48,756	$46,895 - $51,825	$51,170 - $55,432	$55,051 - $58,419	$342,542 - $384,695
6% Annual Increase	2010 2008	$29,393 - $28,927	$14,922 - $16,700	$17,620 - $22,634	$25,988 - $32,702	$33,101 - $42,764	$40,612 - $48,775	$44,169 - $52,832	$49,386 - $54,878	$54,612 - $59,116	$60,618 - $63,584	$370,420 - $422,912
7% Annual Increase	2010 2008	$30,499 - $31,866	$16,037 - $18,069	$19,046 - $25,104	$27,927 - $34,680	$35,629 - $43,360	$42,825 - $50,609	$45,795 - $54,378	$50,715 - $57,563	$54,925 - $60,521	$59,494 - $65,006	$382,891 - $441,155
Max Net Benefits	2010 2008	$32,524 - $52,468	$16,152 - $25,077	$18,407 - $28,772	$26,632 - $35,322	$32,819 - $43,215	$39,890 - $49,009	$42,703 - $51,544	$47,224 - $53,744	$50,182 - $56,371	$54,399 - $59,378	$360,931 - $454,900
Total Cost = Total Benefit	2010 2008	$34,126 - $53,329	$16,823 - $25,785	$18,984 - $29,355	$26,018 - $36,061	$33,323 - $43,353	$40,566 - $48,755	$42,656 - $51,248	$47,114 - $53,735	$50,534 - $56,252	$54,785 - $59,510	$364,929 - $457,383

Table VIII-19c
Present Value of Lifetime Net Social Benefits by Alternative
(Millions of 2010 Dollars)
(3 percent discount rate)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$27,638 - $21,319	$16,470 - $13,485	$23,409 - $25,166	$41,555 - $40,129	$53,081 - $56,538	$68,607 - $70,502	$76,047 - $80,742	$86,574 - $87,822	$98,185 - $99,119	$104,005 - $109,829	$595,571 - $604,652
2% Annual Increase	2010 2008	$29,251 - $24,551	$15,081 - $13,758	$19,139 - $20,762	$28,235 - $29,050	$35,846 - $38,632	$42,099 - $45,959	$46,428 - $51,631	$52,506 - $57,218	$59,964 - $64,431	$62,844 - $68,645	$391,392 - $414,637
3% Annual Increase	2010 2008	$48,710 - $41,036	$20,929 - $18,721	$26,582 - $29,234	$40,175 - $42,631	$52,485 - $57,585	$61,755 - $67,347	$68,646 - $75,417	$78,244 - $81,538	$88,784 - $88,460	$95,692 - $94,820	$582,001 - $596,789
4% Annual Increase	2010 2008	$60,320 - $54,204	$25,139 - $25,206	$33,031 - $38,072	$50,035 - $54,059	$65,509 - $71,086	$80,041 - $83,789	$87,561 - $92,647	$97,262 - $101,080	$107,341 - $111,286	$118,511 - $120,562	$724,751 - $751,993
5% Annual Increase	2010 2008	$52,240 - $51,090	$29,546 - $29,528	$38,685 - $44,197	$59,412 - $62,529	$75,860 - $83,623	$90,260 - $97,821	$98,633 - $106,653	$110,557 - $115,016	$123,343 - $127,345	$135,808 - $137,331	$814,345 - $855,133
6% Annual Increase	2010 2008	$60,253 - $65,417	$34,035 - $35,264	$43,745 - $50,365	$65,421 - $68,432	$80,235 - $90,286	$96,887 - $104,748	$105,271 - $116,860	$118,188 - $124,711	$133,591 - $138,002	$147,580 - $152,334	$885,206 - $946,419
7% Annual Increase	2010 2008	$70,044 - $75,736	$38,940 - $40,043	$49,430 - $56,640	$70,767 - $74,780	$85,960 - $94,465	$100,596 - $109,506	$111,364 - $122,143	$122,339 - $130,580	$135,605 - $142,348	$149,315 - $153,764	$934,361 - $1,000,006
Max Net Benefits	2010 2008	$81,811 - $111,828	$42,547 - $51,915	$48,796 - $60,588	$68,326 - $73,129	$81,122 - $89,614	$93,723 - $101,915	$100,639 - $108,093	$110,117 - $113,991	$119,924 - $123,098	$129,518 - $130,902	$876,524 - $965,074
Total Cost = Total Benefit	2010 2008	$85,580 - $123,300	$43,990 - $57,947	$49,934 - $65,476	$68,462 - $76,831	$82,764 - $93,061	$95,941 - $104,722	$102,929 - $112,362	$114,021 - $119,861	$125,223 - $129,017	$134,446 - $138,049	$903,289 - $1,020,625

Table VIII-20a
Present Value of Lifetime Net Social Benefits by Alternative
(Millions of 2010 dollars)
(7 percent discount rate)

Passenger Cars	Baseline Fleet	MYs 2011-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$16,554 - $14,995	$9,818 - $8,177	$14,244 - $14,099	$21,817 - $20,889	$27,236 - $28,941	$33,833 - $34,171	$37,528 - $39,215	$42,826 - $42,861	$49,219 - $48,652	$52,756 - $53,787	$305,831 - $305,789
2% Annual Increase	2010 2008	$7,183 - $9,611	$4,431 - $5,229	$7,081 - $8,610	$10,797 - $11,889	$15,340 - $16,393	$18,873 - $19,479	$20,935 - $22,045	$23,990 - $25,388	$28,190 - $29,699	$29,921 - $32,118	$166,741 - $180,462
3% Annual Increase	2010 2008	$19,759 - $20,630	$7,540 - $7,145	$11,061 - $12,632	$17,053 - $17,800	$23,162 - $24,912	$26,711 - $28,652	$30,039 - $32,833	$34,741 - $35,869	$41,400 - $39,332	$45,113 - $42,617	$256,578 - $262,420
4% Annual Increase	2010 2008	$28,771 - $29,020	$10,576 - $10,136	$14,859 - $16,698	$22,629 - $22,540	$30,214 - $30,542	$36,841 - $35,991	$40,575 - $40,575	$45,247 - $44,756	$50,182 - $50,691	$55,559 - $56,027	$335,454 - $336,975
5% Annual Increase	2010 2008	$21,949 - $24,222	$13,211 - $12,185	$18,463 - $19,220	$27,857 - $25,812	$35,675 - $35,476	$41,741 - $42,326	$45,860 - $46,488	$51,124 - $50,763	$57,975 - $57,785	$64,882 - $63,433	$378,738 - $377,709
6% Annual Increase	2010 2008	$24,703 - $29,187	$15,319 - $14,876	$20,952 - $22,239	$31,644 - $28,672	$37,837 - $38,147	$45,188 - $44,960	$49,066 - $51,453	$55,300 - $56,157	$63,480 - $63,472	$69,873 - $71,425	$413,360 - $420,586
7% Annual Increase	2010 2008	$31,658 - $35,092	$18,358 - $17,609	$24,369 - $25,292	$34,387 - $32,184	$40,409 - $41,034	$46,400 - $47,335	$52,717 - $54,515	$57,627 - $58,758	$64,947 - $65,925	$72,272 - $71,453	$443,144 - $449,197
Max Net Benefits	2010 2008	$37,545 - $47,213	$20,050 - $21,141	$23,179 - $24,234	$31,292 - $28,409	$37,107 - $34,245	$41,535 - $38,969	$44,028 - $41,764	$47,140 - $44,980	$52,866 - $49,837	$56,330 - $54,376	$391,072 - $385,168
Total Cost = Total Benefit	2010 2008	$41,185 - $55,976	$21,775 - $25,823	$24,820 - $29,002	$34,069 - $32,753	$39,691 - $39,931	$44,471 - $44,968	$48,407 - $49,105	$53,756 - $53,139	$60,027 - $58,480	$64,005 - $63,130	$432,204 - $452,307

Table VIII-20b
Present Value of Lifetime Net Social Benefits by Alternative
(Millions of 2010 dollars)
(7 percent discount rate)

Light Trucks	Baseline Fleet	MYs 2011-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$5,515 - $2,037	$3,348 - $2,606	$4,483 - $6,025	$11,396 - $11,198	$15,190 - $16,270	$20,999 - $22,177	$23,257 - $25,317	$26,378 - $27,337	$29,279 - $30,589	$30,394 - $34,009	$170,238 - $177,564
2% Annual Increase	2010 2008	$16,050 - $9,927	$7,576 - $5,740	$8,180 - $7,962	$11,732 - $11,309	$13,279 - $14,469	$14,752 - $17,231	$16,158 - $19,198	$17,975 - $20,333	$19,754 - $21,806	$20,320 - $22,749	$145,777 - $150,724
3% Annual Increase	2010 2008	$19,029 - $12,094	$9,136 - $7,782	$10,146 - $10,707	$15,010 - $16,233	$18,750 - $21,077	$22,598 - $25,122	$24,781 - $27,392	$27,766 - $29,255	$29,557 - $31,337	$31,355 - $33,140	$208,129 - $214,138
4% Annual Increase	2010 2008	$19,315 - $14,222	$9,472 - $9,963	$11,503 - $13,695	$17,317 - $20,609	$22,109 - $26,221	$27,097 - $30,906	$29,377 - $33,404	$32,464 - $35,965	$35,593 - $38,206	$39,142 - $40,295	$243,391 - $263,485
5% Annual Increase	2010 2008	$19,662 - $16,485	$10,362 - $11,361	$12,427 - $16,054	$19,598 - $24,088	$24,940 - $31,294	$30,372 - $35,786	$32,952 - $38,687	$37,217 - $41,118	$40,609 - $43,982	$43,682 - $46,350	$271,821 - $305,205
6% Annual Increase	2010 2008	$23,287 - $22,896	$11,838 - $13,241	$13,980 - $17,956	$20,620 - $25,938	$26,283 - $33,948	$32,238 - $38,713	$35,059 - $41,933	$39,194 - $43,555	$43,350 - $46,922	$48,117 - $50,460	$293,966 - $335,562
7% Annual Increase	2010 2008	$24,162 - $25,239	$12,722 - $14,332	$15,112 - $19,918	$22,160 - $27,512	$28,295 - $34,421	$33,999 - $40,173	$36,356 - $43,166	$40,256 - $45,693	$43,607 - $48,042	$47,231 - $51,603	$303,900 - $350,099
Max Net Benefits	2010 2008	$25,442 - $40,427	$12,996 - $19,317	$14,620 - $22,280	$21,119 - $27,739	$25,957 - $32,651	$31,305 - $36,932	$33,341 - $38,916	$37,045 - $40,273	$39,614 - $42,158	$44,006 - $44,490	$285,445 - $345,183
Total Cost = Total Benefit	2010 2008	$27,029 - $42,211	$13,344 - $20,451	$15,059 - $23,291	$20,645 - $28,613	$26,462 - $34,426	$32,200 - $38,707	$33,856 - $40,682	$37,389 - $42,651	$40,104 - $44,650	$43,472 - $47,225	$289,559 - $362,908

Table VIII-20c
Present Value of Lifetime Net Social Benefits by Alternative
(Millions of 2010 dollars)
(7 percent discount rate)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011-2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$22,069 - $17,032	$13,166 - $10,783	$18,727 - $20,124	$33,213 - $32,087	$42,426 - $45,211	$54,833 - $56,348	$60,785 - $64,532	$69,203 - $70,198	$78,498 - $79,240	$83,150 - $87,797	$476,069 - $483,353
2% Annual Increase	2010 2008	$23,233 - $19,537	$12,007 - $10,970	$15,261 - $16,572	$22,529 - $23,197	$28,619 - $30,862	$33,625 - $36,710	$37,093 - $41,243	$41,965 - $45,721	$47,944 - $51,505	$50,241 - $54,868	$312,518 - $331,185
3% Annual Increase	2010 2008	$38,789 - $32,724	$16,676 - $14,926	$21,207 - $23,339	$32,064 - $34,032	$41,913 - $45,989	$49,309 - $53,774	$54,820 - $60,225	$62,507 - $65,124	$70,957 - $70,669	$76,467 - $75,756	$464,707 - $476,558
4% Annual Increase	2010 2008	$48,087 - $43,241	$20,049 - $20,099	$26,362 - $30,392	$39,946 - $43,149	$52,324 - $56,763	$63,938 - $66,897	$69,952 - $73,978	$77,711 - $80,721	$85,775 - $88,896	$94,701 - $96,322	$578,845 - $600,459
5% Annual Increase	2010 2008	$41,610 - $40,706	$23,573 - $23,546	$30,890 - $35,274	$47,454 - $49,900	$60,615 - $66,770	$72,113 - $78,112	$78,812 - $85,175	$88,341 - $91,881	$98,584 - $101,767	$108,564 - $109,783	$650,559 - $682,914
6% Annual Increase	2010 2008	$47,989 - $52,083	$27,157 - $28,117	$34,932 - $40,195	$52,264 - $54,610	$64,120 - $72,094	$77,425 - $83,673	$84,125 - $93,386	$94,494 - $99,711	$106,830 - $110,394	$117,990 - $121,885	$707,326 - $756,149
7% Annual Increase	2010 2008	$55,821 - $60,331	$31,080 - $31,941	$39,480 - $45,210	$56,546 - $59,696	$68,704 - $75,455	$80,399 - $87,508	$89,073 - $97,680	$97,883 - $104,451	$108,555 - $113,967	$119,503 - $123,056	$747,044 - $799,296
Max Net Benefits	2010 2008	$62,987 - $87,640	$33,046 - $40,459	$37,799 - $46,514	$52,411 - $56,147	$63,064 - $66,896	$72,840 - $75,901	$77,369 - $80,680	$84,185 - $85,253	$92,480 - $91,994	$100,335 - $98,866	$676,518 - $730,351
Total Cost = Total Benefit	2010 2008	$68,213 - $98,187	$35,119 - $46,274	$39,879 - $52,293	$54,714 - $61,366	$66,154 - $74,358	$76,671 - $83,675	$82,263 - $89,787	$91,144 - $95,790	$100,130 - $103,130	$107,477 - $110,355	$721,764 - $815,215

Table VIII-21a
Present Value of Net Total Benefits[522] by Alternative
Passenger Cars, (3% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$16,084 - $15,483	$9,416 - $8,199	$13,568 - $13,985	$21,234 - $20,495	$26,378 - $27,589	$32,776 - $31,972	$36,420 - $36,638	$41,844 - $40,151	$47,407 - $44,992	$51,342 - $49,513	$296,469 - $289,016
2% Annual Increase	2010 2008	$7,117 - $9,874	$4,232 - $5,331	$6,531 - $8,589	$10,138 - $11,656	$14,680 - $15,830	$17,942 - $18,749	$19,989 - $21,298	$23,190 - $24,718	$27,100 - $28,856	$29,169 - $31,804	$160,087 - $176,705
3% Annual Increase	2010 2008	$19,277 - $21,381	$7,314 - $7,275	$10,673 - $12,606	$16,558 - $17,794	$22,832 - $24,399	$26,530 - $27,826	$29,774 - $31,830	$34,727 - $35,202	$41,153 - $38,442	$45,146 - $41,642	$253,984 - $258,397
4% Annual Increase	2010 2008	$26,894 - $29,883	$9,742 - $10,209	$13,778 - $16,490	$21,395 - $22,116	$28,807 - $29,209	$35,276 - $33,965	$38,974 - $38,093	$43,676 - $41,787	$48,160 - $46,966	$53,087 - $52,136	$319,790 - $320,855
5% Annual Increase	2010 2008	$21,136 - $25,074	$12,354 - $12,205	$17,214 - $18,744	$25,446 - $25,053	$32,535 - $32,290	$37,898 - $37,110	$41,265 - $40,209	$45,142 - $43,088	$50,350 - $47,257	$55,398 - $52,801	$338,737 - $333,831
6% Annual Increase	2010 2008	$24,160 - $28,507	$14,610 - $14,216	$19,528 - $20,769	$28,592 - $26,847	$33,347 - $33,894	$37,787 - $37,005	$40,853 - $39,222	$42,173 - $41,017	$43,047 - $41,837	$51,658 - $48,357	$335,757 - $331,672
7% Annual Increase	2010 2008	$28,128 - $33,093	$16,277 - $16,351	$21,048 - $22,223	$28,525 - $28,170	$33,794 - $34,235	$37,088 - $34,744	$35,898 - $34,555	$35,654 - $36,321	$37,682 - $34,298	$47,379 - $45,549	$321,473 - $319,540
Max Net Benefits	2010 2008	$35,083 - $44,682	$18,917 - $19,061	$21,712 - $22,648	$28,376 - $25,708	$33,486 - $31,396	$37,674 - $36,022	$40,620 - $39,004	$44,191 - $41,840	$48,010 - $45,767	$53,520 - $50,806	$361,589 - $356,934
Total Cost = Total Benefit	2010 2008	$36,631 - $49,921	$19,495 - $19,298	$22,054 - $22,676	$28,016 - $25,954	$33,493 - $32,184	$37,066 - $36,553	$40,554 - $39,957	$43,089 - $43,119	$47,481 - $47,018	$54,256 - $53,103	$362,134 - $369,783

[522] This table is from a societal perspective, thus, while technology costs are included, civil penalties are deleted from the costs because they are a transfer payment (from manufacturers to the U.S. Treasury).

Table VIII-21b
Present Value of Net Total Benefits by Alternative
Light Trucks, (3% Discount Rate)
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$5,383 - $2,183	$3,332 - $2,786	$4,613 - $6,591	$12,064 - $12,286	$15,893 - $17,890	$21,798 - $24,294	$24,365 - $27,657	$27,847 - $29,905	$31,051 - $33,576	$32,648 - $37,026	$178,996 - $194,195
2% Annual Increase	2010 2008	$15,272 - $11,272	$7,462 - $6,473	$8,228 - $8,886	$12,270 - $12,713	$13,973 - $16,150	$15,587 - $19,183	$17,158 - $21,296	$19,264 - $22,671	$21,265 - $24,307	$22,056 - $25,497	$152,535 - $168,447
3% Annual Increase	2010 2008	$18,335 - $13,904	$9,099 - $8,830	$10,342 - $12,051	$15,833 - $18,215	$19,619 - $23,337	$23,778 - $27,692	$26,270 - $30,138	$29,612 - $32,260	$31,622 - $34,460	$33,725 - $36,516	$218,234 - $237,403
4% Annual Increase	2010 2008	$18,355 - $16,058	$9,340 - $10,957	$11,614 - $15,033	$18,173 - $22,492	$22,906 - $28,268	$28,415 - $32,879	$30,879 - $35,556	$34,226 - $38,344	$37,502 - $40,571	$41,064 - $42,889	$252,475 - $283,048
5% Annual Increase	2010 2008	$18,929 - $18,060	$10,346 - $12,245	$12,552 - $17,261	$20,052 - $25,692	$24,325 - $32,252	$29,464 - $36,316	$31,968 - $38,733	$36,249 - $41,242	$39,070 - $43,351	$42,538 - $46,173	$265,492 - $311,326
6% Annual Increase	2010 2008	$22,825 - $23,696	$11,917 - $13,803	$14,130 - $18,720	$20,636 - $26,893	$25,173 - $33,021	$30,354 - $37,356	$33,126 - $39,899	$37,188 - $41,269	$39,839 - $43,126	$44,477 - $47,266	$279,665 - $325,049
7% Annual Increase	2010 2008	$23,032 - $26,379	$12,338 - $15,007	$14,724 - $20,657	$21,669 - $27,875	$26,214 - $32,915	$31,613 - $37,608	$33,874 - $39,609	$37,765 - $40,940	$39,838 - $42,502	$43,913 - $45,853	$284,980 - $329,346
Max Net Benefits	2010 2008	$22,957 - $37,863	$12,048 - $19,134	$14,041 - $22,325	$20,683 - $27,959	$25,041 - $32,331	$30,738 - $36,993	$33,051 - $39,161	$36,667 - $40,882	$39,055 - $42,521	$42,885 - $46,196	$277,166 - $345,366
Total Cost = Total Benefit	2010 2008	$24,453 - $38,052	$12,561 - $19,464	$14,464 - $22,615	$20,294 - $28,399	$25,134 - $32,008	$31,031 - $36,242	$32,770 - $38,274	$36,340 - $40,140	$39,092 - $41,808	$42,851 - $45,723	$278,991 - $342,725

Table VIII-21c
Present Value of Net Total Benefits by Alternative
Combined, (3% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$21,466 - $17,666	$12,748 - $10,986	$18,181 - $20,576	$33,299 - $32,781	$42,271 - $45,479	$54,574 - $56,266	$60,785 - $64,295	$69,691 - $70,056	$78,458 - $78,568	$83,990 - $86,539	$475,465 - $483,211
2% Annual Increase	2010 2008	$22,389 - $21,146	$11,693 - $11,804	$14,759 - $17,475	$22,408 - $24,370	$28,653 - $31,980	$33,528 - $37,931	$37,147 - $42,594	$42,453 - $47,389	$48,366 - $53,163	$51,225 - $57,301	$312,622 - $345,152
3% Annual Increase	2010 2008	$37,613 - $35,285	$16,413 - $16,106	$21,015 - $24,656	$32,391 - $36,009	$42,452 - $47,736	$50,308 - $55,519	$56,044 - $61,967	$64,339 - $67,462	$72,774 - $72,903	$78,871 - $78,157	$472,218 - $495,800
4% Annual Increase	2010 2008	$45,249 - $45,941	$19,082 - $21,167	$25,393 - $31,523	$39,568 - $44,607	$51,713 - $57,477	$63,691 - $66,844	$69,853 - $73,649	$77,902 - $80,131	$85,662 - $87,536	$94,151 - $95,026	$572,264 - $603,903
5% Annual Increase	2010 2008	$40,065 - $43,134	$22,700 - $24,450	$29,766 - $36,004	$45,498 - $50,746	$56,859 - $64,542	$67,362 - $73,426	$73,232 - $78,942	$81,391 - $84,330	$89,419 - $90,608	$97,936 - $98,975	$604,229 - $645,156
6% Annual Increase	2010 2008	$46,986 - $52,203	$26,527 - $28,019	$33,658 - $39,489	$49,227 - $53,740	$58,520 - $66,915	$68,141 - $74,362	$73,979 - $79,121	$79,361 - $82,285	$82,887 - $84,963	$96,136 - $95,623	$615,422 - $656,720
7% Annual Increase	2010 2008	$51,159 - $59,472	$28,616 - $31,358	$35,773 - $42,879	$50,194 - $56,046	$60,008 - $67,150	$68,701 - $72,352	$69,772 - $74,164	$73,418 - $77,262	$77,521 - $76,800	$91,292 - $91,402	$606,453 - $648,886
Max Net Benefits	2010 2008	$58,040 - $82,546	$30,965 - $38,194	$35,753 - $44,974	$49,059 - $53,667	$58,527 - $63,727	$68,412 - $73,015	$73,671 - $78,165	$80,858 - $82,722	$87,065 - $88,288	$96,405 - $97,002	$638,755 - $702,299
Total Cost = Total Benefit	2010 2008	$61,084 - $87,973	$32,057 - $38,762	$36,517 - $45,290	$48,309 - $54,354	$58,627 - $64,192	$68,098 - $72,796	$73,324 - $78,231	$79,429 - $83,259	$86,573 - $88,826	$97,107 - $98,826	$641,125 - $712,509

Table VIII-22a
Present Value of Net Total Benefits[523] by Alternative
Passenger Cars, (7% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$11,949 - $11,737	$6,980 - $6,178	$10,047 - $10,510	$15,852 - $15,365	$19,660 - $20,481	$24,458 - $23,581	$27,200 - $27,008	$31,335 - $29,635	$35,332 - $33,066	$38,395 - $36,329	$221,207 - $213,891
2% Annual Increase	2010 2008	$5,323 - $7,471	$3,137 - $4,041	$4,786 - $6,468	$7,486 - $8,746	$10,905 - $11,814	$13,301 - $13,976	$14,849 - $15,900	$17,314 - $18,507	$20,205 - $21,597	$21,843 - $23,941	$119,152 - $132,462
3% Annual Increase	2010 2008	$14,352 - $16,247	$5,442 - $5,511	$7,938 - $9,494	$12,353 - $13,423	$17,127 - $18,279	$19,956 - $20,787	$22,388 - $23,764	$26,209 - $26,401	$31,009 - $28,801	$34,079 - $31,198	$190,852 - $193,905
4% Annual Increase	2010 2008	$19,731 - $22,651	$7,120 - $7,700	$10,106 - $12,370	$15,815 - $16,573	$21,362 - $21,701	$26,217 - $25,121	$29,001 - $28,125	$32,570 - $30,798	$35,852 - $34,525	$39,463 - $38,392	$237,237 - $237,956
5% Annual Increase	2010 2008	$15,664 - $19,016	$9,081 - $9,186	$12,656 - $13,999	$18,589 - $18,703	$23,758 - $23,571	$27,641 - $26,715	$30,006 - $28,800	$32,603 - $30,659	$36,152 - $33,129	$39,523 - $37,322	$245,672 - $241,102
6% Annual Increase	2010 2008	$18,003 - $21,204	$10,816 - $10,528	$14,354 - $15,276	$20,802 - $19,789	$24,050 - $24,518	$26,700 - $25,992	$28,817 - $26,647	$28,671 - $27,340	$27,549 - $26,424	$34,569 - $31,032	$234,332 - $228,751
7% Annual Increase	2010 2008	$20,241 - $24,315	$11,733 - $11,986	$15,033 - $15,978	$20,071 - $20,255	$23,871 - $24,164	$25,717 - $23,182	$23,045 - $21,304	$21,657 - $22,062	$21,949 - $18,396	$29,830 - $28,244	$213,148 - $209,886
Max Net Benefits	2010 2008	$24,764 - $32,845	$13,320 - $13,675	$15,368 - $15,848	$21,168 - $18,165	$24,603 - $21,813	$27,428 - $25,060	$29,321 - $27,258	$31,633 - $29,550	$34,963 - $32,481	$38,549 - $36,255	$261,117 - $252,950
Total Cost = Total Benefit	2010 2008	$26,362 - $35,926	$14,103 - $12,958	$15,923 - $15,556	$19,641 - $17,938	$23,744 - $22,408	$26,161 - $25,555	$28,689 - $27,949	$29,937 - $30,132	$32,819 - $32,733	$38,600 - $37,693	$255,978 - $258,849

[523] This table is from a societal perspective, thus, while technology costs are included, civil penalties are deleted from the costs because they are a transfer payment (from manufacturers to the U.S. Treasury).

Table VIII-22b
Present Value of Net Total Benefits by Alternative
Light Trucks, (7% Discount Rate)
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$3,948 - $1,641	$2,464 - $2,105	$3,453 - $5,025	$9,105 - $9,374	$11,956 - $13,671	$16,342 - $18,531	$18,323 - $21,076	$20,986 - $22,796	$23,439 - $25,623	$24,740 - $28,178	$134,756 - $148,022
2% Annual Increase	2010 2008	$11,048 - $8,662	$5,482 - $4,975	$6,095 - $6,816	$9,217 - $9,771	$10,521 - $12,396	$11,753 - $14,705	$12,963 - $16,306	$14,598 - $17,384	$16,140 - $18,640	$16,779 - $19,582	$114,595 - $129,239
3% Annual Increase	2010 2008	$13,340 - $10,725	$6,718 - $6,800	$7,702 - $9,267	$11,927 - $13,987	$14,753 - $17,861	$17,906 - $21,158	$19,829 - $23,011	$22,393 - $24,647	$23,938 - $26,311	$25,568 - $27,896	$164,072 - $181,664
4% Annual Increase	2010 2008	$13,285 - $12,327	$6,872 - $8,360	$8,617 - $11,474	$13,664 - $17,123	$17,166 - $21,453	$21,371 - $24,832	$23,243 - $26,856	$25,781 - $28,974	$28,244 - $30,622	$30,878 - $32,393	$189,121 - $214,413
5% Annual Increase	2010 2008	$13,771 - $13,734	$7,646 - $9,281	$9,315 - $13,083	$14,952 - $19,414	$17,857 - $24,117	$21,574 - $27,002	$23,405 - $28,664	$26,572 - $30,536	$28,509 - $31,902	$31,169 - $34,104	$194,771 - $231,835
6% Annual Increase	2010 2008	$16,719 - $17,665	$8,833 - $10,344	$10,490 - $14,043	$15,268 - $20,129	$18,355 - $24,205	$21,980 - $27,294	$24,016 - $29,000	$26,996 - $29,946	$28,577 - $30,931	$31,977 - $34,142	$203,211 - $237,698
7% Annual Increase	2010 2008	$16,695 - $19,752	$9,023 - $11,270	$10,790 - $15,471	$15,901 - $20,707	$18,880 - $23,977	$22,787 - $27,172	$24,435 - $28,397	$27,306 - $29,071	$28,521 - $30,023	$31,650 - $32,450	$205,989 - $238,290
Max Net Benefits	2010 2008	$15,931 - $26,414	$8,896 - $13,589	$10,305 - $16,072	$15,296 - $20,667	$18,402 - $23,400	$22,360 - $26,590	$23,916 - $28,294	$26,723 - $29,552	$28,652 - $30,804	$32,077 - $33,414	$202,558 - $248,796
Total Cost = Total Benefit	2010 2008	$17,355 - $26,935	$9,082 - $14,130	$10,540 - $16,551	$14,920 - $20,951	$18,273 - $23,081	$22,666 - $26,195	$23,970 - $27,707	$26,616 - $29,056	$28,662 - $30,206	$31,538 - $33,438	$203,622 - $248,251

Table VIII-22c
Present Value of Net Total Benefits by Alternative
Combined, (7% Discount Rate)
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	$15,897 - $13,379	$9,444 - $8,284	$13,500 - $15,535	$24,957 - $24,739	$31,616 - $34,152	$40,800 - $42,112	$45,523 - $48,085	$52,320 - $52,431	$58,771 - $58,689	$63,135 - $64,507	$355,963 - $361,913
2% Annual Increase	2010 2008	$16,372 - $16,133	$8,620 - $9,016	$10,881 - $13,285	$16,703 - $18,517	$21,426 - $24,211	$25,054 - $28,681	$27,812 - $32,206	$31,912 - $35,892	$36,345 - $40,237	$38,622 - $43,523	$233,747 - $261,701
3% Annual Increase	2010 2008	$27,692 - $26,972	$12,160 - $12,311	$15,640 - $18,761	$24,279 - $27,411	$31,880 - $36,140	$37,862 - $41,945	$42,217 - $46,776	$48,602 - $51,047	$54,947 - $55,112	$59,647 - $59,094	$354,924 - $375,569
4% Annual Increase	2010 2008	$33,016 - $34,978	$13,992 - $16,060	$18,723 - $23,844	$29,479 - $33,696	$38,528 - $43,154	$47,588 - $49,952	$52,244 - $54,981	$58,351 - $59,772	$64,096 - $65,146	$70,341 - $70,785	$426,358 - $452,369
5% Annual Increase	2010 2008	$29,435 - $32,750	$16,727 - $18,467	$21,971 - $27,081	$33,541 - $38,117	$41,615 - $47,688	$49,215 - $53,718	$53,411 - $57,464	$59,175 - $61,195	$64,661 - $65,030	$70,693 - $71,426	$440,443 - $472,937
6% Annual Increase	2010 2008	$34,722 - $38,869	$19,649 - $20,872	$24,845 - $29,319	$36,071 - $39,917	$42,405 - $48,723	$48,680 - $53,287	$52,833 - $55,647	$55,667 - $57,286	$56,126 - $57,355	$66,546 - $65,174	$437,543 - $466,450
7% Annual Increase	2010 2008	$36,936 - $44,067	$20,756 - $23,256	$25,823 - $31,449	$35,973 - $40,962	$42,752 - $48,141	$48,504 - $50,355	$47,480 - $49,701	$48,963 - $51,133	$50,470 - $48,419	$61,480 - $60,694	$419,136 - $448,176
Max Net Benefits	2010 2008	$40,695 - $59,259	$22,216 - $27,264	$25,673 - $31,920	$36,464 - $38,832	$43,005 - $45,212	$49,788 - $51,650	$53,237 - $55,552	$58,356 - $59,101	$63,615 - $63,285	$70,627 - $69,669	$463,675 - $501,745
Total Cost = Total Benefit	2010 2008	$43,718 - $62,861	$23,185 - $27,089	$26,463 - $32,107	$34,561 - $38,889	$42,017 - $45,489	$48,827 - $51,749	$52,659 - $55,657	$56,553 - $59,188	$61,480 - $62,939	$70,138 - $71,131	$459,600 - $507,100

Table VIII-23a
Liquid Fuel Savings over Lifetimes of Model Year 2011-2025 Passenger Cars with Alternative Increases in CAFE Standards[524]
(Millions of gallons)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	6,093 - 5,501	3,547 - 2,949	5,106 - 5,073	7,826 - 7,524	9,672 - 10,365	11,993 - 12,117	13,215 - 13,828	14,983 - 15,005	17,150 - 16,980	18,282 - 18,999	107,867 - 108,342
2% Annual Increase	2010 2008	2,632 - 3,538	1,596 - 1,896	2,531 - 3,111	3,886 - 4,361	5,489 - 5,931	6,711 - 6,968	7,417 - 7,861	8,456 - 8,980	9,920 - 10,465	10,430 - 11,203	59,067 - 64,316
3% Annual Increase	2010 2008	4,498 - 4,954	2,725 - 2,581	3,964 - 4,560	6,127 - 6,407	8,257 - 8,898	9,452 - 10,139	10,568 - 11,560	12,166 - 12,533	14,437 - 13,720	15,612 - 14,926	87,805 - 90,279
4% Annual Increase	2010 2008	6,695 - 6,939	3,817 - 3,649	5,324 - 6,006	8,167 - 8,096	10,802 - 10,921	13,100 - 12,758	14,328 - 14,304	15,867 - 15,716	17,518 - 17,718	19,522 - 19,817	115,139 - 115,924
5% Annual Increase	2010 2008	8,073 - 8,891	4,764 - 4,382	6,615 - 6,904	10,126 - 9,275	12,905 - 12,903	15,011 - 15,323	16,585 - 16,889	18,437 - 18,451	20,851 - 21,139	24,127 - 23,683	137,494 - 137,839
6% Annual Increase	2010 2008	9,064 - 10,716	5,519 - 5,353	7,504 - 8,000	11,503 - 10,273	13,922 - 13,811	16,769 - 16,711	18,150 - 19,655	20,834 - 21,685	24,668 - 25,086	27,331 - 29,391	155,263 - 160,681
7% Annual Increase	2010 2008	11,633 - 12,885	6,618 - 6,337	8,751 - 9,174	12,632 - 11,686	14,967 - 15,211	17,207 - 18,453	20,381 - 22,239	22,867 - 23,933	26,147 - 27,806	29,403 - 30,154	170,607 - 177,878
Max Net Benefits (3% Discount Rate)	2010 2008	14,530 - 17,484	7,627 - 7,963	8,737 - 9,379	12,615 - 11,480	14,642 - 14,063	16,186 - 15,872	17,307 - 16,854	18,649 - 17,819	20,702 - 19,677	22,249 - 20,987	153,245 - 151,579
Max Net Benefits (7% Discount Rate)	2010 2008	13,815 - 17,387	7,226 - 7,811	8,296 - 8,889	11,286 - 10,522	13,605 - 12,702	15,221 - 14,334	16,022 - 15,266	17,014 - 16,293	19,009 - 17,955	20,149 - 19,550	141,643 - 140,709
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	15,169 - 20,614	7,851 - 9,965	8,895 - 11,053	12,896 - 12,455	14,937 - 15,193	16,720 - 16,982	18,078 - 18,446	20,255 - 19,837	22,500 - 21,787	23,844 - 23,687	161,144 - 170,020

[524] The choice of a 3 or 7 percent discount rate can impact the results of the Max Net Benefits and Total Cost = Total Benefits scenarios. The results of all other scenarios are not impacted by choice of discount rate. Results for both 3 and 7 percent discount rates are therefore presented for both Max Net Benefits and Total Cost = Total Benefit scenarios.

Total Cost = Total Benefit (7% Discount Rate)	2010 2008	15,169 - 20,614	7,851 - 9,965	8,895 - 11,053	12,896 - 12,455	14,937 - 15,193	16,720 - 16,982	18,078 - 18,446	20,255 - 19,837	22,500 - 21,787	23,844 - 23,687	161,144 - 170,020

Table VIII-23b
Liquid Fuel Savings over Lifetimes of Model Year 2011-2025 Light Trucks
with Alternative Increases in CAFE Standards
(Millions of gallons)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	2,041 - 750	1,219 - 954	1,640 - 2,211	4,215 - 4,084	5,575 - 5,864	7,697 - 7,929	8,444 - 8,986	9,482 - 9,616	10,438 - 10,664	10,729 - 11,785	61,480 - 62,845
2% Annual Increase	2010 2008	6,151 - 3,689	2,828 - 2,095	3,045 - 2,911	4,359 - 4,102	4,886 - 5,214	5,376 - 6,155	5,849 - 6,800	6,455 - 7,127	7,039 - 7,577	7,168 - 7,835	53,156 - 53,505
3% Annual Increase	2010 2008	7,259 - 4,510	3,408 - 2,847	3,766 - 3,910	5,541 - 5,890	6,889 - 7,591	8,229 - 8,971	8,955 - 9,715	9,959 - 10,280	10,520 - 10,917	11,046 - 11,475	75,571 - 76,105
4% Annual Increase	2010 2008	7,376 - 5,326	3,530 - 3,660	4,265 - 5,017	6,381 - 7,496	8,099 - 9,459	9,851 - 11,049	10,588 - 11,846	11,622 - 12,654	12,640 - 13,320	13,996 - 13,953	88,347 - 93,780
5% Annual Increase	2010 2008	7,493 - 6,168	3,857 - 4,177	4,602 - 5,881	7,238 - 8,776	9,318 - 11,391	11,304 - 12,900	12,215 - 13,950	13,707 - 14,701	14,826 - 15,606	15,821 - 16,620	100,382 - 110,171
6% Annual Increase	2010 2008	8,851 - 8,561	4,397 - 4,864	5,164 - 6,588	7,605 - 9,448	9,799 - 12,727	12,017 - 14,353	12,971 - 15,550	14,422 - 16,049	16,087 - 17,293	18,055 - 18,547	109,368 - 123,980
7% Annual Increase	2010 2008	9,181 - 9,475	4,730 - 5,273	5,616 - 7,322	8,216 - 10,050	10,808 - 12,723	12,926 - 14,802	13,724 - 15,992	15,102 - 16,936	16,395 - 17,684	17,649 - 19,237	114,346 - 129,494
Max Net Benefits (3% Discount Rate)	2010 2008	9,805 - 15,617	4,762 - 7,393	5,399 - 8,432	7,848 - 10,280	9,758 - 12,991	11,735 - 14,531	12,448 - 15,153	13,673 - 15,681	14,408 - 16,352	15,471 - 17,060	105,306 - 133,490
Max Net Benefits (7% Discount Rate)	2010 2008	9,673 - 15,206	4,828 - 7,180	5,404 - 8,227	7,843 - 10,161	9,694 - 12,048	11,589 - 13,521	12,230 - 14,134	13,475 - 14,481	14,289 - 15,026	15,913 - 15,726	104,938 - 125,711
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	10,271 - 15,875	4,953 - 7,592	5,561 - 8,598	7,660 - 10,479	9,937 - 13,211	11,936 - 14,679	12,463 - 15,302	13,664 - 15,902	14,527 - 16,504	15,757 - 17,285	106,730 - 135,426
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	10,271 - 15,875	4,953 - 7,592	5,561 - 8,598	7,660 - 10,479	9,937 - 13,211	11,936 - 14,679	12,463 - 15,302	13,664 - 15,902	14,527 - 16,504	15,757 - 17,285	96,459 - 119,552

Table VIII-23c
Liquid Fuel Savings over Lifetimes of Model Year 2011-2025
Passenger Cars and Light Trucks Combined
with Alternative Increases in CAFE Standards
(Millions of gallons)

Passenger Cars & Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	8,134 - 6,251	4,766 - 3,904	6,746 - 7,285	12,041 - 11,608	15,247 - 16,230	19,690 - 20,045	21,659 - 22,815	24,466 - 24,621	27,588 - 27,644	29,010 - 30,784	161,213 - 164,935
2% Annual Increase	2010 2008	8,784 - 7,227	4,424 - 3,992	5,576 - 6,022	8,244 - 8,463	10,375 - 11,145	12,086 - 13,123	13,266 - 14,661	14,911 - 16,107	16,958 - 18,042	17,598 - 19,038	103,439 - 110,594
3% Annual Increase	2010 2008	11,757 - 9,464	6,132 - 5,428	7,730 - 8,470	11,668 - 12,297	15,146 - 16,489	17,681 - 19,110	19,523 - 21,275	22,125 - 22,813	24,956 - 24,636	26,659 - 26,401	151,620 - 156,920
4% Annual Increase	2010 2008	14,070 - 12,265	7,347 - 7,309	9,588 - 11,023	14,548 - 15,592	18,901 - 20,380	22,951 - 23,807	24,916 - 26,150	27,489 - 28,370	30,157 - 31,038	33,519 - 33,770	189,416 - 197,439
5% Annual Increase	2010 2008	15,566 - 15,059	8,621 - 8,560	11,217 - 12,785	17,365 - 18,051	22,223 - 24,294	26,314 - 28,223	28,801 - 30,839	32,144 - 33,152	35,677 - 36,745	39,948 - 40,303	222,310 - 232,952
6% Annual Increase	2010 2008	17,914 - 19,278	9,916 - 10,217	12,668 - 14,589	19,108 - 19,721	23,721 - 26,538	28,786 - 31,064	31,121 - 35,205	35,256 - 37,734	40,755 - 42,379	45,386 - 47,938	246,717 - 265,384
7% Annual Increase	2010 2008	20,814 - 22,360	11,348 - 11,610	14,367 - 16,496	20,848 - 21,736	25,775 - 27,934	30,133 - 33,255	34,105 - 38,231	37,969 - 40,869	42,542 - 45,489	47,052 - 49,391	264,140 - 285,012
Max Net Benefits (3% Discount Rate)	2010 2008	24,335 - 33,102	12,389 - 15,356	14,136 - 17,811	20,463 - 21,760	24,401 - 27,054	27,921 - 30,403	29,755 - 32,007	32,322 - 33,500	35,110 - 36,029	37,719 - 38,046	234,216 - 251,968
Max Net Benefits (7% Discount Rate)	2010 2008	23,487 - 32,593	12,054 - 14,991	13,700 - 17,116	19,129 - 20,683	23,299 - 24,750	26,810 - 27,856	28,253 - 29,399	30,489 - 30,774	33,298 - 32,981	36,062 - 35,276	223,093 - 233,827
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	25,440 - 36,489	12,804 - 17,557	14,456 - 19,650	20,557 - 22,935	24,874 - 28,405	28,656 - 31,661	30,540 - 33,747	33,918 - 35,739	37,027 - 38,291	39,602 - 40,972	242,434 - 268,957
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	25,440 - 36,489	12,804 - 17,557	14,456 - 19,650	20,557 - 22,935	24,874 - 28,405	28,656 - 31,661	30,540 - 33,747	33,918 - 35,739	37,027 - 38,291	39,602 - 40,972	242,434 - 268,957

Table VIII-24a
Net Change in Electricity Consumption over Lifetimes of Model Year 2011-2025 Passenger Cars with Alternative Increases in CAFE Standards[525] (in GW-h)

Passenger Cars	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	0.0 - 1,949.6	272.1 - 2,310.8	349.5 - 3,100.3	366.6 - 3,747.2	2,435.7 - 7,134.2	3,202.0 - 17,639.9	6,626.0 - 36,694.2
2% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 2,120.8	0.0 - 2,667.7	272.1 - 2,959.9	349.5 - 3,725.6	354.8 - 4,180.1	2,023.7 - 6,284.5	2,225.8 - 6,642.9	5,226.0 - 28,851.4
3% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	0.0 - 1,442.0	272.1 - 1,800.5	349.5 - 2,563.3	366.6 - 3,012.2	2,149.2 - 5,977.7	2,917.6 - 11,374.7	6,055.1 - 26,982.8
4% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	73.5 - 1,562.7	347.6 - 1,926.5	638.8 - 2,694.9	692.1 - 4,778.0	2,769.3 - 7,844.9	9,749.1 - 18,723.5	14,270.4 - 38,342.9
5% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	2,061.4 - 542.3	2,720.8 - 7,208.8	3,691.9 - 10,168.0	5,601.8 - 10,687.4	7,261.1 - 13,416.6	11,609.5 - 21,178.3	37,249.2 - 39,375.0	70,195.8 - 102,846.4
6% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	32.0 - 460.9	2,043.7 - 722.7	3,285.9 - 4,885.1	10,267.7 - 18,022.2	10,568.1 - 35,074.0	24,997.5 - 48,022.8	50,318.5 - 70,012.7	66,383.0 - 113,471.4	167,896.5 - 290,664.0
7% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	32.0 - 2,478.3	6,390.9 - 4,364.5	8,121.4 - 9,222.4	10,992.8 - 26,094.0	33,649.0 - 57,940.9	48,359.2 - 66,198.7	67,508.0 - 103,830.6	89,892.5 - 120,608.7	264,946.0 - 390,730.5
Max Net Benefits (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 1,312.3	32.0 - 1,806.7	11,498.8 - 10,940.9	14,406.0 - 15,351.4	14,865.4 - 16,358.0	16,048.4 - 17,690.9	17,136.1 - 19,094.8	23,751.5 - 24,440.4	29,033.2 - 28,581.6	126,771.5 - 135,576.9
Max Net Benefits (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 1,312.3	35.9 - 1,813.9	2,069.5 - 6,478.5	8,503.8 - 10,208.3	9,583.3 - 10,730.2	9,927.1 - 11,684.2	10,135.5 - 12,398.6	13,245.2 - 15,733.4	15,993.4 - 20,739.4	69,493.7 - 91,098.8
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 14,274.3	35.9 - 14,822.4	12,875.2 - 17,142.9	13,844.7 - 22,018.9	16,294.3 - 23,290.6	17,533.1 - 26,328.6	27,801.7 - 29,438.9	32,354.3 - 36,455.0	36,201.0 - 48,568.1	156,940.2 - 232,339.8

[525] The choice of a 3 or 7 percent discount rate can impact the results of the Max Net Benefits and Total Cost = Total Benefits scenarios. The results of all other scenarios are not impacted by choice of discount rate. Results for both 3 and 7 percent discount rates are therefore presented for both Max Net Benefits and Total Cost = Total Benefit scenarios.

Total Cost = Total Benefit (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 14,274.3	35.9 - 14,822.4	12,875.2 - 17,142.9	13,844.7 - 22,018.9	16,294.3 - 23,290.6	17,533.1 - 26,328.6	27,801.7 - 29,438.9	32,354.3 - 36,455.0	36,201.0 - 48,568.1	156,940.2 - 232,339.8

Table VIII-24b
Net Change in Electricity Consumption over Lifetimes of Model Year 2011-2025
Light Trucks with Alternative Increases in CAFE Standards
(in GW-h)

Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
2% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0
3% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 1,144.6	0.0 - 1,144.6
4% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.2 - 0.0	0.2 - 0.0	0.2 - 0.0	0.2 - 206.5	0.2 - 211.8	5,304.2 - 1,357.4	5,305.2 - 1,775.7
5% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	487.2 - 1,160.2	485.4 - 1,151.8	497.8 - 1,159.1	532.7 - 1,362.6	537.6 - 1,397.1	990.0 - 9,681.6	3,530.8 - 15,912.4
6% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	0.0 - 0.0	540.4 - 7,952.7	538.1 - 8,220.3	551.4 - 9,244.6	585.1 - 9,425.2	6,062.8 - 12,799.0	11,659.0 - 14,257.4	19,936.8 - 61,899.2
7% Annual Increase	2010 2008	0.0 - 0.0	0.0 - 0.0	33.0 - 239.8	32.8 - 230.5	4,341.9 - 1,399.0	4,325.8 - 1,713.8	4,435.7 - 3,719.9	5,299.1 - 6,955.8	9,644.8 - 7,510.5	9,543.2 - 16,715.0	37,656.3 - 38,484.2
Max Net Benefits (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 0.0	35.7 - 250.5	35.6 - 241.1	592.9 - 12,967.5	671.4 - 12,932.8	689.1 - 13,068.0	690.8 - 13,076.7	691.5 - 13,434.0	676.2 - 13,516.0	4,083.3 - 79,486.7
Max Net Benefits (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 0.0	35.7 - 250.5	35.6 - 241.1	35.5 - 5,338.1	35.4 - 5,342.0	36.3 - 5,412.8	35.9 - 5,427.5	36.8 - 5,599.8	4,327.7 - 5,642.3	4,578.9 - 33,254.0
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 45.8	35.7 - 299.2	35.6 - 288.3	519.8 - 13,443.1	517.6 - 13,387.7	1,253.5 - 13,468.4	1,254.9 - 13,461.2	1,304.3 - 13,837.1	5,116.0 - 13,920.2	10,037.3 - 82,151.1
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 45.8	35.7 - 299.2	35.6 - 288.3	519.8 - 13,443.1	517.6 - 13,387.7	1,253.5 - 13,468.4	1,254.9 - 13,461.2	1,304.3 - 13,837.1	5,116.0 - 13,920.2	10,037.3 - 82,151.1

Table VIII-24c
Net Change in Electricity Consumption over Lifetimes of Model Year 2011-2025
Passenger Cars and Light Trucks Combined
with Alternative Increases in CAFE Standards
(in GW-h)

Passenger Cars & Light Trucks	Baseline Fleet	MYs 2011 - 2016	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	15-Year Total
Preferred Alternative	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	0.0 - 1,949.6	272.1 - 2,310.8	349.5 - 3,100.3	366.6 - 3,747.2	2,435.7 - 7,134.2	3,202.0 - 17,639.9	6,626.0 - 36,694.2
2% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 2,120.8	0.0 - 2,667.7	272.1 - 2,959.9	349.5 - 3,725.6	354.8 - 4,180.1	2,023.7 - 6,284.5	2,225.8 - 6,642.9	5,226.0 - 28,851.4
3% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	0.0 - 1,442.0	272.1 - 1,800.5	349.5 - 2,563.3	366.6 - 3,012.2	2,149.2 - 5,977.7	2,917.6 - 12,519.4	6,055.1 - 28,127.4
4% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	0.0 - 542.3	73.7 - 1,562.7	347.8 - 1,926.5	639.0 - 2,694.9	692.3 - 4,984.5	2,769.5 - 8,056.7	15,053.2 - 20,081.0	19,575.5 - 40,118.6
5% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	0.0 - 277.8	2,061.4 - 542.3	3,208.0 - 8,369.0	4,177.3 - 11,319.7	6,099.6 - 11,846.5	7,793.9 - 14,779.2	12,147.1 - 22,575.4	38,239.2 - 49,056.6	73,726.5 - 118,758.8
6% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	32.0 - 460.9	2,043.7 - 722.7	3,826.2 - 12,837.8	10,805.8 - 26,242.5	11,119.6 - 44,318.6	25,582.6 - 57,448.0	56,381.3 - 82,811.6	78,042.0 - 127,728.8	187,833.3 - 352,563.2
7% Annual Increase	2010 2008	0.0 - 0.0	0.0 - (7.7)	65.0 - 2,718.1	6,423.7 - 4,595.0	12,463.4 - 10,621.4	15,318.7 - 27,807.8	38,084.7 - 61,660.8	53,658.3 - 73,154.5	77,152.8 - 111,341.1	99,435.6 - 137,323.7	302,602.3 - 429,214.8
Max Net Benefits (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 1,312.3	67.8 - 2,057.2	11,534.4 - 11,182.0	14,999.0 - 28,318.9	15,536.9 - 29,290.8	16,737.6 - 30,759.0	17,826.8 - 32,171.5	24,443.0 - 37,874.5	29,709.4 - 42,097.6	130,854.7 - 215,063.6
Max Net Benefits (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 1,312.3	71.6 - 2,064.5	2,105.1 - 6,719.6	8,539.3 - 15,546.4	9,618.7 - 16,072.2	9,963.4 - 17,097.0	10,171.4 - 17,826.0	13,282.0 - 21,333.1	20,321.2 - 26,381.6	74,072.6 - 124,352.8
Total Cost = Total Benefit (3% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 14,320.1	71.6 - 15,121.7	12,910.8 - 17,431.2	14,364.5 - 35,462.0	16,811.9 - 36,678.3	18,786.6 - 39,797.0	29,056.6 - 42,900.2	33,658.6 - 50,292.1	41,317.0 - 62,488.3	166,977.5 - 314,490.9
Total Cost = Total Benefit (7% Discount Rate)	2010 2008	0.0 - 0.0	0.0 - 14,320.1	71.6 - 15,121.7	12,910.8 - 17,431.2	14,364.5 - 35,462.0	16,811.9 - 36,678.3	18,786.6 - 39,797.0	29,056.6 - 42,900.2	33,658.6 - 50,292.1	41,317.0 - 62,488.3	166,977.5 - 314,490.9

H. Social Benefits, Private Benefits, and Potential Unquantified Consumer Welfare Impacts of the Final MY 2017-2021 and Augural 2022-2025 Standards

There are two viewpoints for evaluating the costs and benefits of the increase in CAFE standards: the private perspective of vehicle buyers themselves on the higher fuel economy levels that the rule would require, and the economy-wide or "social" perspective on the costs and benefits of requiring higher fuel economy. In order to appreciate how these viewpoints may diverge, it is important to distinguish between costs and benefits that are "private" and costs and benefits that are "social," The agency's analysis of benefits and costs from requiring higher fuel efficiency, presented above, includes several categories of benefits (identified as "social benefits") that are not limited to automobile purchasers, and that extend throughout the U.S. economy. Examples of these benefits include reductions in the energy security costs associated with U.S. petroleum imports, and in the economic damages expected to result from air pollution (including but not limited to climate change). In contrast, other categories of benefits—principally future fuel savings projected to result from higher fuel economy, but also for example time savings—will be experienced exclusively by the initial purchasers and subsequent owners of vehicle models whose fuel economy manufacturers elect to improve ("private benefits").

The economy-wide or "social" benefits from requiring higher fuel economy represent an important share of the total economic benefits from raising CAFE standards. At the same time, NHTSA estimates that benefits *to vehicle buyers themselves* will significantly exceed vehicle manufacturers' costs for complying with the stricter fuel economy standards this rule establishes. In short, consumers will benefit on net. Since the agency also assumes that the costs of new technologies manufacturers will employ to improve fuel economy will ultimately be borne by vehicle buyers in the form of higher purchase prices, NHTSA concludes that the benefits to potential vehicle buyers from requiring higher fuel efficiency will far outweigh the costs they will be required to pay to obtain it. NHTSA recognizes that this conclusion raises certain issues, addressed directly below.

As an illustration, Tables VIII-25 and VIII-26 report the agency's estimates of the average lifetime values of fuel savings for MY 2017-2025 passenger cars and light trucks calculated using future retail fuel prices (that is, inclusive of fuel taxes), which are those likely to be used by vehicle buyers to project the value of fuel savings they expect from higher fuel economy. The tables compare NHTSA's estimates of the average lifetime value of fuel savings for cars and light trucks to the price increases projected to result from manufacturers' efforts to recover their costs for complying with increased CAFE standards for those model years by increasing vehicles' sales prices. In response to comments received on the Preliminary Regulatory Impact

Analysis (PRIA) requesting that any payback analysis include a broad range of additional ownership costs potentially impacted by this rule, Tables VIII-25 and VIII-26 have been updated to include, as a separate line item, CAFE-related increases in per-vehicle ownership costs including maintenance, insurance, taxes/fees, and financing costs in spite of the fact that consumers may not fully factor these additional ownership costs into vehicle purchasing decisions.[526] Tables VIII-25 and VIII-26 show that the estimates of the present value of lifetime fuel savings (discounted at both 3 and 7 percent rates) outweigh projected vehicle price increases and increased vehicle ownership costs for both cars and light trucks in every model year, even under the assumption that all of manufacturers' technology outlays are passed on to buyers in the form of higher selling prices for new cars and light trucks. By model year 2025, NHTSA projects that average lifetime fuel savings will exceed the sum of the average price increase and average ownership cost increase by nearly $3,400 (2010 baseline estimate) or $2,900 (2008 baseline estimate) for cars, and close to $4,700 (2010 baseline estimate) or about $5,200 (2008 baseline estimate) for light trucks, all assuming a 3 percent discount rate. If applying a 7 percent discount rate to these costs and benefits, the net benefit for MY 2025 passenger cars is about $2,200 (2010 baseline estimate) or slightly above $1,800 (2008 baseline estimate). For light trucks, the corresponding values are about $3,300 and $3,700 (2010 and 2008 baseline estimates, respectively).

[526] Further information on NHTSA's analysis of this rule's impact on finance, insurance, and tax or fee costs related to vehicle purchase and ownership is provided in Chapter VII (see section on vehicle sales impact).

Table VIII-25a
Net Present Value of Lifetime[527] Fuel Savings vs. Avg. Vehicle Purchase and Ownership Cost Increases
Under Preferred Alternative, 3% Discount Rate
Passenger Cars

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Value of Fuel Savings	2010 2008	$1,067 - $904	$1,565 - $1,574	$2,402 - $2,325	$2,971 - $3,123	$3,662 - $3,600	$4,005 - $4,045	$4,511 - $4,324	$5,083 - $4,783	$5,363 - $5,186
Average Increase in Purchase Cost	2010 2008	($284) - ($208)	($424) - ($377)	($603) - ($571)	($762) - ($837)	($934) - ($1,034)	($1,024) - ($1,168)	($1,129) - ($1,255)	($1,328) - ($1,440)	($1,361) - ($1,577)
Average Increase in Ownership Costs (Maintenance, Insurance, Taxes/Fees, Financing)	2010 2008	($115) - ($90)	($171) - ($165)	($261) - ($261)	($326) - ($374)	($418) - ($449)	($464) - ($512)	($521) - ($551)	($610) - ($628)	($633) - ($685)
Average Total Increase (Purchase + Ownership Costs)	2010 2008	($399) - ($298)	($594) - ($542)	($864) - ($832)	($1,087) - ($1,211)	($1,352) - ($1,483)	($1,488) - ($1,680)	($1,650) - ($1,806)	($1,938) - ($2,068)	($1,993) - ($2,262)
Difference (Fuel Savings less Average Total Increase)	2010 2008	$668 - $607	$970 - $1,032	$1,538 - $1,493	$1,883 - $1,912	$2,310 - $2,117	$2,516 - $2,365	$2,862 - $2,518	$3,144 - $2,715	$3,370 - $2,925

[527] For Tables VIII-25 and VIII-26, the lifetime of vehicles is 30 years for passenger cars and 37 years for light trucks. Note that only a small percentage of the fuel savings benefit occurs beyond the first half of a vehicle's lifetime, due to discounting, and declines in VMT and survival rates as vehicle's age.

Table VIII-25b
Net Present Value of Lifetime Fuel Savings vs. Avg. Vehicle Purchase and Ownership Cost Increases
Under Preferred Alternative, 3% Discount Rate
Light Trucks

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Value of Fuel Savings	2010 2008	$660 - $501	$906 - $1,204	$2,321 - $2,277	$3,130 - $3,275	$4,337 - $4,388	$4,788 - $4,983	$5,440 - $5,385	$6,021 - $6,033	$6,195 - $6,678
Average Increase in Purchase Cost	2010 2008	($158) - ($87)	($187) - ($179)	($416) - ($331)	($596) - ($470)	($863) - ($648)	($911) - ($752)	($1,000) - ($808)	($1,081) - ($888)	($1,047) - ($1,040)
Average Increase in Ownership Costs (Maintenance, Insurance, Taxes/Fees, Financing)	2010 2008	($64) - ($37)	($75) - ($88)	($173) - ($164)	($237) - ($228)	($364) - ($298)	($395) - ($347)	($441) - ($374)	($502) - ($414)	($488) - ($480)
Average Total Increase (Purchase + Ownership Costs)	2010 2008	($222) - ($124)	($263) - ($267)	($589) - ($495)	($834) - ($698)	($1,227) - ($947)	($1,305) - ($1,099)	($1,441) - ($1,182)	($1,583) - ($1,302)	($1,535) - ($1,519)
Difference (Fuel Savings less Average Total Increase)	2010 2008	$438 - $376	$643 - $937	$1,733 - $1,781	$2,296 - $2,577	$3,110 - $3,441	$3,482 - $3,884	$3,999 - $4,203	$4,439 - $4,732	$4,660 - $5,159

Table VIII-26a
Net Present Value of Lifetime[528] Fuel Savings vs. Avg. Vehicle Purchase and Ownership Cost Increases
Under Preferred Alternative, 7% Discount Rate
Passenger Cars

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Value of Fuel Savings	2010 2008	$838 - $710	$1,229 - $1,237	$1,886 - $1,827	$2,332 - $2,453	$2,875 - $2,827	$3,143 - $3,175	$3,540 - $3,394	$3,988 - $3,753	$4,206 - $4,068
Average Increase in Purchase Cost	2010 2008	($284) - ($208)	($424) - ($377)	($603) - ($571)	($762) - ($837)	($934) - ($1,034)	($1,024) - ($1,168)	($1,129) - ($1,255)	($1,328) - ($1,440)	($1,361) - ($1,577)
Average Increase in Ownership Costs (Maintenance, Insurance, Taxes/Fees, Financing)	2010 2008	($114) - ($88)	($170) - ($161)	($256) - ($252)	($320) - ($363)	($406) - ($438)	($450) - ($499)	($503) - ($537)	($589) - ($611)	($609) - ($665)
Average Total Increase (Purchase + Ownership Costs)	2010 2008	($398) - ($296)	($594) - ($539)	($859) - ($824)	($1,082) - ($1,200)	($1,340) - ($1,473)	($1,474) - ($1,666)	($1,632) - ($1,792)	($1,917) - ($2,051)	($1,970) - ($2,242)
Difference (Fuel Savings less Average Total Increase)	2010 2008	$439 - $414	$635 - $698	$1,028 - $1,003	$1,250 - $1,253	$1,535 - $1,354	$1,669 - $1,508	$1,909 - $1,602	$2,071 - $1,702	$2,236 - $1,826

[528] For Tables VIII-25 and VIII-26, the lifetime of vehicles is 30 years for passenger cars and 37 years for light trucks. Note that only a small percentage of the fuel savings benefit occurs beyond the first half of a vehicle's lifetime, due to discounting, and declines in VMT and survival rates as vehicle's age.

Table VIII-26b
Net Present Value of Lifetime Fuel Savings vs. Avg. Vehicle Purchase and Ownership Cost Increases
Under Preferred Alternative, 7% Discount Rate
Light Trucks

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025
Value of Fuel Savings	2010 2008	$513 - $389	$704 - $935	$1,802 - $1,767	$2,429 - $2,542	$3,364 - $3,404	$3,712 - $3,865	$4,216 - $4,175	$4,665 - $4,676	$4,798 - $5,174
Average Increase in Purchase Cost	2010 2008	($158) - ($87)	($187) - ($179)	($416) - ($331)	($596) - ($470)	($863) - ($648)	($911) - ($752)	($1,000) - ($808)	($1,081) - ($888)	($1,047) - ($1,040)
Average Increase in Ownership Costs (Maintenance, Insurance, Taxes/Fees, Financing)	2010 2008	($63) - ($37)	($75) - ($84)	($171) - ($156)	($238) - ($218)	($359) - ($289)	($387) - ($336)	($431) - ($361)	($485) - ($399)	($470) - ($464)
Average Total Increase (Purchase + Ownership Costs)	2010 2008	($222) - ($123)	($263) - ($263)	($587) - ($487)	($834) - ($688)	($1,222) - ($937)	($1,298) - ($1,087)	($1,431) - ($1,169)	($1,565) - ($1,287)	($1,518) - ($1,503)
Difference (Fuel Savings less Average Total Increase)	2010 2008	$291 - $265	$442 - $672	$1,215 - $1,279	$1,595 - $1,854	$2,142 - $2,467	$2,414 - $2,777	$2,785 - $3,006	$3,100 - $3,389	$3,280 - $3,670

Assuming the comparisons in Tables VIII-25 and VIII-26 are accurate, they raise the question of why current vehicle purchasing patterns do not result in average fuel economy levels approaching those that this rule would require, and why stricter CAFE standards should be necessary to increase the fuel economy of new cars and light trucks. They also raise the question of why manufacturers do not elect to provide higher fuel economy even in the absence of increases in CAFE standards, since the comparisons in the preceding tables suggest that doing so would *reduce* the effective price of purchasing many new vehicle models, and thus increase sales of new vehicles. More specifically, why would potential buyers of new vehicles hesitate to make investments in vehicles with higher fuel economy that would produce the substantial economic returns illustrated by the comparisons presented in Tables VIII-25 and VIII-26? And why would manufacturers voluntarily forego opportunities to increase the attractiveness, value, and competitive positioning of their passenger car and light truck models by improving their fuel economy?

One explanation for why this situation might persist is that the market for vehicle fuel economy does not appear to work perfectly, in which case properly designed CAFE standards would be expected to increase consumer welfare. Some of these imperfections might stem from standard market failures, such as limited availability of information to consumers about the value of higher fuel economy.[529] However, such information is increasingly available and has become easier to obtain, and new fuel economy labels will provide a wide range of information about the economic and environmental benefits of increased fuel economy. Other explanations point to phenomena observed in the field of behavioral economics, including loss aversion, inadequate consumer attention to long-term savings, or a lack of salience of relevant benefits (such as fuel savings, or time savings associated with refueling) to consumers at the time they make purchasing decisions. Both theoretical and empirical research suggests that many consumers are unwilling to make energy-efficient investments even when those investments appear to pay off in the relatively short-term[530]. This research is in line with related findings that consumers may undervalue benefits or costs that are less salient, or that they will realize only in the future.[531]

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[529] "Out of Sight, Out of Mind: The Effects of Expenses on Mutual Fund Flows," Journal of Business vol. 78, no. 6, pp. 2095-2020. Available at http://faculty.haas.berkeley.edu/odean/papers/MutualFunds/Out%20of%20Sight%200112281.pdf (last accessed August 1, 2012) or Docket No. NHTSA-2010-0131.

[530] Jaffe, A. B., and Stavins, R. N. (1994). The Energy Paradox and the Diffusion of Conservation Technology. Resource and Energy Economics, 16(2); see Hunt Alcott and Nathan Wozny, Gasoline Prices, Fuel Economy, and the Energy Paradox (2010, available at http://www.sciencedirect.com/science/article/B6VFJ-45DMPNK-7/2/0d3440e9948aab163f984aeb7c8472a7 (last accessed August 1, 2012).

[531] Hossain, Janjim, and John Morgan (2009). ". . . Plus Shipping and Handling: Revenue (Non) Equivalence in Field Experiments on eBay," Advances in Economic Analysis and Policy vol. 6; Barber, Brad, Terrence Odean, and Lu Zheng (2005). Available at http://faculty.haas.berkeley.edu/rjmorgan/eBay.pdf (last accessed August 1, 2012) or Docket No. NHTSA-2010-0131.

Many commenters on the agency's proposed CAFE standards for MY 2017-25 noted that recent poll results and changes in attitudes suggest that consumers are becoming more aware of the importance and value of fuel economy, and that this will increasingly be reflected in their future vehicle purchasing decisions. NRDC, the Sierra Club, Consumer Federation of America, and Consumers' Union each cited recent polls indicating that consumers are increasingly concerned about fuel prices and U.S. energy security, and are increasingly aware that purchasing vehicles with higher fuel economy can reduce both their gasoline costs and U.S. dependence on imported petroleum. Some of these commenters also noted that recent polls have shown growing support for higher CAFE standards as a strategy for increasing the range of vehicle models offering high fuel economy, and increased willingness of vehicle buyers to pay for improved fuel economy and advanced technologies such as electric vehicles.

The agency agrees that there appears to be growing awareness of fuel economy generally and increased interest in higher fuel economy among vehicle buyers, but notes that some of this may reflect the persistence of high fuel prices in recent years. Thus if fuel prices decline from recent high levels, some of this increased awareness and willingness to pay for higher fuel economy could erode. In addition, if significant failures in the market for fuel economy – such as those identified in the preceding discussion – exist, then increased consumer awareness of and interest in fuel economy may be inadequate by themselves to result in the levels of fuel economy that would be economically desirable. In this case, increased CAFE standards are still likely to be necessary to require manufacturers to supply – and buyers to demand – the higher fuel economy levels that can be economically justified on the basis of their benefits and costs.

Previous research provides some support for the agency's conclusion that the benefits buyers will receive from requiring manufacturers to increase fuel economy outweigh the costs they would pay to acquire those benefits, even if private markets have not provided that amount of fuel economy. For example, some research suggest that many consumers appear unwilling to make energy-efficiency investments that appear likely to pay off in the relatively short-term, in part because they are deterred by the prospect that those investments require immediate, known outlays but produce deferred and uncertain returns. Such "loss aversion" – particularly when accompanied by a sense of uncertainty about gains – may make purchasing a more fuel-efficient vehicle seem unattractive to some potential buyers, even when doing so *is* likely to be a sound economic decision. As an illustration, Greene et al. (2009) calculate that the expected net present value of increasing the fuel economy of a passenger car from 28 to 35 miles per gallon falls from $405 when calculated using standard net present value calculations, to nearly zero when uncertainty regarding future cost savings and buyers' reluctance to accept the risk of losses are taken into account.[532]

The well-known finding that as gas prices rise, consumers show more willingness to pay for fuel-efficient vehicles is not necessarily inconsistent with the possibility that many consumers undervalue potential savings in gasoline costs and fuel economy when purchasing new vehicles. In ordinary circumstances, such costs may be a relatively "shrouded" attribute in consumers' decisions, in part because the savings from purchasing a more fuel efficient vehicle are cumulative and extend over a significant period of time. At the same time, it may be difficult for potential buyers to disentangle the cost of purchasing a more fuel-efficient vehicle from its overall purchase price, or to isolate the value of higher fuel economy from accompanying differences in other vehicle attributes. This possibility is consistent with recent evidence to the effect that many consumers are willing to pay less than $1 upfront to obtain a $1 reduction in the discounted present value of future gasoline costs.[533]

Some research suggests that the market's apparent unwillingness to provide more fuel efficient vehicles stems from consumers' inability to value future fuel savings correctly. For example, Larrick and Soll (2008) find evidence that consumers do not understand how to translate changes in fuel economy, which is denominated in miles per gallon (MPG), into resulting changes in fuel consumption, measured for example in gallons per 100 miles travelled or per month or year.[534] It is true that the recently redesigned fuel economy label should help overcome this difficulty, because it draws attention to purely economic effects of fuel economy, but MPG remains a prominent measure. Sanstad and Howarth (1994) argue that consumers often resort to imprecise but convenient rules of thumb to compare vehicles that offer different fuel economy ratings, and that this can cause many buyers to underestimate the value of fuel savings, particularly from

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[532] Greene, D., J. German, and M. Delucchi (2009). "Fuel Economy: The Case for Market Failure" in Reducing Climate Impacts in the Transportation Sector, Sperling, D., and J. Cannon, eds. Springer Science. Surprisingly, the authors find that uncertainty regarding the future price of gasoline appears to be less important than uncertainty surrounding the expected lifetimes of new vehicles. (Docket NHTSA–2009–0059–0154). On loss aversion in general, and its relationship to prospect theory (which predicts that certain losses will loom larger than probabilistic gains of higher expected value), see Kahneman.

[533] *See, e.g.,* Alcott and Wozny. On shrouded attributes and their importance, see Gabaix, Xavier, and David Laibson. 2006. "Shrouded Attributes, Consumer Myopia, and Information Suppression in Competitive Markets." *Quarterly Journal of Economics* 121(2): 505-540. Available at http://www.economics.harvard.edu/faculty/laibson/files/Shrouded.pdf (last accessed August 1, 2012) or Docket No. NHTSA-2010-0131.

[534] Larrick, R. P., and J.B. Soll (2008). "The MPG illusion." *Science* 320: 1593-1594. Available at http://www.sciencemag.org/content/320/5883/1593.full?ijkey=3pScQm7pQBzqs&keytype=ref&siteid=sci (requires subscription; last accessed August 1, 2012) or Docket No. NHTSA-2011-0131

significant increases in fuel economy.[535] If the behavior identified in these studies is widespread, then the agency's estimates suggesting that the benefits to vehicle owners from requiring higher fuel economy significantly exceed the costs of providing it may be consistent with private markets not providing that fuel economy level.

Some commenters endorsed the agency's analysis of the potential for various sources of market failure to inhibit manufacturers from supplying adequate fuel economy levels, and to cause potential buyers to underestimate the value of purchasing models that offer higher fuel economy. Consumer Federation of America endorsed the agency's focus on sources of manufacturers' hesitance to offer models with higher fuel economy, as well as on the more commonly cited market failures that can make buyers unwilling to invest in higher fuel economy. CFA also submitted more detailed discussions of some of these sources of potential market failure in support of its general comments. ICCT noted that the combination of uncertainty about the cost and effectiveness of new technologies to improve fuel economy with buyers' aversion to potential losses from purchasing higher-priced vehicles offering uncertain fuel savings was sufficient to explain the underinvestment in fuel economy, and to justify higher fuel economy standards. ICCT also argued that by removing consumers' option to buy low fuel economy vehicles, higher fuel economy standards minimize the effect of aversion on buyers' willingness to invest in higher fuel economy.

Another possible explanation for the apparent inconsistency between the agency's claim that the typical vehicle buyer will experience net savings from these standards and the fact that the average fuel economy of new vehicles sold currently falls well short of the level those standards would require is that many of the technologies projected by the agency to be available through MY2025 offer significantly improved efficiency per unit of cost, yet were not available for application to new vehicles sold currently. Still another is that the value of future savings resulting from the proposed standards will vary widely among potential vehicle buyers. These differences undoubtedly reflect variation in the amount they drive, differences in their driving styles that affect the fuel economy they expect to achieve, and varying expectations about future fuel prices, but they may also partly reflect differences in buyers' understanding of what increased fuel economy is likely to mean to them financially, or in buyers' preferences for paying lower prices today versus anticipated savings over the future.

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[535] Sanstad, A., and R. Howarth (1994). " 'Normal' Markets, Market Imperfections, and Energy Efficiency." Energy Policy 22(10): 811–818. Available at http://www.sciencedirect.com/science/article/pii/0301421594901392 (last accessed August 1, 2012)

Unless the agency has overestimated their *average* value, however, the fact that the value of fuel savings varies among potential buyers cannot explain why typical buyers do not currently purchase what appear to be cost- saving increases in fuel economy. A possible explanation for this situation is that the effects of differing fuel economy levels are relatively modest when compared to those provided by other, more prominent features of new vehicles, such as passenger and cargo-carrying capacity, performance, or safety. In this situation, it may simply not be in many shoppers' interest to spend the time and effort necessary to determine the economic value of higher fuel economy, to isolate the component of a new vehicle's selling price that is related to its fuel economy, and compare these two (this possibility is consistent with the view that fuel economy is a relatively "shrouded" attribute). In this case, the agency's estimates of the *average* value of fuel savings that will result from requiring cars and light trucks to achieve higher fuel economy may be correct, yet those savings may not be large enough to lead a sufficient number of buyers to purchase vehicles with higher fuel economy to raise average fuel economy above its current levels.

Defects in the market for cars and light trucks could also lead manufacturers to undersupply fuel economy, even in cases where many (informed) buyers would be willing to pay the increased prices necessary to provide it. Most obviously, an absence of vigorous competition among producers of cars and light trucks may lead manufacturers to undersupply attributes that contribute to the overall quality of new vehicles, including fuel economy, because such "imperfect" competition reduces producers' profit incentive to supply the level of fuel economy that buyers are willing to pay for. Incomplete or "asymmetric" access to information on vehicle attributes such as fuel economy – whereby manufacturers of new vehicles or sellers of used cars and light trucks have more complete knowledge of vehicles' actual fuel economy levels, or of the value of purchasing higher fuel economy, than do potential buyers – may also prevent sellers of new or used vehicles from capturing its full value. In this situation, the level of fuel efficiency provided in the markets for new or used vehicles might remain persistently lower than that demanded by potential buyers.

Constraints on the combinations of fuel economy, carrying capacity, and performance that current technologies permit manufacturers to offer in individual vehicle models undoubtedly limit the range of fuel economy available within certain vehicle classes, particularly those including larger vehicles. However, it is also possible that deliberate decisions by manufacturers further limit the range of fuel economy available to buyers within individual vehicle market segments, such as large automobiles, SUVs, or minivans. Manufacturers may deliberately limit the range of fuel economy levels they offer in those market segments (by choosing not to invest in fuel economy and investing instead in providing a range of other vehicle attributes) because they underestimate the premiums that prospective buyers of those models are willing to pay for improved fuel economy, and thus mistakenly believe it will be unprofitable for them to offer more fuel-efficient models within those segments. Of course, this possibility is most realistic if it is also assumed that buyers are imperfectly informed, or if fuel economy savings are not sufficiently salient to shoppers in those particular market segments. As an illustration, the range of highway fuel economy ratings among current minivan models extends from 22 to 28 mpg, while their combined city and highway ratings range only from 18 to 20 mpg.[536] If this phenomenon is widespread, the average fuel efficiency of their entire new vehicle fleet could remain below the levels that potential buyers demand and are willing to pay for.

Another possible explanation for the paradox posed by buyers' apparent unwillingness to invest in higher fuel economy when it appears to offer such large financial returns is that NHTSA's estimates of benefits and costs from requiring manufacturers to improve fuel efficiency do not match potential buyers' assessment of the likely benefits and costs from purchasing models with higher fuel economy ratings. This could occur because the agency's underlying assumptions about some of the factors that affect the value of fuel savings differ from those made by potential buyers, because NHTSA has used different estimates for some components of the benefits from saving fuel from those of buyers, or simply because the agency has failed to account for some potential costs of achieving higher fuel economy.

For example, buyers may not value increased fuel economy as highly as the agency's calculations suggest, because they have shorter time horizons than the full vehicle lifetimes NHTSA uses in these calculations, because they discount future fuel savings using higher rates than those prescribed by OMB for evaluating Federal regulations, or they expect to drive substantially fewer miles over the course of vehicle ownership than the VMT schedules upon which NHTSA based its central cost-benefit analysis. Potential buyers may also anticipate lower fuel prices in the future than those forecast by the Energy Information Administration, or may expect larger differences between vehicles' MPG ratings and their own actual on-road fuel economy than the 20 percent gap (30 percent for HEVs) the agency estimates.

To illustrate the first of these possibilities, Table VIII-27 shows the effect of differing assumptions about vehicle buyers' time horizons for assessing the value of future fuel savings. Specifically, the table compares the average value of fuel savings from purchasing a MY 2025

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[536] This is the range of combined city and highway fuel economy levels from lowest (Toyota Sienna AWD) to highest (Honda Odyssey) available for model year 2010; http://www.fueleconomy.gov/feg/bestworstEPAtrucks.htm (last accessed September 26, 2011).

car or light truck when fuel savings are evaluated over different time horizons to the estimated increase in its price.

Unlike Tables VIII-25 and VIII-26, Table VIII-27 looks at the value of fuel savings only for the vehicle lifetime as anticipated by the consumer, that is, 14 years for passenger cars and 16 years for light trucks. Table VIII-27 shows that over the consumer's anticipated lifetime of model year 2025 vehicles, NHTSA projects that average lifetime fuel savings will exceed the average purchase price increase of passenger cars by around $3,300 or about $2,900 (2010 and 2008 baselines, respectively), and that of light trucks by about $4,400 or around $4,900 (2010 and 2008 baselines, respectively), assuming a 3 percent discount rate. If a 7 percent discount rate is applied, fuel savings will exceed average price increases of passenger cars by about $2,500 or around $2,100 (2010 and 2008 baselines, respectively), and that of light trucks by around $3,400 or about $3,800 (2010 and 2008 baselines, respectively).

If buyers are instead assumed to evaluate fuel savings over a 10-year time horizon, however, the present value of fuel savings exceeds the projected price increase for a MY 2025 passenger car by about $2,500 under the 2010 baseline fleet analysis and by about $2,100 under the 2008 baseline fleet analysis, using a 3 percent discount rate. If applying a 7 percent discount rate, these figures drop to about $1,900 and $1,600, respectively. The present value of fuel savings for a MY 2025 light truck exceeds the projected vehicle price increase by about $3,300 under the 2010 baseline fleet analysis and somewhat more than $3,600 under the 2008 baseline fleet analysis, using a 3 percent discount rate. If applying a 7 percent discount rate, these figures drop to about $2,700 and $3,000, respectively.

Finally, Table VIII-27 shows that under the assumption that buyers value fuel savings only over the length of time for which they typically finance new car purchases (slightly more than 5 years during 2010), the value of fuel savings, valued according to a 3 percent discount rate, exceeds the estimated increase in the price of a MY 2025 passenger car by a bit more than $800, or somewhat over $500 in the case of the 2008 baseline analysis. If utilizing a 7 percent discount rate, the corresponding values are a bit less than $700 for the 2010 baseline analysis, or about $400 in the case of the 2008 baseline analysis. Owners of light trucks will also see a net benefit over the course of the average loan term, with the present value of fuel savings exceeding purchase price increases by about $1,500 or $1,700 (2010 and 2008 baselines, respectively) at a 3 percent discount rate, or in the event of a 7 percent discount rate, by about $1,300 or $1,500 (2010 and 2008 baselines, respectively).

Table VIII-27
Value of Fuel Savings vs. Vehicle Price Increases
with Alternative Assumptions about Vehicle Buyer Time Horizons[537],[538]

Vehicle	Measure	Baseline Fleet	3% Discount Rate				7% Discount Rate		
			Expected Lifetime	10 Years	Average Loan Term		Expected Lifetime	10 Years	Average Loan Term
MY 2025 Passenger Car	Fuel Savings	2010 2008	$4,659 - $4,506	$3,820 - $3,694	$2,193 - $2,121		$3,838 - $3,712	$3,293 - $3,186	$2,040 - $1,973
	Price Increase	2010 2008	($1,361) - ($1,577)	($1,361) - ($1,577)	($1,361) - ($1,577)		($1,361) - ($1,577)	($1,361) - ($1,577)	($1,361) - ($1,577)
	Difference	2010 2008	$3,298 - $2,929	$2,459 - $2,118	$833 - $545		$2,477 - $2,135	$1,933 - $1,609	$679 - $397
MY 2025 Light Truck	Fuel Savings	2010 2008	$5,472 - $5,900	$4,343 - $4,683	$2,525 - $2,722		$4,472 - $4,823	$3,758 - $4,053	$2,353 - $2,538
	Price Increase	2010 2008	($1,047) - ($1,040)	($1,047) - ($1,040)	($1,047) - ($1,040)		($1,047) - ($1,040)	($1,047) - ($1,040)	($1,047) - ($1,040)
	Difference	2010 2008	$4,425 - $4,860	$3,296 - $3,643	$1,477 - $1,682		$3,424 - $3,783	$2,711 - $3,013	$1,306 - $1,498

537 In this Table, "expected lifetime" refers to 14 years for passenger cars and 16 years for light trucks.
538 The average term on new-vehicle loans made by auto finance companies during 2010 was 63 months; see Board of Governors of the Federal Reserve System, Federal Reserve Statistical Release G. 19, Consumer Credit, http://www.federalreserve.gov/releases/g19/Current/ (last accessed August 1, 2012). The Federal Reserve Board suspended publication of this series in Q1 2011, as "the statistical foundation for [this] series has deteriorated." In this FRIA, NHTSA relies on the most recent data from this series prior to suspension of publication.

Potential vehicle buyers may also discount future fuel future savings using higher rates than those typically used to evaluate federal regulations. (For some consumers, these high discount rates might reflect rational behavior[539]; for others, they might reflect an excessive focus on the short-term and a neglect of the future.) OMB guidance prescribes that future benefits and costs of regulations that mainly affect private consumption decisions, as will be the case if manufacturers' costs for complying with higher fuel economy standards are passed on to vehicle buyers, should be discounted using a consumption rate of time preference.[540] OMB estimates that savers currently discount future consumption at an average real or inflation-adjusted rate of about 3 percent when they face little risk about its likely level, which makes it a reasonable estimate of the consumption rate of time preference. However, vehicle buyers may view the value of future fuel savings that results from purchasing a vehicle with higher fuel economy as risky or uncertain, or they may instead discount future consumption at rates reflecting their costs for financing the higher capital outlays required to purchase more fuel-efficient models. In either case, they may discount future fuel savings at rates other than the 3 and 7 percent levels assumed in NHTSA's evaluation.

Table VIII-28 shows the effect of alternative discount rates on vehicle buyers' evaluation of the fuel savings projected to result from the CAFE standards established by this rule, again using MY 2025 passenger cars and light trucks as an example. As Table VIII-27 showed, average future fuel savings discounted at the 3 percent consumer rate exceed the agency's estimated price increases by more than $2,900 for MY 2025 passenger cars and by more than $4,400 for MY 2025 light trucks over the expected vehicle lifetime from the consumer perspective. If vehicle buyers instead discount future fuel savings at the average new-car loan rate (5.16%)[541], however, these differences decline to at most just above $2,800 for cars and slightly above $4,200 for light trucks, as Table VIII-28 illustrates. This is a particularly plausible alternative assumption, because buyers are likely to finance the increases in purchase prices resulting from compliance with higher CAFE standards as part of the process financing the vehicle purchase itself. Finally, as the table also shows, discounting future fuel savings using a consumer credit card rate (which

[539] For example, it may be rational for a consumer who drives very few miles per year [and expects this pattern to continue well into the future] to place little value on fuel savings, thereby implying a large discount rate.
[540] Office of Management and Budget, Circular A-4, "Regulatory Analysis," September 17, 2003, 33. Available at http://www.whitehouse.gov/sites/default/files/omb/assets/regulatory_matters_pdf/a-4.pdf (last accessed August 1, 2012) or Docket No. NHTSA-2010-0131.
[541] This rate is the average of Global Insight forecasts of auto loan rates, the average of commercial bank auto loan and auto finance company loan rates for years 2017 to 2025, adjusted for inflation using Global Insight forecasts of the Consumer Price Index. No data on the distribution of commercial bank auto loans vs. auto finance loans were identified, therefore NHTSA assumed an equal distribution across these categories.

averaged 13.8% during 2010)[542] reduces these differences to no more than $1,500 for a MY 2025 passenger car and no more than $2,500 for a MY 2025 light truck. Thus even at relatively high discount rates, the higher fuel economy levels required by this final rule would generate significant net benefits to vehicle buyers.

[542] *Ibid.* The average interest rate on consumer credit card accounts at commercial banks was 13.78% during 2010.

Table VIII-28
Value of Lifetime[543] Fuel Savings vs. Vehicle Price Increases
with Alternative Assumptions about Consumer Discount Rates[544]

Vehicle	Measure	Baseline Fleet	Value at Alternative Discount Rates			
			Consumer Rate (3%)	New Car Loan Rate (5.16%)	Alternate Consumer Rate (7%)	Consumer Credit Card Rate (13.8%)
MY 2025 Passenger Car	Fuel Savings	2010 2008	$4,659 - $4,506	$4,178 - $4,041	$3,838 - $3,712	$2,818 - $2,725
	Price Increase	2010 2008	($1,361) - ($1,577)	($1,361) - ($1,577)	($1,361) - ($1,577)	($1,361) - ($1,577)
	Difference	2010 2008	$3,298 - $2,929	$2,817 - $2,464	$2,477 - $2,135	$1,457 - $1,148
MY 2025 Light Truck	Fuel Savings	2010 2008	$5,472 - $5,900	$4,883 - $5,266	$4,472 - $4,823	$3,252 - $3,507
	Price Increase	2010 2008	($1,047) - ($1,040)	($1,047) - ($1,040)	($1,047) - ($1,040)	($1,047) - ($1,040)
	Difference	2010 2008	$4,425 - $4,860	$3,836 - $4,226	$3,424 - $3,783	$2,205 - $2,467

[543] In this Table, "expected lifetime" refers to 14 years for passenger cars and 16 years for light trucks.

[544] The fuel-economy-improving technologies chosen within the CAFE model are to a small extent affected by the choice of the consumer discount rate applied to fuel savings. The CAFE model is run at 3 and 7 percent corresponding discount rates only. Analysis of the effect of alternate discount rates on the value of fuel savings is therefore slightly less precise to the extent that the CAFE model may have selected a different mix of technologies at the given alternate discount rate.

Combinations of a shorter time horizon and a higher discount rate could further reduce or even eliminate the difference between the value of fuel savings and the agency's estimates of increases in vehicle prices. One plausible combination would be for buyers to discount fuel savings over the term of a new car loan, using the interest rate on that loan as a discount rate. Assuming a 60-month loan at the previously stated rate of 5.16%, the outcomes differ between passenger cars and light trucks for MY 2025. For passenger cars, the typical consumer would see fuel savings outpace the vehicle price increase by $745 or $460 (2010 and 2008 baselines, respectively) in this 60-month period. For consumers of light trucks, these differences are $1,066 and $1,040 (2010 and 2008 baselines, respectively).

Some evidence suggests directly that vehicle buyers may employ combinations of higher discount rates and shorter time horizons than the agency assumes; for example, consumers surveyed by Kubik (2006) reported that fuel savings would have to be adequate to pay back the additional purchase price of a more fuel-efficient vehicle in less than 3 years to persuade a typical buyer to purchase it.[545] As these comparisons and evidence illustrate, reasonable alternative assumptions about how consumers might evaluate the major benefit from requiring higher fuel economy can significantly reduce its magnitude from the agency's estimate.

Imaginable combinations of shorter time horizons, higher discount rates, and lower expectations about future fuel prices or annual vehicle use and fuel savings could make potential buyers hesitant or even unwilling to purchase vehicles offering the fuel economy levels this rule will require. At the same time, they would also cause vehicle buyers' collective assessment of how the benefits from requiring higher fuel economy compare to the costs they will be required to pay for it to differ significantly from NHTSA's assessment of the aggregate benefits and costs of this rule. If consumers' views about critical variables such as future fuel prices or the appropriate discount rate differ sufficiently from the assumptions used by the agency, potential vehicle buyers might conclude that the value of fuel savings and other benefits they will experience from higher fuel economy are not sufficient to justify the increase in purchase prices they expect to pay.

Table VIII-29 illustrates the effect of variation among potential buyers' expectations about how much they are likely to drive new vehicles over their lifetimes on their evaluation of fuel savings projected to result from the CAFE standards this rule establishes, again using MY 2025

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[545] Kubik, M. (2006). Consumer Views on Transportation and Energy. Second Edition. Technical Report: National Renewable Energy Laboratory. Available at http://www.nrel.gov/docs/fy05osti/36785.pdf or Docket No. NHTSA-2010-0131.

passenger cars and light trucks as an example. Table VIII-29 compares the perspective of potential buyers who expect to drive the lifetime mileage estimate used utilized in the agency's central analysis to those of buyers who expect to drive only 50 and 25 percent of that lifetime mileage. While in both cases – even at a 7 percent discount rate – fuel savings are likely to outweigh increased prices for light trucks, potential buyers of passenger cars who expect to drive only 25 percent of the average figure used in the agency's analysis might expect no net benefit from the higher fuel economy levels the rule requires.[546]

[546] The 25 percent VMT schedule is an extreme case; by year 14 (the horizon for passenger cars in Table VIII-29), only 4 percent of vehicles have cumulative VMT at or below 25 percent of average cumulative VMT.

Table VIII-29
Value of Lifetime[547] Fuel Savings vs. Vehicle Price Increases
with Alternative Assumptions about VMT

Vehicle	Measure	Baseline Fleet	3% Discount Rate				7% Discount Rate		
			Expected VMT Schedule	50% of Expected VMT	25% of Expected VMT		Expected VMT Schedule	50% of Expected VMT	25% of Expected VMT
MY 2025 Passenger Car	Fuel Savings	2010 2008	$4,659 - $4,506	$2,498 - $2,469	$1,249 - $1,234		$3,838 - $3,712	$2,022 - $1,998	$1,011 - $999
	Price Increase	2010 2008	($1,361) - ($1,577)	($1,361) - ($1,577)	($1,361) - ($1,577)		($1,361) - ($1,577)	($1,361) - ($1,577)	($1,361) - ($1,577)
	Difference	2010 2008	$3,298 - $2,929	$1,138 - $892	($112) - ($342)		$2,477 - $2,135	$661 - $422	($350) - ($577)
MY 2025 Light Truck	Fuel Savings	2010 2008	$5,472 - $5,900	$3,203 - $3,404	$1,601 - $1,702		$4,472 - $4,823	$2,568 - $2,729	$1,284 - $1,364
	Price Increase	2010 2008	($1,047) - ($1,040)	($1,047) - ($1,040)	($1,047) - ($1,040)		($1,047) - ($1,040)	($1,047) - ($1,040)	($1,047) - ($1,040)
	Difference	2010 2008	$4,425 - $4,860	$2,155 - $2,364	$554 - $662		$3,424 - $3,783	$1,520 - $1,689	$236 - $325

[547] In this Table, "expected lifetime" refers to 14 years for passenger cars and 16 years for light trucks.

Another possibility is that achieving the fuel economy improvements required by stricter fuel economy standards might lead manufacturers to forego planned future improvements in performance, carrying capacity, safety, or other features of their vehicle models that represent important sources of utility to vehicle owners. In extreme cases, manufacturers might even find it necessary to change the levels of these attributes that some currently available models offer. Although the specific economic values that vehicle buyers attach to individual vehicle attributes such as fuel economy, performance, passenger- and cargo-carrying capacity, and other sources of vehicles' utility are difficult to infer from their purchasing decisions and vehicle prices – as evidenced by significant variability in findings in economic literature on these topics – changes in vehicle attributes can significantly affect the overall utility that vehicles offer to potential buyers. Compromises in these or other highly-valued attributes would be viewed by potential buyers as an additional cost of improving fuel economy that the agency has failed to acknowledge or include in its estimates of the costs of complying with stricter CAFE standards.

As indicated in its previous discussion of technology costs, NHTSA has approached this potential problem by developing cost estimates for fuel economy-improving technologies that include allowances for any additional manufacturing costs that would be necessary to maintain the reference fleet (or baseline) levels of performance, comfort, capacity, or safety of light-duty vehicle models to which those technologies are applied. In doing so, the agency followed the precedent established by the 2011 NAS Report on improving fuel economy, which estimated "constant performance and utility" costs for technologies that manufacturers could employ to increase the fuel efficiency of cars or light trucks. Although NHTSA has revised its estimates of manufacturers' costs for some technologies significantly for use in this rulemaking, these revised estimates are still intended to represent costs that would allow manufacturers to maintain the performance, carrying capacity, and utility of vehicle models while improving their fuel economy.

The agency readily acknowledges the difficulty of estimating technology costs that include adequate provision for the accompanying changes in vehicle design that are necessary to maintain performance, capacity, and utility. While NHTSA believe that its cost estimates for fuel economy-improving technologies are sufficient to prevent significant compromises in other attributes of the vehicle models to which manufacturers apply them, it is possible that these costs do not include adequate allowance for the necessary investments by manufacturers to maintain baseline levels of these critical vehicle attributes. If this is the case, the true economic costs of achieving higher fuel economy would include the opportunity costs to vehicle owners of any sacrifices in vehicles' performance, carrying capacity, and utility that accompanied increases in their fuel economy. In that event, the agencies' estimated technology costs would underestimate the true economic costs of complying with stricter fuel economy emission standards.

Another possible reconciliation of the agency's claim that the *average* vehicle buyer will experience large fuel savings from the higher CAFE standards this rule establishes with the fact that the *average* fuel economy of vehicles currently purchased falls well short of the new standards is that the values consumers place on the future savings they expect to obtain from higher fuel economy vary widely. As an illustration, one recent review of consumers' willingness to pay for improved fuel economy found estimates that varied from less than 1% to almost ten times the present value of the resulting fuel savings when those are discounted at 7% over the vehicle's expected lifetime.[548,549] Although the wide variation in these estimates undoubtedly reflects methodological and measurement differences among the studies surveyed, it probably also reflects the fact that the expected savings from purchasing a vehicle with higher fuel economy vary widely among individuals, because they travel different amounts, have different driving styles, or have different expectations about future fuel prices.

This is likely to be reflected in the fact that many buyers with high valuations of increased fuel economy *already* purchase vehicle models that offer it, while those with lower values of fuel economy emphasize other vehicle attributes in their purchasing decisions. A related possibility is that because the effects of differing fuel economy levels are relatively unimportant when compared to other, more prominent features of new vehicles – passenger and cargo-carrying capacity, performance, safety, etc. – it is simply not in many shoppers' interest to spend the time and effort necessary to determine the economic value of higher fuel economy, attempt to isolate the component of a new vehicle's selling price that is related to its fuel economy, and compare these two. (This may be so even though more fuel-efficient choices might ultimately prove to be in consumers' economic self-interest.) In either case, although the agency's estimates of the *average* value of fuel savings that will result from requiring cars and light trucks to achieve higher fuel economy may be correct, it may not be large enough to lead a sufficient number of buyers to purchase vehicles with higher fuel economy to increase average fuel economy from its current levels.

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[548] Greene, David L., "How Consumers Value Fuel Economy: A Literature Review," Draft report to U.S. Environmental Protection Agency, Oak Ridge National Laboratory, March, 2010; see Table 10, p. 37. Available at http://www.epa.gov/otaq/climate/regulations/420r10008.pdf (last accessed August 1, 2012) or Docket NHTSA-2010-0131

[549] Jin-Tan Liu (1988). "Automotive Fuel Economy Improvements and Consumers' Surplus." Transportation Research Part A 22A(3): 203-218 (Docket EPA-HQ-OAR-2009-0472-0045). The study actually calculated the willingness to pay for reduced vehicle operating costs, of which vehicle fuel economy is a major component.

The agency has been unable to reach a conclusive answer to the question of why the apparently large differences between its estimates of benefits from requiring higher fuel economy and the costs of supplying it do not result in higher average fuel economy for new cars and light trucks. One explanation is that NHTSA's estimates are reasonable, and the market for fuel economy is simply not operating efficiently. For reasons stated above, NHTSA believes that a number of imperfections in the relevant market (including the lack of salience of fuel economy benefits and an emphasis on the short-term) likely play a key role, thus justifying the conclusion that the private benefits are substantial. However, the agency acknowledges that this situation may also reflect the fact that some combination of overestimating the value of fuel savings and omitting potential reductions in the welfare of vehicle buyers means that it has not fully characterized the impact of the CAFE standards this rule establishes on consumers. To recognize this possibility, and as part of a sensitivity analysis, this section presents an alternative accounting of the benefits and costs of CAFE standards for MY 2017-2025 passenger cars and light trucks and discusses its implications.

Table VIII-30 displays the economic impacts of the rule from the perspective of potential buyers, and also reconciles the estimated net benefits of the rule as they are likely to be viewed by vehicle buyers with its net benefits to the economy as a whole. As the table shows, the total benefits to vehicle buyers (line 6) consists of the value of fuel savings at retail fuel prices (line 1), the economic value of vehicle occupants' savings in refueling time (line 2), and the economic benefits from added rebound-effect driving (line 3). As the zero entries in line 5 of the table suggest, the agency's estimate of the retail value of fuel savings reported in line 1 is assumed to be correct, and no losses in consumer welfare from changes in vehicle attributes (other than those from increases in vehicle prices) are assumed to occur. Thus there is no reduction in the total private benefits to vehicle owners, so that net private benefits to vehicle buyers (line 6) are equal to total private benefits (reported previously in line 4).

As Tables VIII-30 and VIII-31 (presented at 3 and 7 percent discount rates, respectively) also show, the decline in fuel tax revenues (line 7) that results from reduced fuel purchases is in effect an external cost from the viewpoint of vehicle buyers, which offsets part of the benefits of fuel savings when those are viewed from the economy-wide or "social" perspective.[550] Thus the sum

[550] Strictly speaking, fuel taxes represent a transfer of resources from consumers of fuel to government agencies and not a use of economic resources. Reducing the volume of fuel purchases simply reduces the value of this transfer, and thus cannot produce a real economic cost or benefit. Representing the change in fuel tax revenues in effect as an economy-wide cost is necessary to offset the portion of fuel savings included in line 1 that represents savings in fuel tax payments by consumers. This prevents the savings in tax revenues from being counted as a benefit from the economy-wide perspective.

of lines 1 and 7 is the savings in fuel production costs that was reported previously as the value of fuel savings at pre-tax prices in the agency's usual accounting of benefits and costs (see Chapter X). Line 8 represents the costs of increased congestion delays, accidents, and noise that result from additional driving due to the fuel economy rebound effect. Line 9 represents the net change in maintenance costs (during the vehicle warranty period only) resulting from the implementation of certain fuel-economy-improving technologies that increase or decrease vehicle maintenance expenses. Line 10 represents the loss in social welfare associated with decreased operating life of fully electric vehicles due to battery degradation (note, NHTSA assumed that EVs reach end-of-life when batteries degrade to 55 percent of their original capacity[551]) and the possibility of replacement. Line 11 represents the aggregate social cost of lines 7 through 10.

Lines 12 and 13 of Tables VIII-30 and VIII-31 report the value of reductions in air pollution and climate-related externalities resulting from lower emissions during fuel production and consumption, while line 14 reports the savings in petroleum market externalities to the U.S. economy from reduced production of crude petroleum and refined fuel. Net social benefits (line 16) is thus the sum of the social costs summarized in line 11 and the benefits resulting from the externalities summarized in line 15.

Line 17 in both Table VIII-30 and Table VIII-31 shows manufacturers' technology outlays for meeting higher CAFE standards for passenger cars and light trucks, which represent the principal cost of requiring higher fuel economy. The net total benefits (line 18) resulting from the rule consist of the sum of private (line 6) and social (line 16) benefits, partially offset by the technology costs (line 17).

Tables VIII-30 and VIII-31 highlight several important features of this rule's economic impacts. First, comparing the rule's net private (line 6) and external (line 15) benefits makes it clear that a substantial majority of the benefits from requiring higher fuel economy are experienced by vehicle buyers, with only a small share distributed throughout the remainder of the U.S. economy. In turn, the vast majority of private benefits stem from fuel savings, which highlights the importance of the many assumptions the agency uses to estimate and value future fuel savings resulting from higher fuel economy, as well as of the assumption that the rule has no

[551] The assumption of EV end-of-life occurring at 55 percent battery capacity is based on NHTSA analysis of EV battery life data developed by the National Renewable Energy Laboratory (NREL).

adverse impacts on vehicle buyers. The aggregate external benefits are small compared to total technology costs.

As a consequence, the net economic benefits of the rule closely mirror the benefits to private vehicle buyers and the technology costs for achieving higher fuel economy, again highlighting the importance of correctly valuing fuel savings from the perspective of those who experience them and accounting for any other effects of the rule on the economic welfare of vehicle buyers.

Table VIII-30
Private, Social, and Total Benefits and Costs of MY 2017 – 2025 CAFE Standards
Passenger Cars and Light Trucks Combined
in Billions of 2010$
(3% Discount Rate)

Entry	Baseline Fleet	Model Year										
		2011-2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**15-Yr Total**
1) Value of Fuel Savings (at Retail Fuel Prices)	2010 2008	$24.5 - $18.8	$14.6 - $12.0	$20.8 - $22.4	$37.2 - $36.0	$47.3 - $50.5	$61.3 - $62.7	$67.9 - $71.8	$77.2 - $78.0	$87.7 - $88.0	$92.8 - $97.9	$531.2 - $538.1
2) Savings in Refueling Time	2010 2008	$0.8 - $0.7	$0.5 - $0.4	$0.6 - $0.7	$1.0 - $1.1	$1.3 - $1.6	$1.6 - $1.9	$1.8 - $2.2	$2.1 - $2.4	$2.4 - $2.7	$2.5 - $2.9	$14.6 - $16.6
3) Consumer Surplus in Additional Driving	2010 2008	$2.2 - $1.7	$1.3 - $1.0	$1.7 - $1.9	$3.1 - $3.0	$3.9 - $4.2	$5.1 - $5.1	$5.6 - $5.9	$6.5 - $6.4	$7.3 - $7.2	$7.8 - $8.0	$44.4 - $44.5
4) Total Private Benefits (=1+2+3)	2010 2008	$27.5 - $21.2	$16.3 - $13.4	$23.2 - $25.1	$41.3 - $40.1	$52.5 - $56.2	$68.0 - $69.8	$75.3 - $79.9	$85.8 - $86.8	$97.3 - $97.9	$103.0 - $108.8	$590.2 - $599.2
5) Reduction in Private Benefits	2010 2008	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0
6) Net Private Benefits (=4+5)	2010 2008	$27.5 - $21.2	$16.3 - $13.4	$23.2 - $25.1	$41.3 - $40.1	$52.5 - $56.2	$68.0 - $69.8	$75.3 - $79.9	$85.8 - $86.8	$97.3 - $97.9	$103.0 - $108.8	$590.2 - $599.2
7) Change in Fuel Tax Revenues	2010 2008	($2.5) - ($1.9)	($1.4) - ($1.2)	($2.0) - ($2.2)	($3.6) - ($3.5)	($4.5) - ($4.8)	($5.8) - ($5.9)	($6.4) - ($6.7)	($7.2) - ($7.2)	($8.1) - ($8.0)	($8.5) - ($8.9)	($50.2) - ($50.4)
8) Increased Costs of Congestion, etc.	2010 2008	($1.4) - ($1.0)	($0.8) - ($0.6)	($1.1) - ($1.2)	($2.0) - ($1.9)	($2.5) - ($2.6)	($3.2) - ($3.2)	($3.6) - ($3.7)	($4.1) - ($4.0)	($4.6) - ($4.5)	($4.8) - ($5.1)	($28.1) - ($27.8)
9) Increased Costs of Vehicle Maintenance	2010 2008	($0.0) - ($0.0)	($0.0) - ($0.1)	($0.0) - ($0.2)	($0.2) - ($0.5)	($0.2) - ($0.6)	($0.6) - ($0.5)	($0.7) - ($0.7)	($0.9) - ($0.8)	($1.2) - ($0.8)	($1.3) - ($0.8)	($5.2) - ($4.9)
10) Relative Value Loss (EVs)	2010 2008	$0.0 - $0.0	$0.0 - ($0.0)	$0.0 - ($0.0)	$0.0 - ($0.0)	$0.0 - ($0.0)	($0.0) - ($0.0)	($0.0) - ($0.1)	($0.0) - ($0.1)	($0.0) - ($0.1)	($0.0) - ($0.2)	($0.1) - ($0.6)
11) Increase in Costs (=7+8+9+10)	2010 2008	($3.9) - ($3.0)	($2.2) - ($1.9)	($3.2) - ($3.6)	($5.9) - ($5.9)	($7.3) - ($8.0)	($9.6) - ($9.7)	($10.7) - ($11.1)	($12.2) - ($12.0)	($13.9) - ($13.5)	($14.7) - ($15.0)	($83.5) - ($83.7)
12) Reduced Health Damages from Criteria Emissions	2010 2008	$0.7 - $0.6	$0.4 - $0.4	$0.6 - $0.6	$1.1 - $1.0	$1.3 - $1.4	$1.8 - $1.7	$1.9 - $1.9	$2.2 - $2.1	$2.4 - $2.2	$2.5 - $2.1	$14.9 - $14.0
13) Reduced Climate Damages from CO2 Emissions	2010 2008	$2.1 - $1.6	$1.3 - $1.0	$1.8 - $2.0	$3.3 - $3.2	$4.3 - $4.5	$5.6 - $5.7	$6.3 - $6.6	$7.2 - $7.3	$8.3 - $8.3	$8.9 - $9.2	$48.9 - $49.3

14) Reduced Petroleum Market Externalities	2010 2008	\$1.2 - \$0.9	\$0.7 - \$0.6	\$1.0 - \$1.1	\$1.8 - \$1.8	\$2.2 - \$2.4	\$2.9 - \$3.0	\$3.2 - \$3.4	\$3.6 - \$3.7	\$4.1 - \$4.2	\$4.3 - \$4.6	\$25.0 - \$25.8
15) Reduction in Externalities (=11+12+13)	2010 2008	\$4.0 - \$3.1	\$2.4 - \$2.0	\$3.4 - \$3.7	\$6.1 - \$6.0	\$7.8 - \$8.3	\$10.2 - \$10.4	\$11.4 - \$12.0	\$13.0 - \$13.0	\$14.7 - \$14.7	\$15.6 - \$16.0	\$88.9 - \$89.2
16) Net Social Benefits =(11+15)	2010 2008	\$0.1 - \$0.1	\$0.2 - \$0.1	\$0.2 - \$0.1	\$0.3 - \$0.1	\$0.6 - \$0.3	\$0.6 - \$0.7	\$0.7 - \$0.9	\$0.8 - \$1.0	\$0.8 - \$1.2	\$1.0 - \$1.0	\$5.3 - \$5.4
17) Technology Costs	2010 2008	(\$6.2) - (\$3.7)	(\$3.7) - (\$2.5)	(\$5.2) - (\$4.6)	(\$8.3) - (\$7.3)	(\$10.8) - (\$11.1)	(\$14.0) - (\$14.2)	(\$15.3) - (\$16.4)	(\$16.9) - (\$17.8)	(\$19.7) - (\$20.6)	(\$20.0) - (\$23.3)	(\$120.1) - (\$121.4)
18) Net Total Benefits (6+16+17)	2010 2008	\$21.5 - \$17.7	\$12.7 - \$11.0	\$18.2 - \$20.6	\$33.3 - \$32.8	\$42.3 - \$45.5	\$54.6 - \$56.3	\$60.8 - \$64.3	\$69.7 - \$70.1	\$78.5 - \$78.6	\$84.0 - \$86.5	\$475.5 - \$483.2

Table VIII-31
Private, Social, and Total Benefits and Costs of MY 2017 – 2025 CAFE Standards
Passenger Cars and Light Trucks Combined
in Billions of 2010$
(7% Discount Rate)

Entry	Baseline Fleet	Model Year										
		2011-2016	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**	**2024**	**2025**	**15-Yr Total**
1) Value of Fuel Savings (at Retail Fuel Prices)	2010 2008	$19.2 - $14.7	$11.4 - $9.4	$16.3 - $17.6	$29.1 - $28.1	$37.0 - $39.5	$47.9 - $49.0	$53.0 - $56.1	$60.3 - $60.9	$68.5 - $68.8	$72.5 - $76.4	$415.1 - $420.5
2) Savings in Refueling Time	2010 2008	$0.6 - $0.5	$0.4 - $0.3	$0.5 - $0.6	$0.8 - $0.9	$1.0 - $1.2	$1.3 - $1.5	$1.4 - $1.8	$1.6 - $1.9	$1.9 - $2.1	$1.9 - $2.3	$11.5 - $13.1
3) Consumer Surplus in Additional Driving	2010 2008	$1.7 - $1.4	$1.0 - $0.8	$1.4 - $1.5	$2.4 - $2.3	$3.1 - $3.3	$4.0 - $4.0	$4.4 - $4.6	$5.1 - $5.0	$5.7 - $5.6	$6.1 - $6.2	$34.7 - $34.8
4) Total Private Benefits (=1+2+3)	2010 2008	$21.5 - $16.6	$12.8 - $10.5	$18.2 - $19.6	$32.3 - $31.3	$41.1 - $44.0	$53.1 - $54.6	$58.9 - $62.4	$67.0 - $67.8	$76.0 - $76.5	$80.4 - $85.0	$461.3 - $468.4
5) Reduction in Private Benefits	2010 2008	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0	$0.0 - $0.0
6) Net Private Benefits (=4+5)	2010 2008	$21.5 - $16.6	$12.8 - $10.5	$18.2 - $19.6	$32.3 - $31.3	$41.1 - $44.0	$53.1 - $54.6	$58.9 - $62.4	$67.0 - $67.8	$76.0 - $76.5	$80.4 - $85.0	$461.3 - $468.4
7) Change in Fuel Tax Revenues	2010 2008	($2.0) - ($1.5)	($1.1) - ($0.9)	($1.6) - ($1.7)	($2.9) - ($2.8)	($3.6) - ($3.8)	($4.6) - ($4.7)	($5.1) - ($5.3)	($5.7) - ($5.7)	($6.4) - ($6.4)	($6.7) - ($7.1)	($39.7) - ($40.0)
8) Increased Costs of Congestion, etc.	2010 2008	($1.1) - ($0.8)	($0.6) - ($0.5)	($0.9) - ($0.9)	($1.6) - ($1.5)	($2.0) - ($2.0)	($2.5) - ($2.5)	($2.8) - ($2.9)	($3.2) - ($3.2)	($3.6) - ($3.6)	($3.8) - ($4.0)	($22.1) - ($21.9)
9) Increased Costs of Vehicle Maintenance	2010 2008	($0.0) - ($0.0)	($0.0) - ($0.1)	($0.0) - ($0.2)	($0.2) - ($0.4)	($0.2) - ($0.4)	($0.4) - ($0.4)	($0.5) - ($0.5)	($0.7) - ($0.6)	($0.9) - ($0.6)	($1.0) - ($0.6)	($3.9) - ($3.7)
10) Relative Value Loss (EVs)	2010 2008	$0.0 - $0.0	$0.0 - ($0.0)	$0.0 - ($0.0)	$0.0 - ($0.0)	$0.0 - ($0.0)	($0.0) - ($0.0)	($0.0) - ($0.0)	($0.0) - ($0.0)	($0.0) - ($0.0)	($0.0) - ($0.1)	($0.0) - ($0.2)
11) Increase in Costs (=7+8+9+10)	2010 2008	($3.1) - ($2.3)	($1.8) - ($1.5)	($2.5) - ($2.8)	($4.6) - ($4.6)	($5.7) - ($6.3)	($7.6) - ($7.7)	($8.4) - ($8.7)	($9.6) - ($9.5)	($10.9) - ($10.6)	($11.5) - ($11.7)	($65.8) - ($65.9)
12) Reduced Health Damages from Criteria Emissions	2010 2008	$0.6 - $0.5	$0.3 - $0.3	$0.5 - $0.5	$0.9 - $0.8	$1.1 - $1.1	$1.4 - $1.4	$1.5 - $1.5	$1.7 - $1.6	$1.9 - $1.8	$2.0 - $1.7	$11.9 - $11.2
13) Reduced Climate Damages from CO2 Emissions	2010 2008	$2.1 - $1.6	$1.3 - $1.0	$1.8 - $2.0	$3.3 - $3.2	$4.3 - $4.5	$5.6 - $5.7	$6.3 - $6.6	$7.2 - $7.3	$8.3 - $8.3	$8.9 - $9.2	$48.9 - $49.3

14) Reduced Petroleum Market Externalities	2010 2008	$1.0 - $0.7	$0.6 - $0.5	$0.8 - $0.9	$1.4 - $1.4	$1.8 - $1.9	$2.3 - $2.4	$2.5 - $2.7	$2.8 - $2.9	$3.2 - $3.3	$3.4 - $3.7	$19.7 - $20.4
15) Reduction in Externalities (=11+12+13)	2010 2008	$3.6 - $2.8	$2.2 - $1.8	$3.1 - $3.3	$5.6 - $5.4	$7.1 - $7.5	$9.3 - $9.4	$10.3 - $10.9	$11.8 - $11.8	$13.4 - $13.3	$14.2 - $14.6	$80.5 - $80.8
16) Net Social Benefits =(11+15)	2010 2008	$0.5 - $0.4	$0.4 - $0.3	$0.6 - $0.5	$0.9 - $0.7	$1.4 - $1.2	$1.7 - $1.8	$1.9 - $2.1	$2.2 - $2.4	$2.5 - $2.7	$2.7 - $2.8	$14.8 - $15.0
17) Technology Costs	2010 2008	($6.2) - ($3.7)	($3.7) - ($2.5)	($5.2) - ($4.6)	($8.3) - ($7.3)	($10.8) - ($11.1)	($14.0) - ($14.2)	($15.3) - ($16.4)	($16.9) - ($17.8)	($19.7) - ($20.6)	($20.0) - ($23.3)	($120.1) - ($121.4)
18) Net Total Benefits (6+16+17)	2010 2008	$15.9 - $13.4	$9.4 - $8.3	$13.5 - $15.5	$25.0 - $24.7	$31.6 - $34.2	$40.8 - $42.1	$45.5 - $48.1	$52.3 - $52.4	$58.8 - $58.7	$63.1 - $64.5	$356.0 - $361.9

As discussed in detail previously, it is possible that NHTSA has over or underestimated the value of fuel savings to buyers and subsequent owners of the cars and light trucks to which higher CAFE standards will apply. It is also possible that the agency has failed to identify and value reductions in consumer welfare that could result from buyers' responses to higher vehicle prices or changes in vehicle attributes that manufacturers make as part of their efforts to achieve higher fuel economy. To acknowledge these possibilities and examine their potential impact on the rule's benefits and costs, and in order to provide a sensitivity analysis, Tables VIII-32 and VIII-33 show the rule's cumulative economic impacts by model year for MY 2011-2025 passenger cars and light trucks under varying assumptions about the agency's potential misestimation of fuel savings and the value of potential changes in vehicle attributes such as performance, carrying capacity, or safety.

Tables VIII-32 and VIII-33 provide examples of effects of *both* potential overestimation of the value of fuel savings to vehicle buyers and the possible omission of welfare losses from changes in other vehicle attributes in the entry labeled "Reduction in Private Benefits" (line 5). Although the examples reported previously in Tables VIII-25 through VIII-29 illustrated sources of possible overestimation of fuel savings using specific alternatives to the agency's assumptions, NHTSA has been unable to determine exactly how buyers' time horizons or discount rates might differ from those assumed in its analysis. Nor has NHTSA analyzed how vehicle buyers' expectations about future fuel prices or differences between fuel economy ratings and actual on-road fuel economy might differ from those it employs to estimate the value of fuel savings. Finally, NHTSA has not attempted to project changes in vehicle attributes other than fuel economy, or to estimate the economic value of resulting losses in vehicle utility.

Instead Tables VIII-32 and VIII-33 illustrate, at 3 and 7 percent discount rates, respectively, the effect of these possibilities using different assumptions about the fraction of total private benefits to vehicle buyers that might be offset by some combination of these factors. It is important to note that these assumptions are used merely for the sake of analysis and illustration; there is no claim here that they have an empirical basis, or that they are founded in any existing estimates, theoretical or empirical, of actual offsets.[552] As Tables VIII-32 and VIII-33 show, if there is no offset to private benefits, the rule's total and net private and social benefits are exactly as shown in the last column of the corresponding table (Table VIII-24 or VIII-29) above. If, however, these factors combine to offset as much as 25% of the agency's estimate of total private benefits (line 5), the rule's net private (line 6) and net total (line 18) benefits remain substantially

[552] While some empirical evidence suggests that consumers are largely making rational decisions, other evidence suggests this is not the case. Since there is not agreement in the literature on this point, it is not possible to estimate the potential degree of consumer loss in welfare.

positive. If the private savings turn out to be 25% less than projected, the benefits of the rule continue to justify the costs by a large measure. If the offset is assumed to be as much as 50%, the net total benefits (line 18) would significantly decline, but would remain positive, and the benefits would continue to justify the costs by a large measure.

Table VIII-32
Effect of Overestimation of Fuel Savings or Omission of Welfare Losses on Net Private and Total Benefits of MY 2017-2025 CAFE Standards
Passenger Cars and Light Trucks Combined
in Billions of 2010$, (3% Discount Rate)

Entry	**Baseline Fleet**	**Fraction of Private Benefits Offset by Overestimation of Fuel Savings or Omission of Welfare Losses to Vehicle Buyers**		
		None	**25%**	**50%**
1) Value of Fuel Savings (at Retail Fuel Prices)	2010 2008	$531.2 - $538.1	$531.2 - $538.1	$531.2 - $538.1
2) Savings in Refueling Time	2010 2008	$14.6 - $16.6	$14.6 - $16.6	$14.6 - $16.6
3) Consumer Surplus in Additional Driving	2010 2008	$44.4 - $44.5	$44.4 - $44.5	$44.4 - $44.5
4) Total Private Benefits (=1+2+3)	2010 2008	$590.2 - $599.2	$590.2 - $599.2	$590.2 - $599.2
5) Reduction in Private Benefits	2010 2008	$0.0 - $0.0	$147.6 - $149.8	$295.1 - $299.6
6) Net Private Benefits (=4+5)	2010 2008	$590.2 - $599.2	$442.7 - $449.4	$295.1 - $299.6
7) Change in Fuel Tax Revenues	2010 2008	($50.2) - ($50.4)	($50.2) - ($50.4)	($50.2) - ($50.4)
8) Increased Costs of Congestion, etc.	2010 2008	($28.1) - ($27.8)	($28.1) - ($27.8)	($28.1) - ($27.8)
9) Increased Costs of Vehicle Maintenance	2010 2008	($5.2) - ($4.9)	($5.2) - ($4.9)	($5.2) - ($4.9)
10) Relative Value Loss (EVs)	2010 2008	($0.1) - ($0.6)	($0.1) - ($0.6)	($0.1) - ($0.6)
11) Increase in Costs (=7+8+9+10)	2010 2008	($83.5) - ($83.7)	($83.5) - ($83.7)	($83.5) - ($83.7)
12) Reduced Health Damages from Criteria Emissions	2010 2008	$14.9 - $14.0	$14.9 - $14.0	$14.9 - $14.0
13) Reduced Climate Damages from CO2 Emissions	2010 2008	$48.9 - $49.3	$48.9 - $49.3	$48.9 - $49.3
14) Reduced Petroleum Market Externalities	2010 2008	$25.0 - $25.8	$25.0 - $25.8	$25.0 - $25.8
15) Reduction in Externalities (=11+12+13)	2010 2008	$88.9 - $89.2	$88.9 - $89.2	$88.9 - $89.2
16) Net Social Benefits =(11+15)	2010 2008	$5.3 - $5.4	$5.3 - $5.4	$5.3 - $5.4
17) Technology Costs	2010 2008	($120.1) - ($121.4)	($120.1) - ($121.4)	($120.1) - ($121.4)
18) Net Total Benefits (6+16+17)	2010 2008	$475.5 - $483.2	$448.0 - $454.8	$300.4 - $305.0

Table VIII-33
Effect of Overestimation of Fuel Savings or Omission of Welfare Losses on Net Private and Total Benefits of MY 2017-2025 CAFE Standards
Passenger Cars and Light Trucks Combined
in Billions of 2010$, (3% Discount Rate)

Entry	Baseline Fleet	Fraction of Private Benefits Offset by Overestimation of Fuel Savings or Omission of Welfare Losses to Vehicle Buyers		
		None	**25%**	**50%**
1) Value of Fuel Savings (at Retail Fuel Prices)	2010 2008	$415.1 - $420.5	$415.1 - $420.5	$415.1 - $420.5
2) Savings in Refueling Time	2010 2008	$11.5 - $13.1	$11.5 - $13.1	$11.5 - $13.1
3) Consumer Surplus in Additional Driving	2010 2008	$34.7 - $34.8	$34.7 - $34.8	$34.7 - $34.8
4) Total Private Benefits (=1+2+3)	2010 2008	$461.3 - $468.4	$461.3 - $468.4	$461.3 - $468.4
5) Reduction in Private Benefits	2010 2008	$0.0 - $0.0	$115.3 - $117.1	$230.7 - $234.2
6) Net Private Benefits (=4+5)	2010 2008	$461.3 - $468.4	$346.0 - $351.3	$230.7 - $234.2
7) Change in Fuel Tax Revenues	2010 2008	($39.7) - ($40.0)	($39.7) - ($40.0)	($39.7) - ($40.0)
8) Increased Costs of Congestion, etc.	2010 2008	($22.1) - ($21.9)	($22.1) - ($21.9)	($22.1) - ($21.9)
9) Increased Costs of Vehicle Maintenance	2010 2008	($3.9) - ($3.7)	($3.9) - ($3.7)	($3.9) - ($3.7)
10) Relative Value Loss (EVs)	2010 2008	($0.0) - ($0.2)	($0.0) - ($0.2)	($0.0) - ($0.2)
11) Increase in Costs (=7+8+9+10)	2010 2008	($65.8) - ($65.9)	($65.8) - ($65.9)	($65.8) - ($65.9)
12) Reduced Health Damages from Criteria Emissions	2010 2008	$11.9 - $11.2	$11.9 - $11.2	$11.9 - $11.2
13) Reduced Climate Damages from CO2 Emissions	2010 2008	$48.9 - $49.3	$48.9 - $49.3	$48.9 - $49.3
14) Reduced Petroleum Market Externalities	2010 2008	$19.7 - $20.4	$19.7 - $20.4	$19.7 - $20.4
15) Reduction in Externalities (=11+12+13)	2010 2008	$80.5 - $80.8	$80.5 - $80.8	$80.5 - $80.8
16) Net Social Benefits =(11+15)	2010 2008	$14.8 - $15.0	$14.8 - $15.0	$14.8 - $15.0
17) Technology Costs	2010 2008	($120.1) - ($121.4)	($120.1) - ($121.4)	($120.1) - ($121.4)
18) Net Total Benefits (6+16+17)	2010 2008	$356.0 - $361.9	$360.7 - $366.3	$245.4 - $249.2

It is important to reemphasize that NHTSA views the estimates of this rule's economic impacts presented in Tables VIII-32 and VIII-33 as illustrative only. The agency has attempted to develop the most accurate estimates of the value of fuel savings that are possible. The design of the CAFE standards (*e.g.*, the footprint curves), the stringency of the standards, and the lead time provided to manufacturers for complying with the new standards have all been tailored to ensure that desirable vehicle attributes other than fuel economy will not be compromised. NHTSA has also attempted to ensure that its estimates of technology costs include adequate provisions to prevent the degradation of performance, safety, or other valuable attributes as consequences of manufacturers' efforts to comply with higher CAFE standards.

A major lesson is that the benefits of the rule justify the costs even on the assumption that the private savings are significantly offset (an assumption that the agency believes to be to be highly unlikely). Nevertheless, the agency believes that it is important to acknowledge a degree of uncertainty in its estimates of how buyers are likely to value fuel savings, as well as in its conclusion that no losses in the performance, utility, or safety of cars and light trucks subject to this rule will occur. One conclusion is that even if the private savings are significantly overstated, the benefits of this rule continue to exceed the costs. NHTSA is committed to developing improved methods for estimating the value of improvements in fuel economy, as well as the magnitude and economic consequences of accompanying changes in other vehicle attributes, as part of its future CAFE rulemaking activities.

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IX. IMPACT OF WEIGHT REDUCTION ON SAFETY

The primary goals of CAFE and GHG standards are to reduce fuel consumption and GHG emissions from the on-road light-duty vehicle fleet, but in addition to these intended effects, the agencies also consider the potential of the standards to affect vehicle safety.[553] As a safety agency, NHTSA has long considered the potential for adverse safety consequences when establishing CAFE standards, and under the CAA, EPA considers factors related to public health and human welfare, including safety, in regulating emissions of air pollutants from mobile sources. Safety trade-offs associated with fuel economy increases have occurred in the past, particularly before NHTSA CAFE standards were attribute- based, and the agencies must be mindful of the possibility of future ones. These past safety trade-offs may have occurred because manufacturers chose at the time, partly in response to CAFE standards, to build smaller and lighter vehicles, rather than adding more expensive fuel-saving technologies while maintaining vehicle size and safety, and the smaller and lighter vehicles did not fare as well in crashes as larger and heavier vehicles. Historically, as shown in FARS data analyzed by NHTSA, the safest cars generally have been heavy and large, while the cars with the highest fatal-crash rates have been light and small. The question, then, is whether past is necessarily prologue when it comes to potential changes in vehicle size (both footprint and "overhang") and mass in response to the more stringent future CAFE and GHG standards. Manufacturers have stated that they will reduce vehicle mass as one of the cost-effective means of increasing fuel economy and reducing CO_2 emissions in order to meet the standards, and the agencies have incorporated this expectation into our modeling analysis supporting the standards. Because the agencies discern a historical relationship between vehicle mass, size, and safety, it is reasonable to assume that these relationships will continue in the future. The agencies are encouraged by comments to the NPRM from the Alliance of Automotive Manufacturers reflecting a commitment to safety stating that, while improving the fuel efficiency of the vehicles, the vehicle manufacturers are "mindful that such improvements must be implemented in a manner that does not compromise the rate of safety improvement that has been achieved to date." The question of whether vehicle design can mitigate the adverse effects of mass reduction is discussed below.

On May 7, 2010, the National Highway Traffic Safety Administration (NHTSA) and the Environmental Protection Agency (EPA) published a joint final rule to establish Corporate Average Fuel Economy (CAFE) standards and greenhouse-gas (GHG) emission standards for passenger cars and light trucks manufactured in model years (MY) 2012-2016. The standards for MY 2012-2016 are "footprint-based," with footprint being defined as a measure of a vehicle's size, roughly equal to the wheelbase times the average of the front and rear track

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[553] In this rulemaking document, "vehicle safety" is defined as societal fatality rates per vehicle miles traveled (VMT), which include fatalities to occupants of all the vehicles involved in the collisions, plus any pedestrians.

widths. Manufacturers are less likely than they were in the past to reduce vehicle footprint in order to reduce mass for increased fuel economy. The primary mechanism in this rulemaking for mitigating the potential negative effects on safety is the application of footprint-based standards, which create a disincentive for manufacturers to produce smaller-footprint vehicles. This is because, as footprint decreases, the corresponding fuel economy/GHG emission target becomes more stringent. We also believe that the shape of the footprint curves themselves is approximately "footprint-neutral," that is, that it should neither encourage manufacturers to increase the footprint of their fleets, nor to decrease it. Several technologies, such as substitution of light, high-strength materials for conventional materials during vehicle redesigns, have the potential to reduce weight and conserve fuel while maintaining a vehicle's footprint and maintaining or possibly improving the vehicle's structural strength and handling.

On November 16, 2011, NHTSA and EPA published a joint Notice of Proposed Rulemaking (NPRM) to establish CAFE and GHG standards for passenger cars and light trucks manufactured in model years (MY) 2017-2025.[554] The proposed standards for MY 2017-2025 are again footprint-based.

In considering what technologies are available for improving fuel economy, including mass reduction, an important corollary issue for NHTSA to consider is the potential effect that those technologies may have on safety. NHTSA has thus far specifically considered the likely effect of mass reduction that maintains footprint on fatal crashes. The relationship between a vehicle's mass, size, and fatality risk is complex, and it varies in different types of crashes. NHTSA, along with others, has been examining this relationship for over a decade. The safety chapter of NHTSA's April 2010 final regulatory impact analysis (FRIA) of CAFE standards for MY 2012-2016 passenger cars and light trucks included a statistical analysis of relationships between fatality risk, mass, and footprint in MY 1991-1999 passenger cars and LTVs (light trucks and vans), based on calendar year (CY) 1995-2000 crash and vehicle-registration data.[555]

The principal findings of NHTSA's 2010 analysis were that mass reduction in lighter cars, even while holding footprint constant, would significantly increase societal fatality risk, whereas mass reduction in the heavier LTVs would significantly reduce net societal fatality risk, because it would reduce the fatality risk of occupants in lighter vehicles which collide with the heavier LTVs. NHTSA concluded that, as a result, any reasonable combination of mass reductions while holding footprint constant in MYs 2012-2016 vehicles – concentrated, at least to some extent, in

[554] 76 Fed. Reg. 74854 (December 1, 2011).

[555] Kahane, C. J. (2010). "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 1991-1999 and Other Passenger Cars and LTVs," *Final Regulatory Impact Analysis: Corporate Average Fuel Economy for MY 2012-MY 2016 Passenger Cars and Light Trucks*. Washington, DC: National Highway Traffic Safety Administration, pp. 464-542, available at http://www.nhtsa.gov/staticfiles/rulemaking/pdf/cafe/CAFE_2012-2016_FRIA_04012010.pdf (last accessed August 1, 2012)

the heavier LTVs and limited in the lighter cars – would likely be approximately safety-neutral; it would not significantly increase fatalities and might well decrease them.

NHTSA's 2010 report partially agreed and partially disagreed with analyses published during 2003-2005 by Dynamic Research, Inc. (DRI). NHTSA and DRI both found a significant protective effect for footprint, and that reducing mass and footprint together (downsizing) on smaller vehicles was harmful. DRI's analyses estimated a significant overall reduction in fatalities from mass reduction in all light-duty vehicles if wheelbase and track width were maintained, whereas NHTSA's report showed overall fatality reductions only in the heavier LTVs, and benefits only in some types of crashes for other vehicle types. Much of NHTSA's 2010 report, as well as recent work by DRI, involved sensitivity tests on the databases and models, which generated a range of estimates somewhere between the initial DRI and NHTSA results.[556]

In April 2010, NHTSA, working closely with EPA and the Department of Energy (DOE), commenced a new statistical analysis of the relationships between fatality rates, mass and footprint, updating the crash and exposure databases to the latest available model years, refining the methodology in response to peer reviews of the 2010 report and taking into account changes in vehicle technologies. The previous databases of MYs 1991-1999 vehicles in CYs 1995-2000 crashes had become outdated as new safety technologies, vehicle designs and materials were introduced. The new databases are comprised of MYs 2000-2007 vehicles in CY 2002-2008 crashes with the most up-to-date possible data, given the processing lead time for crash data and the need for enough crash cases to permit statistically meaningful analyses. NHTSA made the first version of the new databases available to the public in May 2011 and an updated version in April 2012,[557] enabling other researchers to analyze the same data and hopefully minimizing discrepancies in the results due to inconsistencies across the data used.[558]

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[556] Van Auken, R. M., and Zellner, J. W. (2003). *A Further Assessment of the Effects of Vehicle Weight and Size Parameters on Fatality Risk in Model Year 1985-98 Passenger Cars and 1986-97 Light Trucks*. Report No. DRI-TR-03-01. Torrance, CA: Dynamic Research, Inc.; Van Auken, R. M., and Zellner, J. W. (2005a). *An Assessment of the Effects of Vehicle Weight and Size on Fatality Risk in 1985 to 1998 Model Year Passenger Cars and 1985 to 1997 Model Year Light Trucks and Vans*. Paper No. 2005-01-1354. Warrendale, PA: Society of Automotive Engineers; Van Auken, R. M., and Zellner, J. W. (2005b). *Supplemental Results on the Independent Effects of Curb Weight, Wheelbase, and Track on Fatality Risk in 1985-1998 Model Year Passenger Cars and 1986-97 Model Year LTVs*. Report No. DRI-TR-05-01. Torrance, CA: Dynamic Research, Inc.; Van Auken, R.M., and Zellner, J. W. (2011).2012a). *Updated Analysis of the Effects of Passenger Vehicle Size and Weight on Safety, Phase I*. Report No. DRI-TR-11-01. (Docket No. NHTSA-2010-0152-0030). Torrance, CA: Dynamic Research, Inc.
[557] http://www.nhtsa.gov/fuel-economy
[558] 75 Fed. Reg. 25324 (May 7, 2010); the discussion of planned statistical analyses is on pp. 25395-25396.

One way to estimate these effects is via statistical analyses of societal fatality rates per vehicle miles traveled (VMT), by vehicles' mass and footprint, for the current on-road vehicle fleet. The basic analytical method used for the 2011-2012 NHTSA reports is the same as in NHTSA's 2010 report: cross-sectional analyses of the effect of mass and footprint reductions on the societal fatality rate per billion vehicle miles of travel (VMT), while controlling for driver age and gender, vehicle type, vehicle safety features, crash times and locations, and other factors. Separate logistic regression models are run for three types of vehicles and nine types of crashes. Societal fatality rates include occupants of all vehicles in the crash, as well as non-occupants, such as pedestrians and cyclists. NHTSA's 2011-2012 reports[559] analyze MYs 2000-2007 cars and LTVs in CYs 2002-2008 crashes. Fatality rates were derived from FARS data, 13 State crash files, and registration and mileage data from R.L. Polk.

The most noticeable change in MYs 2000-2007 vehicles from MYs 1991-1999 has been the increase in crossover utility vehicles (CUV), which are SUVs of unibody construction, sometimes built upon a platform shared with passenger cars. CUVs have blurred the distinction between cars and trucks. The new analysis treats CUVs and minivans as a separate vehicle class, because they differ in some respects from pickup-truck-based LTVs and in other respects from passenger cars. In the 2010 report, the many different types of LTVs were combined into a single analysis, and NHTSA believes that this may have made the analyses too complex and might have contributed to some of the uncertainty in the results.

The new database has more accurate VMT estimates than NHTSA's earlier databases, derived from a file of odometer readings by make, model, and model year recently developed by R.L. Polk and purchased by NHTSA.[560] For the 2011-2012 reports, the relative distribution of crash types has been changed to reflect the projected distribution of crashes during the period from 2017 to 2025, based on the estimated effectiveness of electronic stability control (ESC) in reducing the number of fatalities in rollover crashes and crashes with a stationary object. The annual target population of fatalities or the annual fatality distribution baseline[561] was not decreased in the period between 2017 and 2025 for the safety statistics analysis, but is taken into

[559] Kahane, C. J. (2011). "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs – Preliminary Report," is available in the NHTSA docket, NHTSA-2010-0152 as item no. 0023. Kahane, C. J. (2012). "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs – Final Report," DOT HS 811-665 is in NHTSA-2010-0131-0336 and will also be in docket NHTSA-2010-0152. You can access the docket at http://www.regulations.gov/ by typing 'NHTSA-2010-0152' where it says "enter keyword or ID" and then clicking on "search."

[560] In the 1991-1999 data base, VMT was estimated only by vehicle class, based on NASS CDS data.

[561] MY 2004 -2007 vehicles with fatal crashes occurred in CY 2004-2008 are selected as the annual fatality distribution baseline in the Kahane analysis.

account later in the Volpe model analysis, since all vehicles in the future will be equipped with ESC.[562]

For the 2011-2012 reports, vehicles are now grouped into five classes rather than four: passenger cars (including both 2-door and 4-door cars) are split in half by median weight; CUVs and minivans; and truck-based LTVs, which are also split in half by median weight of the model year 2000-2007 vehicles.

Table IX-153 presents the *2011 preliminary report's* estimated percent increase in U.S. societal fatality risk per ten billion VMT for each 100-pound reduction in vehicle mass, while holding footprint constant, for each of the five classes of vehicles.

Table IX-153
Results of 2011 NHTSA *Preliminary Report:* Fatality Increase (%) per 100-Pound Mass Reduction While Holding Footprint Constant

MY 2000-2007 CY 2002-2008	Fatality Increase (%) Per 100-Pound Mass Reduction While Holding Footprint Constant	
	Point Estimate	95% Confidence Bounds
Cars < 3,106 pounds	1.44	+ .29 to +2.59
Cars ≥ 3,106 pounds	.47	- .58 to +1.52
CUVs and minivans	- .46	-1.75 to + .83
Truck-based LTVs < 4,594 pounds	.52	- .43 to +1.46
Truck-based LTVs ≥ 4,594 pounds	- .39	-1.06 to + .27

Charles Farmer, Paul E. Green, and Anders Lie, who reviewed NHTSA's 2010 report, again peer-reviewed the 2011 preliminary report.[563] In preparing its 2012 final report, NHTSA also took into account Wenzel's[564] assessment of the preliminary report and its peer reviews, DRI's

[562] In the Volpe model, NHTSA assumed that the safety trend would result in 12.6 percent reduction between 2007 and 2020 due to the combination of ESC, new safety standard, and behavior changes anticipated.
[563] Items 0035 (Lie), 0036 (Farmer) and 0037 (Green) in Docket No. NHTSA-2010-0152.
[564] For the 2012 Wenzel reports see: "U.S. DOT/DOE - Final Report - An Analysis of the Relationship between Casualty Risk Per Crash and Vehicle Mass and Footprint for Model Year 2000-2007 Light Duty Vehicles", Docket

analyses published early in 2012, and public comments such as those by ICCT.[565] These comments prompted supplementary analyses, especially sensitivity tests, discussed below. However, the basic analysis of the 2012 final report is almost unchanged from the 2011 preliminary report, differing only in the addition of some crash data that became available in the interim and a minor change in the formula for estimating annual VMT. Table IX-154 presents the 2012 final report's estimated percent increase in U.S. societal fatality risk per ten billion VMT for each 100-pound reduction in vehicle mass, while holding footprint constant, for each of the five classes of vehicles.

Table IX-154
Results of 2012 NHTSA Final Report: Fatality Increase (%) per 100-Pound Mass Reduction While Holding Footprint Constant

MY 2000-2007 CY 2002-2008	Fatality Increase (%) Per 100-Pound Mass Reduction While Holding Footprint Constant	
	Point Estimate	95% Confidence Bounds
Cars < 3,106 pounds	1.56	+ .39 to +2.73
Cars ≥ 3,106 pounds	.51	- .59 to +1.60
CUVs and minivans	- .37	-1.55 to + .81
Truck-based LTVs < 4,594 pounds	.52	- .45 to +1.48
Truck-based LTVs ≥ 4,594 pounds	- .34	- .97 to + .30

Only the 1.56 percent risk increase in the lighter cars is statistically significant. There are nonsignificant increases in the heavier cars and the lighter truck-based LTVs, and nonsignificant societal benefits for mass reduction in CUVs, minivans, and the heavier truck-based LTVs. The report concludes that judicious combinations of mass reductions that maintain footprint and are proportionately higher in the heavier vehicles are likely to be safety-neutral – i.e., they are unlikely to have a societal effect large enough to be detected by statistical analyses of crash data. The primarily non-significant results are not due to a paucity of data, but because the societal effect of mass reduction while maintaining footprint, if any, is small.

NHTSA-0131-0315; "Lawrence Berkeley National Laboratory -Assessment of NHTSA Report Relationships Btw Fatality Risk Mass and Footprint in MY 2000-2007 PC and LTV", Docket NHTSA-2010-0131-0315; and a peer review of Wenzel's reports – "Final Report of Peer Review of LBNL Reports", Docket NHTSA-2010-0131-0328.
[565] Item 0258 in Docket No. NHTSA-2010-0131.

MY 2000-2007 vehicles of all types are heavier and larger than their MY 1991-1999 counterparts. The average mass of passenger cars increased by 5 percent from 2000 to 2007 and the average mass of pickup trucks increased by 19 percent. Other types of vehicles became heavier, on the average, by amounts within this range. There are several reasons for these increases: during this time, some of the lighter make-models were discontinued; many models were redesigned to be heavier and larger; and consumers more often selected stretched versions such as crew cabs in their new-vehicle purchases.

It is interesting to compare the new results to NHTSA's 2010 analysis of MY 1991-1999 vehicles in CY 1995-2000, especially the new point estimate to the "actual regression result scenario" in the 2010 report:

Table IX-155
2010 Report: MY 1991-1999, CY 1995-2000 Fatality Increase (%) per 100-Pound Mass Reduction While Holding Footprint Constant

	Actual Regression Result Scenario	Upper-Estimate Scenario	Lower-Estimate Scenario
Cars < 2,950 pounds	2.21	2.21	1.02
Cars ≥ 2,950 pounds	0.90	0.90	0.44
LTVs < 3,870 pounds	0.17	0.55	0.41
LTVs ≥ 3,870 pounds	-1.90	-0.62	-0.73

Table IX-156
Fatality Increase (%) per 100-Pound Mass Reduction While Holding Footprint Constant

	NHTSA (2010)	NHTSA (2012)
Lighter cars	2.21%	1.56%
Heavier cars	0.90%	0.51%
Lighter LTVs	0.17%*	0.52%
Heavier LTVs	-1.90%*	-0.34%
CUV/ minivan		-0.37%

*Includes CUV/minivan

The new results are directionally similar to the 2010 results: fatality increase in the lighter cars, safety benefit in the heavier LTVs. But the effects may have become weaker at both ends. (NHTSA does not consider this conclusion to be definitive because of the relatively wide confidence bounds of the estimates.) The fatality increase in the lighter cars tapered off from 2.21 percent to 1.56 percent while the societal fatality-reduction benefit of mass reduction in the heaviest LTVs diminished from 1.90 percent to 0.34 percent and is no longer statistically significant.

The agencies believe that the changes may be due to a combination of the characteristics of newer vehicles and revisions to the analysis. NHTSA believes, above all, that several light, small car models with poor safety performance were discontinued by 2000 or during MYs 2000-2007. Also, the tendency of light, small vehicles to be driven in a manner that results in high crash rates is not as strong as it used to be.[566] Both agencies believe that at the other end of the weight/size spectrum, blocker beams and other voluntary compatibility improvements in LTVs, as well as compatibility-related self-protection improvements to cars, have made the heavier LTVs less aggressive in collisions with lighter vehicles (although the effect of mass disparity remains). This report's analysis of CUVs and minivans as a separate class of vehicles may have relieved some inaccuracies in the 2010 regression results for LTVs. Interestingly, the new actual-regression results are quite close to the previous report's "lower-estimate scenario," which was an attempt to adjust for supposed inaccuracies in some regressions and for a seemingly excessive trend toward higher crash rates in smaller and lighter cars.

The principal difference between the heavier vehicles, especially truck-based LTVs, and the lighter vehicles, especially passenger cars, is that mass reduction has a different effect in collisions with another car or LTV. When two vehicles of unequal mass collide, the delta V is higher in the lighter vehicle, in the same proportion as the mass ratio. As a result, the fatality risk is also higher. Removing some mass from the heavy vehicle reduces delta V in the lighter vehicle, where fatality risk is higher, resulting in a large benefit, offset by a small penalty because delta V increases in the heavy vehicle, where fatality risk is low – adding up to a net societal benefit. Removing some mass from the lighter vehicle results in a large penalty offset by a small benefit – adding up to net harm. These considerations drive the overall result: fatality increase in the lighter cars, reduction in the heavier LTVs, and little effect in the intermediate groups. However, in some types of crashes, especially first-event rollovers and impacts with fixed objects, mass reduction is usually not harmful and often beneficial, because the lighter vehicles respond more quickly to braking and steering. Offsetting that benefit is the continuing historical tendency of lighter and smaller vehicles to be driven less well – although it continues to be unknown why that is so, and to what extent, if any, the lightness or smallness of the vehicle contributes to people driving it less safely.

[566] Kahane (2012), pp. 30-36.

The estimates in Table IX-2 of the model are formulated for each 100-pound reduction in mass; in other words, if risk increases by 1 percent for 100 pounds reduction in mass, it would increase by 2 percent for a 200-pound reduction, and 3 percent for a 300-pound reduction (more exactly, 2.01 percent and 3.03 percent, because the effects work like compound interest). Confidence bounds around the point estimates will grow wider by the same proportions.

The regression results are best suited to predict the effect of a small change in mass, leaving all other factors, including footprint, the same. With each additional change from the current environment, the model may become somewhat less accurate and it is difficult to assess the sensitivity to additional mass reduction greater than 100 pounds. The agencies recognize that the light-duty vehicle fleet in the MYs 2017-2025 timeframe will be different from the MYs 2000-2007 fleet analyzed for this study. Nevertheless, one consideration provides some basis for confidence in applying the regression results to estimate the effects of mass reductions larger than 100 pounds or over longer time periods. This is NHTSA's fourth evaluation of the effects of mass reduction and/or downsizing, comprising databases ranging from MYs 1985 to 2007. The results of the four studies are not identical, but they have been consistent up to a point. During this time period, many makes and models have increased substantially in mass, sometimes as much as 30-40 percent.[567] If the statistical analysis has, over the past years, been able to accommodate mass increases of this magnitude, perhaps it will also succeed in modeling the effects of mass reductions on the order of 10-20 percent, if they occur in the future.

Revisions to the 2012 analysis: The basic analysis method is unchanged from the 2011 preliminary report and is basically the same as in NHTSA's 2010 report: cross-sectional analyses of the societal fatality rate per billion vehicle miles of travel (VMT) by mass and footprint, while controlling for driver age, gender, and other factors, in separate logistic regressions by vehicle class and crash type. "Societal" fatality rates include fatalities to occupants of all the vehicles involved in the collisions, plus any pedestrians. The data is now MY 2000-2007 vehicles in CY 2002-2008, updated from the previous database of MY 1991-1999 vehicles in CY 1995-2000. The new data has accurate VMT estimates, derived in part from a file of odometer readings by make, model, and model year recently developed by R.L. Polk and purchased by NHTSA.[568] The vehicles are now grouped into three classes rather than two, for the reasons discussed above: passenger cars (including both 2-door and 4-door cars); CUVs and minivans; and truck-based LTVs.

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[567] For example, one of the most popular models of small 4-door sedans increased in curb weight from 1,939 pounds in MY 1985 to 2,766 pounds in MY 2007, a 43 percent increase. A high-sales mid-size sedan grew from 2,385 to 3,354 pounds (41%); a best-selling pickup truck from 3,390 to 4,742 pounds (40%) in the basic model with 2-door cab and rear-wheel drive; and a popular minivan from 2,940 to 3,862 pounds (31%).

[568] In the 1991-1999 database, VMT was estimated only by vehicle class, based on NASS CDS data.

There are also nine types of crashes rather than the six in the 2010 report; specifically, "collision with car" and "collision with LTV" in the previous analysis have been replaced by four types of crashes: collision with car, CUV, or minivan < 3,082 pounds; collision with car, CUV, or minivan ≥ 3,082 pounds; collision with truck-based LTV < 4,150 pounds; and collision with truck-based LTV ≥ 4,150 pounds. Splitting the "other" vehicles into a lighter and a heavier group permits more accurate analyses of the mass effect in collisions of two light vehicles. Grouping partner-vehicle CUVs and minivans with cars rather than LTVs is more appropriate because their front-end profile and rigidity more closely resembles a car than a typical truck-based LTV.

The curb weight of passenger cars is formulated, as in the 2010 report, as a two-piece linear variable in order to estimate one effect of mass reduction in the lighter cars and another effect in the heavier cars. The boundary between "lighter" and "heavier" cars is 3,106 pounds (which is the median mass of MY 2000-2007 cars in fatal crashes, up from 2,950 in 1991-1999). Likewise, for truck-based LTVs, curb weight is a two-piece linear variable with the boundary at 4,594 pounds (again, the 2000-2007 median, much higher than the median of 3,870 in 1991-1999). Curb weight is formulated as a simple linear variable for CUVs and minivans: because CUVs and minivans account for a much smaller share of new-vehicle sales, there is much less crash data available than for cars or truck-based LTVs.

For a given vehicle class and weight range (if applicable), the regression coefficients for mass (while holding footprint constant) in the nine types of crashes are averaged, weighted by the number of baseline fatalities that would have occurred for the subgroup MY 2004-2007 vehicles in CY 2004-2008 if these vehicles had all been equipped with ESC. The adjustment for ESC, a new feature of the analysis, takes into account that the results will be used to analyze effects of mass reduction in future vehicles, which will all be ESC-equipped, as required by NHTSA's regulations. A similar adjustment to the baseline fatalities probably should have been applied in the 2010 report, but was not.

Techniques have been added to test significance and to estimate 95% confidence bounds (sampling error) for each mass effect and to estimate the combined annual effect of removing 100 pounds of mass from every vehicle (or of removing different amounts of mass from the various classes of vehicles), while holding footprint constant.

NHTSA considered the near multicollinearity of mass and footprint to be a major issue in the 2010 report and voiced concern about inaccurately estimated regression coefficients.[569] The high correlations between mass and footprint and variance inflation factors (VIF) have not changed

[569] Van Auken and Green also discussed the issue in their presentations at the NHTSA Workshop on Vehicle Mass-Size-Safety in Washington, DC on February 25, 2011, http://www.nhtsa.gov/Laws+&+Regulations/CAFE+-+Fuel+Economy/NHTSA+Workshop+on+Vehicle+Mass-Size-Safety (last accessed August 1, 2012)

from MY 1991-1999 to MY 2000-2007; large vehicles continued to be, on the average, heavier than small vehicles to the same extent as in the previous decade.[570] Nevertheless, multicollinearity appears to be less of a problem in the analysis this time. The "decile" analysis comparing fatality rates of vehicles of different mass but nearly identical footprint (modified in response to peer-review comments to control for factors such as driver age and gender) largely corroborates the main regression results. Whereas perhaps 4 of the 27 basic regressions still display possible symptoms of near multicollinearity, namely exceptionally strong coefficients in opposite directions for mass and footprint, the positive coefficient goes twice to mass, twice to footprint: in short, there appears to be no systematic bias. Separating the CUVs and minivans from the other LTVs may also have helped to stabilize the results. NHTSA has no other explanation of why multicollinearity became less of a problem, except this: when there are only a few (2-4) regressions in each report that seem to display symptoms of multicollinearity, it could readily happen by chance that all of them give the positive coefficient to the same variable in one report (curb weight in 2010) but split close to 50-50 this time.

Another issue noted in the 2010 report was the historical trend of lighter and smaller vehicles to be less well driven – as evidenced, for example, in the higher odds of culpability for their drivers, even after controlling for the driver's age and gender and the vehicle's safety technologies. The trend contributes to the higher fatality risk of the lighter and smaller vehicles in statistical analyses. It is unknown if a vehicle's lightness or smallness in any way contributes to how people drive it or if the trend merely reflects that better drivers, on the average, prefer larger vehicles. The trend is still there in the new data, but it appears to have diffused. In the earlier database, the trend was attributed primarily to mass, not footprint. Now it is about equally attributed to mass and footprint.

In the 2010 report, largely because of those two issues – multicollinearity and the trend of lighter/smaller vehicles to be less well driven – NHTSA supplemented the actual regression results with alternative "upper-estimate" and "lower-estimate" scenarios that set aside some of the individual regression coefficients and replaced them with a range of estimates derived from other sources. Because these issues no longer seem critical, this report presents only a single set of estimates based on the actual regression results and it does not include such alternative scenarios.

Calculation of MY 2017-2025 safety impact

[570] Greene, W. H. (1993). *Econometric Analysis*, Second Edition. New York: Macmillan Publishing Company, pp. 266-268; Allison, P.D. (1999), *Logistic Regression Using the SAS System*. Cary, NC: SAS Institute Inc., pp. 48-51. VIF scores are in the 6-9 range for curb weight and footprint in NHTSA's new database – i.e., in the somewhat unfavorable 2.5-10 range where near multicollinearity begins to become a concern in logistic regression analyses.

Neither the CAFE standards nor our analysis mandates mass reduction, or mandates that mass reduction occur in any specific manner. However, mass reduction is one of the technology applications available to the manufacturers and a degree of mass reduction is used by the Volpe model to determine the capabilities of manufacturers and to predict both cost and fuel consumption impacts of improved CAFE standards.

The agency utilized the relationships between weight and safety from Kahane (2012), expressed as percentage increases in fatalities per 100-pound weight reduction, and examined the weight impacts assumed in this CAFE analysis. However, there are several identifiable safety trends already in place or expected to occur in the foreseeable future that are not accounted for in the study. For example, there are two important new safety standards that have already been issued and will be phasing in after MY 2008. Federal Motor Vehicle Safety Standard No. 126 (49 CFR § 571.126) will require electronic stability control in all new vehicles by MY 2012, and the upgrade to Federal Motor Vehicle Safety Standard No. 214 (Side Impact Protection, 49 CFR § 571.214) will likely result in all new vehicles being equipped with head-curtain air bags by MY 2014. Additionally, we anticipate continued improvements in driver (and passenger) behavior, such as higher safety belt use rates. All of these will tend to reduce the absolute number of fatalities. The agency estimated the overall change in calculated fatalities by calendar year after adjusting for ESC, Side Impact Protection, and other Federal safety standards and behavioral changes projected through this time period. Thus, while the percentage increases in Kahane (2012) were applied, the reduced base has resulted in smaller absolute increases than those that were predicted in the 2003 report.

The agency examined the impacts of identifiable safety trends over the lifetime of the vehicles produced in each model year. An estimate of these impacts was contained in a previous agency report.[571] The impacts were estimated on a year-by-year basis, but could be examined in a combined fashion. The agency assumed that the safety trends will result in a reduction in the target population of fatalities from which the weight impacts are derived. Using this method, we found a 9.6 percent reduction in fatality levels between 2010 and 2020 for the combination of safety standards and behavioral changes anticipated (ESC, head-curtain air bags, and increase belt use). Since the same safety standards are taking effect in the same years, the estimates derived from applying Kahane's percentages to a baseline of 2010 fatalities were thus multiplied

[571] Blincoe, L. and Shankar, U, "The Impact of Safety Standards and Behavioral Trends on Motor Vehicle Fatality Rates," DOT HS 810 777, January 2007. See Table 4 comparing 2020 to 2007 (37,906/43,363 = 12.6% reduction (1-.126 = .874). We have updated that analysis to compare predicted 2020 fatalities to 2010 fatalities and find a 9.6% reduction for 2020 compared to 2010. We are assuming that using the 2020 number will give us an average from MY 2017-2025.

by 0.904 to account for changes that the agency believes will take place in passenger car and light truck safety between the 2010 baseline on-road fleet used for this particular safety analysis and 2020, which we assume represents the average year between 2017 and 2025.

In the CAFE model, a maximum amount of weight reduction was allowed for each subclass of vehicles to achieve a safety neutral result. No weight reduction was allowed for subcompact and compact passenger cars, up to 3.5% weight reduction was allowed for mid-size cars, up to 10% for large cars, and up to 20% for minivans, SUVs, and pickup trucks. This is one method the manufacturers could use to comply with the fuel economy standards and not increase societal fatalities.

After applying these percentage increases to the estimated weight reductions per vehicle size by model year assumed in the Volpe model, Table IX-5 shows the results of NHTSA's safety analysis separately for each model year[572] based on the MY 2010 and MY 2008 baseline fleet. Presented are the undiscounted fatality impact, however, the dollar impacts are discounted by either the 3 percent or 7 percent discount rate. These are estimated increases or decreases in fatalities over the lifetime of the model year fleet. A positive number means that fatalities are projected to increase, a negative number ( ) means that fatalities are projected to decrease. The results are significantly affected by the assumptions put into the Volpe model to take more weight out of the heavy LTVs than out of other vehicles. Since the negative coefficients only appear for LTVs greater than 4,594 lbs., an improvement in safety can only occur if more weight is taken out of heavy light trucks than passenger cars or smaller light trucks.

Combining passenger car and light truck estimates for the Preferred Alternative results in a decrease in fatalities over the cumulative lifetime of the nine model years of MY 2017-2025 of 8 to 107 fatalities, broken up into an increase of 135 to 78 fatalities in passenger cars and a decrease of 143 to 185 fatalities in light trucks. The effects on fatalities range from a combined decrease of 300 fatalities for the 5% alternative to a combined effect of saving 58 fatalities for the 2% alternative. The difference in the results by alternative depends upon how much weight reduction is used in that alternative and the types and sizes of vehicles that the weight reduction applies to.

Additionally, the societal impacts of increasing fatalities can be monetized using NHTSA's estimated comprehensive cost per life of $6,348,253 in 2010 dollars. This consists of a value of a statistical life of $6.0 million in 2010 dollars plus external economic costs associated with fatalities such as medical care, insurance administration costs and legal costs and updated for

[572] NHTSA has changed the definitions of a passenger car and light truck for fuel economy purposes between the time of the Kahane 2003 analysis and this final rule. About 1.4 million 2 wheel drive SUVs have been redefined as passenger cars instead of light trucks. The Kahane 2012 analysis continues with the definitions used in the Kahane 2003 analysis. Thus, there are different definitions between Tables IX-1, IX-2, and IX-3 (which use the old definitions) and Tables IX-4 and beyond (which use the new definitions).

inflation to 2010 dollars.[573] Typically, NHTSA would also estimate the impact on injuries and add that to the societal costs of fatalities, but in this case NHTSA does not have a model estimating the impact of weight on injuries. However, based on past studies, fatalities account for roughly 44 percent of total comprehensive costs due to injury.[574] If weight impacts non-fatal injuries roughly proportional to its impact on fatalities, then total costs would be roughly 2.27 times the value of fatalities alone, or around $14.41 million per fatality. The potential societal costs for fatalities and injuries combined are also shown in Table IX-5 and Table IX-6, and are discounted by the appropriate discount rate for passenger cars separately from light trucks. We assume that any impact on fatalities will occur over the lifetime of the vehicle and the chance of it occurring in any particular year is directly related to the weighted vehicle miles traveled in that year. Since light trucks are driven longer and survive longer than passenger cars, they have a different discount rate applied to their lifetime monetized benefits to bring their monetized value back to a present value. The multipliers[575] to bring monetized lifetime benefits back to present value are:

	Passenger Cars	Light Trucks
3% Discount rate	0.8024	0.7872
7% Discount rate	0.6268	0.6083

Decreases in societal costs over the lifetime of the nine model years are $64 to 1,203 million for the Preferred Alternative discounted at 3 percent and $36 to $922 million discounted at 7percent. The estimates by alternative range from a decrease of $3,399 million for the 5% alternative at a 3 percent discount rate to an increase of $690 million for the 2% alternative at a 3 percent discount rate.

[573] Blincoe et al, The Economic Impact of Motor Vehicle Crashes 2000, May 2002. Data from this report were updated for inflation and combined with the current DOT guidance on value of a statistical life to estimate the comprehensive value of a statistical life. Available at http://www-nrd.nhtsa.dot.gov/Pubs/809446.PDF (last accessed August 1, 2012) or Docket No. NHTSA-2010-0131

[574] Based on data in Blincoe et al updated for inflation and reflecting the Department's current VSL of $6.0 million in 2009 dollars.

[575] Thus, for example taking the undiscounted fatalities * $6,348,253 * 2.27 *0.8024 = the present discounted value of monetized safety impacts. If one wanted to discount the fatalities, multiply fatalities * the present discount multiplier.

Table IX-5a
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
Preferred Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 2	7 - 5	13 - 13	12 - 12	18 - 13	19 - 10	23 - 11	22 - 9	19 - 1	135 - 78
Light Trucks	2010 2008	(5) - (5)	(9) - (13)	0 - (17)	(5) - (29)	(18) - (27)	(21) - (27)	(24) - (27)	(30) - (29)	(31) - (11)	(143) - (185)
Total	2010 2008	(2) - (3)	(3) - (8)	13 - (3)	7 - (17)	(1) - (14)	(2) - (17)	(2) - (16)	(8) - (20)	(12) - (10)	(8) - (107)
Millions of Dollars											
Passenger Cars	2010 2008	$33 - $26	$79 - $62	$148 - $155	$140 - $144	$207 - $149	$222 - $115	$262 - $128	$251 - $105	$224 - $14	$1,566 - $899
Light Trucks	2010 2008	($53) - ($58)	($107) - ($152)	$3 - ($190)	($53) - ($330)	($209) - ($303)	($236) - ($310)	($276) - ($304)	($341) - ($332)	($357) - ($124)	($1,630) - ($2,102)
Total	2010 2008	($20) - ($31)	($28) - ($90)	$151 - ($35)	$87 - ($186)	($3) - ($154)	($15) - ($195)	($14) - ($176)	($89) - ($227)	($133) - ($109)	($64) - ($1,203)

Table IX-5b
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
1% Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	0 - 1	5 - 3	4 - 5	4 - 4	8 - 6	7 - 4	12 - 4	11 - 4	11 - 5	61 - 35
Light Trucks	2010 2008	(3) - (5)	(3) - (5)	(6) - (7)	(6) - (9)	(4) - (10)	(2) - (12)	(3) - (12)	(4) - (13)	(5) - (12)	(36) - (85)
Total	2010 2008	(3) - (3)	2 - (3)	(2) - (2)	(2) - (5)	3 - (4)	4 - (8)	9 - (9)	7 - (9)	6 - (7)	25 - (50)
Millions of Dollars											
Passenger Cars	2010 2008	$1 - $16	$54 - $31	$41 - $61	$50 - $44	$88 - $67	$77 - $44	$141 - $45	$129 - $47	$125 - $53	$705 - $409
Light Trucks	2010 2008	($32) - ($52)	($33) - ($60)	($64) - ($81)	($67) - ($103)	($47) - ($114)	($27) - ($131)	($39) - ($142)	($46) - ($153)	($53) - ($133)	($409) - ($969)
Total	2010 2008	($31) - ($36)	$20 - ($29)	($22) - ($20)	($18) - ($59)	$41 - ($47)	$50 - ($86)	$102 - ($97)	$83 - ($106)	$71 - ($80)	$297 - ($560)

Table IX-5c
Comparison of the Calculated Weight Safety-Related Fatality Impacts
over the Lifetime of the Vehicles Produced in each Model Year
2% Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	2 - 2	5 - 3	12 - 10	10 - 10	15 - 10	16 - 10	22 - 16	20 - 17	18 - 15	119 - 94
Light Trucks	2010 2008	(5) - (6)	(8) - (13)	1 - (20)	(2) - (29)	(4) - (31)	(5) - (32)	(8) - (34)	(13) - (37)	(16) - (38)	(61) - (240)
Total	2010 2008	(3) - (3)	(3) - (10)	12 - (10)	9 - (19)	11 - (21)	11 - (22)	14 - (18)	7 - (20)	1 - (23)	58 - (146)
Millions of Dollars											
Passenger Cars	2010 2008	$23 - $25	$63 - $39	$134 - $118	$117 - $115	$175 - $120	$182 - $121	$252 - $182	$228 - $196	$203 - $178	$1,377 - $1,094
Light Trucks	2010 2008	($52) - ($63)	($96) - ($153)	$9 - ($226)	($18) - ($327)	($50) - ($351)	($58) - ($369)	($94) - ($387)	($146) - ($423)	($183) - ($431)	($688) - ($2,729)
Total	2010 2008	($29) - ($38)	($33) - ($114)	$143 - ($107)	$99 - ($212)	$125 - ($231)	$123 - ($249)	$159 - ($205)	$82 - ($227)	$20 - ($253)	$690 - ($1,636)

Table IX-5d
Comparison of the Calculated Weight Safety-Related Fatality Impacts
over the Lifetime of the Vehicles Produced in each Model Year
3% Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 3	8 - 6	15 - 13	14 - 12	18 - 12	19 - 10	20 - 12	19 - 13	14 - 6	130 - 87
Light Trucks	2010 2008	(5) - (5)	(11) - (14)	(15) - (16)	(31) - (30)	(37) - (30)	(40) - (34)	(43) - (36)	(44) - (39)	(52) - (45)	(276) - (250)
Total	2010 2008	(2) - (3)	(3) - (8)	0 - (4)	(17) - (18)	(19) - (18)	(21) - (25)	(23) - (23)	(25) - (25)	(38) - (39)	(147) - (162)
Millions of Dollars											
Passenger Cars	2010 2008	$35 - $31	$91 - $68	$176 - $147	$162 - $141	$211 - $144	$216 - $113	$228 - $144	$218 - $153	$162 - $71	$1,500 - $1,012
Light Trucks	2010 2008	($53) - ($61)	($120) - ($156)	($169) - ($186)	($356) - ($342)	($418) - ($343)	($451) - ($390)	($485) - ($407)	($496) - ($437)	($589) - ($513)	($3,138) - ($2,836)
Total	2010 2008	($18) - ($31)	($29) - ($88)	$7 - ($39)	($193) - ($202)	($207) - ($198)	($235) - ($278)	($257) - ($263)	($278) - ($284)	($427) - ($441)	($1,638) - ($1,824)

Table IX-5e
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
4% Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 3	7 - 6	11 - 13	7 - 11	12 - 10	13 - 8	16 - 11	15 - 4	8 - (2)	93 - 64
Light Trucks	2010 2008	(6) - (2)	(12) - (12)	(15) - (21)	(36) - (37)	(44) - (31)	(49) - (36)	(43) - (37)	(47) - (41)	(55) - (50)	(307) - (269)
Total	2010 2008	(3) - 1	(6) - (6)	(4) - (8)	(28) - (26)	(31) - (21)	(36) - (29)	(26) - (26)	(31) - (37)	(47) - (52)	(214) - (205)
Millions of Dollars											
Passenger Cars	2010 2008	$36 - $37	$75 - $70	$127 - $152	$85 - $124	$141 - $120	$146 - $87	$191 - $126	$177 - $45	$94 - ($23)	$1,071 - $738
Light Trucks	2010 2008	($69) - ($27)	($140) - ($139)	($173) - ($242)	($406) - ($421)	($495) - ($356)	($556) - ($411)	($486) - ($423)	($529) - ($466)	($630) - ($568)	($3,483) - ($3,054)
Total	2010 2008	($33) - $9	($64) - ($70)	($46) - ($89)	($321) - ($297)	($355) - ($236)	($410) - ($323)	($295) - ($297)	($352) - ($421)	($536) - ($591)	($2,412) - ($2,315)

Table IX-5f
Comparison of the Calculated Weight Safety-Related Fatality Impacts
over the Lifetime of the Vehicles Produced in each Model Year
5% Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 3	8 - 6	15 - 9	11 - 1	18 - 1	18 - (0)	21 - 3	15 - 1	9 - 1	117 - 24
Light Trucks	2010 2008	(6) - (1)	(14) - (11)	(16) - (17)	(42) - (43)	(51) - (44)	(53) - (49)	(39) - (48)	(46) - (54)	(46) - (56)	(312) - (323)
Total	2010 2008	(3) - 2	(6) - (5)	(1) - (8)	(31) - (42)	(33) - (44)	(34) - (49)	(18) - (45)	(31) - (54)	(38) - (56)	(195) - (300)
Millions of Dollars											
Passenger Cars	2010 2008	$33 - $35	$90 - $66	$174 - $109	$125 - $10	$203 - $7	$212 - ($0)	$239 - $36	$176 - $6	$99 - $6	$1,352 - $274
Light Trucks	2010 2008	($71) - ($7)	($158) - ($127)	($182) - ($193)	($472) - ($488)	($574) - ($504)	($597) - ($555)	($438) - ($546)	($520) - ($616)	($528) - ($638)	($3,540) - ($3,673)
Total	2010 2008	($37) - $28	($68) - ($61)	($8) - ($84)	($347) - ($478)	($371) - ($497)	($385) - ($555)	($199) - ($510)	($344) - ($610)	($429) - ($632)	($2,189) - ($3,399)

Table IX-5g
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
6% Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	4 - 3	8 - 7	14 - 11	12 - 8	18 - 9	18 - 6	21 - 9	20 - 6	11 - 6	127 - 64
Light Trucks	2010 2008	(6) - (1)	(14) - (12)	(18) - (19)	(42) - (45)	(53) - (45)	(56) - (54)	(42) - (52)	(52) - (57)	(63) - (36)	(347) - (323)
Total	2010 2008	(3) - 2	(5) - (6)	(4) - (9)	(30) - (37)	(35) - (37)	(37) - (48)	(21) - (43)	(31) - (52)	(53) - (31)	(220) - (259)
Millions of Dollars											
Passenger Cars	2010 2008	$44 - $35	$96 - $77	$158 - $124	$140 - $98	$214 - $100	$213 - $69	$246 - $105	$233 - $65	$125 - $64	$1,469 - $737
Light Trucks	2010 2008	($73) - ($10)	($155) - ($138)	($205) - ($221)	($479) - ($511)	($607) - ($514)	($633) - ($617)	($481) - ($594)	($586) - ($651)	($721) - ($410)	($3,940) - ($3,666)
Total	2010 2008	($29) - $26	($60) - ($61)	($47) - ($97)	($339) - ($413)	($394) - ($414)	($420) - ($548)	($235) - ($490)	($353) - ($586)	($596) - ($346)	($2,471) - ($2,929)

Table IX-5h
Comparison of the Calculated Weight Safety-Related Fatality Impacts
over the Lifetime of the Vehicles Produced in each Model Year
7% Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 1	7 - 6	14 - 10	13 - 9	19 - 10	19 - 8	22 - 9	18 - 8	8 - 2	123 - 63
Light Trucks	2010 2008	(9) - (1)	(16) - (12)	(19) - (19)	(49) - (53)	(64) - (49)	(68) - (59)	(55) - (48)	(64) - (55)	(70) - (30)	(414) - (327)
Total	2010 2008	(6) - 1	(8) - (6)	(5) - (9)	(37) - (44)	(45) - (40)	(49) - (51)	(33) - (39)	(47) - (47)	(62) - (29)	(291) - (264)
Millions of Dollars											
Passenger Cars	2010 2008	$33 - $15	$86 - $75	$162 - $118	$146 - $101	$220 - $111	$217 - $93	$256 - $105	$205 - $97	$95 - $19	$1,420 - $735
Light Trucks	2010 2008	($98) - ($8)	($180) - ($138)	($219) - ($221)	($558) - ($600)	($729) - ($561)	($769) - ($674)	($620) - ($546)	($730) - ($626)	($796) - ($344)	($4,699) - ($3,717)
Total	2010 2008	($65) - $7	($94) - ($63)	($56) - ($103)	($412) - ($498)	($509) - ($450)	($552) - ($580)	($364) - ($441)	($526) - ($529)	($701) - ($325)	($3,279) - ($2,983)

Table IX-5i
Comparison of the Calculated Weight Safety-Related Fatality Impacts
over the Lifetime of the Vehicles Produced in each Model Year
Maximum Net Benefit Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	5 - 1	7 - 3	12 - 6	9 - 5	16 - 6	16 - 6	22 - 10	20 - 7	19 - 7	127 - 51
Light Trucks	2010 2008	(9) - (8)	(15) - (15)	(21) - (25)	(42) - (44)	(58) - (54)	(62) - (56)	(46) - (52)	(47) - (53)	(62) - (38)	(363) - (344)
Total	2010 2008	(3) - (7)	(8) - (12)	(9) - (18)	(33) - (39)	(42) - (48)	(46) - (50)	(24) - (42)	(27) - (46)	(43) - (31)	(237) - (294)
Millions of Dollars											
Passenger Cars	2010 2008	$61 - $9	$86 - $31	$136 - $71	$106 - $55	$184 - $69	$186 - $74	$259 - $116	$231 - $84	$219 - $81	$1,468 - $590
Light Trucks	2010 2008	($100) - ($89)	($171) - ($173)	($241) - ($279)	($481) - ($495)	($661) - ($619)	($703) - ($641)	($525) - ($586)	($538) - ($602)	($708) - ($429)	($4,129) - ($3,913)
Total	2010 2008	($38) - ($79)	($85) - ($141)	($105) - ($208)	($375) - ($440)	($476) - ($550)	($518) - ($568)	($266) - ($470)	($307) - ($518)	($490) - ($348)	($2,661) - ($3,323)

Table IX-5j
Comparison of the Calculated Weight Safety-Related Fatality Impacts
over the Lifetime of the Vehicles Produced in each Model Year
Total Cost = Total Benefit Alternative
Fatalities Undiscounted, Dollars Discounted at 3%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	5 - 1	10 - 3	15 - 10	13 - 2	20 - 3	19 - 4	22 - 7	18 - 6	13 - 5	135 - 41
Light Trucks	2010 2008	(9) - (12)	(16) - (19)	(18) - (26)	(46) - (46)	(53) - (49)	(59) - (50)	(45) - (44)	(48) - (47)	(63) - (33)	(358) - (325)
Total	2010 2008	(4) - (11)	(6) - (16)	(3) - (16)	(34) - (44)	(33) - (46)	(40) - (46)	(23) - (37)	(30) - (42)	(50) - (27)	(223) - (283)
Millions of Dollars											
Passenger Cars	2010 2008	$61 - $10	$114 - $37	$175 - $121	$147 - $23	$226 - $35	$222 - $43	$254 - $84	$210 - $64	$156 - $63	$1,568 - $479
Light Trucks	2010 2008	($106) - ($134)	($177) - ($214)	($205) - ($301)	($527) - ($518)	($601) - ($552)	($670) - ($562)	($516) - ($503)	($545) - ($535)	($718) - ($371)	($4,066) - ($3,689)
Total	2010 2008	($44) - ($125)	($64) - ($177)	($30) - ($180)	($380) - ($494)	($375) - ($517)	($448) - ($519)	($261) - ($418)	($335) - ($471)	($562) - ($308)	($2,499) - ($3,210)

Table IX-6a
Comparison of the Calculated Weight Safety-Related Fatality Impacts
over the Lifetime of the Vehicles Produced in each Model Year
Preferred Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 2	7 - 5	13 - 13	12 - 12	18 - 13	19 - 10	23 - 11	22 - 9	19 - 1	135 - 78
Light Trucks	2010 2008	(5) - (5)	(9) - (13)	0 - (17)	(5) - (29)	(18) - (27)	(21) - (27)	(24) - (27)	(30) - (29)	(31) - (11)	(143) - (185)
Total	2010 2008	(2) - (3)	(3) - (8)	13 - (3)	7 - (17)	(1) - (14)	(2) - (17)	(2) - (16)	(8) - (20)	(12) - (10)	(8) - (107)
Millions of Dollars											
Passenger Cars	2010 2008	$26 - $21	$62 - $49	$116 - $121	$109 - $112	$161 - $116	$173 - $90	$205 - $100	$196 - $82	$175 - $11	$1,223 - $702
Light Trucks	2010 2008	($41) - ($45)	($83) - ($117)	$2 - ($147)	($41) - ($255)	($162) - ($234)	($182) - ($240)	($214) - ($235)	($263) - ($257)	($276) - ($95)	($1,259) - ($1,624)
Total	2010 2008	($15) - ($24)	($21) - ($69)	$118 - ($26)	$69 - ($142)	($0) - ($117)	($9) - ($150)	($9) - ($135)	($67) - ($175)	($101) - ($84)	($36) - ($922)

Table IX-6b
Comparison of the Calculated Weight Safety-Related Fatality Impacts
over the Lifetime of the Vehicles Produced in each Model Year
1% Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	0 - 1	5 - 3	4 - 5	4 - 4	8 - 6	7 - 4	12 - 4	11 - 4	11 - 5	61 - 35
Light Trucks	2010 2008	(3) - (5)	(3) - (5)	(6) - (7)	(6) - (9)	(4) - (10)	(2) - (12)	(3) - (12)	(4) - (13)	(5) - (12)	(36) - (85)
Total	2010 2008	(3) - (3)	2 - (3)	(2) - (2)	(2) - (5)	3 - (4)	4 - (8)	9 - (9)	7 - (9)	6 - (7)	25 - (50)
Millions of Dollars											
Passenger Cars	2010 2008	$1 - $12	$42 - $24	$32 - $48	$39 - $34	$69 - $52	$60 - $35	$110 - $35	$101 - $37	$97 - $42	$551 - $320
Light Trucks	2010 2008	($25) - ($40)	($26) - ($46)	($49) - ($63)	($52) - ($80)	($36) - ($88)	($21) - ($101)	($30) - ($110)	($36) - ($118)	($41) - ($103)	($316) - ($749)
Total	2010 2008	($24) - ($28)	$16 - ($22)	($17) - ($15)	($13) - ($45)	$33 - ($36)	$39 - ($66)	$80 - ($74)	$65 - ($81)	$56 - ($61)	$235 - ($429)

Table IX-6c
Comparison of the Calculated Weight Safety-Related Fatality Impacts
over the Lifetime of the Vehicles Produced in each Model Year
2% Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	2 - 2	5 - 3	12 - 10	10 - 10	15 - 10	16 - 10	22 - 16	20 - 17	18 - 15	119 - 94
Light Trucks	2010 2008	(5) - (6)	(8) - (13)	1 - (20)	(2) - (29)	(4) - (31)	(5) - (32)	(8) - (34)	(13) - (37)	(16) - (38)	(61) - (240)
Total	2010 2008	(3) - (3)	(3) - (10)	12 - (10)	9 - (19)	11 - (21)	11 - (22)	14 - (18)	7 - (20)	1 - (23)	58 - (146)
Millions of Dollars											
Passenger Cars	2010 2008	$18 - $20	$49 - $31	$105 - $92	$92 - $90	$137 - $94	$142 - $94	$197 - $142	$178 - $153	$159 - $139	$1,076 - $854
Light Trucks	2010 2008	($40) - ($49)	($74) - ($118)	$7 - ($174)	($14) - ($253)	($39) - ($271)	($45) - ($285)	($72) - ($299)	($113) - ($327)	($141) - ($333)	($531) - ($2,109)
Total	2010 2008	($22) - ($29)	($25) - ($88)	$112 - ($82)	$78 - ($163)	$98 - ($177)	$97 - ($191)	$125 - ($157)	$65 - ($174)	$17 - ($194)	$544 - ($1,255)

Table IX-6d
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
3% Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 3	8 - 6	15 - 13	14 - 12	18 - 12	19 - 10	20 - 12	19 - 13	14 - 6	130 - 87
Light Trucks	2010 2008	(5) - (5)	(11) - (14)	(15) - (16)	(31) - (30)	(37) - (30)	(40) - (34)	(43) - (36)	(44) - (39)	(52) - (45)	(276) - (250)
Total	2010 2008	(2) - (3)	(3) - (8)	0 - (4)	(17) - (18)	(19) - (18)	(21) - (25)	(23) - (23)	(25) - (25)	(38) - (39)	(147) - (162)
Millions of Dollars											
Passenger Cars	2010 2008	$28 - $24	$71 - $53	$138 - $115	$127 - $110	$165 - $113	$169 - $88	$178 - $112	$170 - $120	$126 - $56	$1,172 - $791
Light Trucks	2010 2008	($41) - ($47)	($93) - ($121)	($131) - ($144)	($275) - ($265)	($323) - ($265)	($349) - ($302)	($375) - ($314)	($383) - ($338)	($455) - ($396)	($2,425) - ($2,192)
Total	2010 2008	($13) - ($23)	($22) - ($68)	$7 - ($29)	($148) - ($155)	($158) - ($152)	($180) - ($214)	($197) - ($202)	($213) - ($218)	($329) - ($340)	($1,253) - ($1,401)

Table IX-6e
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
4% Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 3	7 - 6	11 - 13	7 - 11	12 - 10	13 - 8	16 - 11	15 - 4	8 - (2)	93 - 64
Light Trucks	2010 2008	(6) - (2)	(12) - (12)	(15) - (21)	(36) - (37)	(44) - (31)	(49) - (36)	(43) - (37)	(47) - (41)	(55) - (50)	(307) - (269)
Total	2010 2008	(3) - 1	(6) - (6)	(4) - (8)	(28) - (26)	(31) - (21)	(36) - (29)	(26) - (26)	(31) - (37)	(47) - (52)	(214) - (205)
Millions of Dollars											
Passenger Cars	2010 2008	$28 - $29	$59 - $54	$99 - $119	$66 - $97	$110 - $94	$114 - $68	$149 - $98	$138 - $35	$74 - ($18)	$837 - $577
Light Trucks	2010 2008	($53) - ($21)	($108) - ($108)	($134) - ($187)	($313) - ($325)	($383) - ($275)	($430) - ($317)	($376) - ($327)	($409) - ($360)	($487) - ($439)	($2,691) - ($2,360)
Total	2010 2008	($25) - $8	($49) - ($53)	($35) - ($68)	($247) - ($228)	($273) - ($181)	($315) - ($249)	($227) - ($229)	($270) - ($325)	($413) - ($457)	($1,855) - ($1,783)

Table IX-6f
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
5% Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 3	8 - 6	15 - 9	11 - 1	18 - 1	18 - (0)	21 - 3	15 - 1	9 - 1	117 - 24
Light Trucks	2010 2008	(6) - (1)	(14) - (11)	(16) - (17)	(42) - (43)	(51) - (44)	(53) - (49)	(39) - (48)	(46) - (54)	(46) - (56)	(312) - (323)
Total	2010 2008	(3) - 2	(6) - (5)	(1) - (8)	(31) - (42)	(33) - (44)	(34) - (49)	(18) - (45)	(31) - (54)	(38) - (56)	(195) - (300)
Millions of Dollars											
Passenger Cars	2010 2008	$26 - $27	$70 - $52	$136 - $85	$98 - $8	$158 - $5	$166 - ($0)	$187 - $28	$138 - $5	$77 - $5	$1,056 - $214
Light Trucks	2010 2008	($55) - ($6)	($122) - ($98)	($140) - ($149)	($365) - ($377)	($444) - ($389)	($462) - ($429)	($339) - ($422)	($402) - ($476)	($408) - ($493)	($2,736) - ($2,838)
Total	2010 2008	($28) - $22	($52) - ($47)	($4) - ($64)	($267) - ($369)	($285) - ($384)	($296) - ($429)	($152) - ($394)	($264) - ($471)	($330) - ($488)	($1,680) - ($2,624)

Table IX-6g
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
6% Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	4 - 3	8 - 7	14 - 11	12 - 8	18 - 9	18 - 6	21 - 9	20 - 6	11 - 6	127 - 64
Light Trucks	2010 2008	(6) - (1)	(14) - (12)	(18) - (19)	(42) - (45)	(53) - (45)	(56) - (54)	(42) - (52)	(52) - (57)	(63) - (36)	(347) - (323)
Total	2010 2008	(3) - 2	(5) - (6)	(4) - (9)	(30) - (37)	(35) - (37)	(37) - (48)	(21) - (43)	(31) - (52)	(53) - (31)	(220) - (259)
Millions of Dollars											
Passenger Cars	2010 2008	$35 - $28	$75 - $60	$124 - $97	$109 - $76	$167 - $78	$167 - $54	$192 - $82	$182 - $51	$98 - $50	$1,148 - $576
Light Trucks	2010 2008	($56) - ($8)	($120) - ($107)	($158) - ($171)	($370) - ($394)	($469) - ($397)	($489) - ($477)	($372) - ($459)	($453) - ($503)	($557) - ($317)	($3,045) - ($2,833)
Total	2010 2008	($22) - $20	($45) - ($47)	($35) - ($74)	($261) - ($318)	($302) - ($319)	($323) - ($423)	($179) - ($377)	($271) - ($453)	($459) - ($267)	($1,897) - ($2,257)

Table IX-6h
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
7% Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	3 - 1	7 - 6	14 - 10	13 - 9	19 - 10	19 - 8	22 - 9	18 - 8	8 - 2	123 - 63
Light Trucks	2010 2008	(9) - (1)	(16) - (12)	(19) - (19)	(49) - (53)	(64) - (49)	(68) - (59)	(55) - (48)	(64) - (55)	(70) - (30)	(414) - (327)
Total	2010 2008	(6) - 1	(8) - (6)	(5) - (9)	(37) - (44)	(45) - (40)	(49) - (51)	(33) - (39)	(47) - (47)	(62) - (29)	(291) - (264)
Millions of Dollars											
Passenger Cars	2010 2008	$26 - $12	$67 - $58	$127 - $92	$114 - $79	$172 - $87	$170 - $73	$200 - $82	$160 - $76	$74 - $15	$1,109 - $574
Light Trucks	2010 2008	($76) - ($6)	($139) - ($106)	($169) - ($171)	($431) - ($463)	($563) - ($434)	($594) - ($520)	($479) - ($422)	($564) - ($484)	($615) - ($266)	($3,631) - ($2,873)
Total	2010 2008	($50) - $6	($72) - ($48)	($42) - ($78)	($317) - ($384)	($391) - ($347)	($425) - ($447)	($279) - ($340)	($405) - ($408)	($541) - ($251)	($2,522) - ($2,299)

Table IX-6i
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
Maximum Net Benefit Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	4 - 1	5 - 4	12 - 6	8 - 4	14 - 5	14 - 6	20 - 7	16 - 8	14 - 9	105 - 50
Light Trucks	2010 2008	(8) - (6)	(14) - (13)	(20) - (22)	(41) - (41)	(50) - (33)	(51) - (36)	(39) - (37)	(45) - (39)	(65) - (25)	(333) - (254)
Total	2010 2008	(5) - (5)	(10) - (9)	(8) - (17)	(33) - (37)	(36) - (28)	(37) - (31)	(19) - (30)	(29) - (31)	(51) - (17)	(228) - (204)
Millions of Dollars											
Passenger Cars	2010 2008	$32 - $7	$42 - $37	$105 - $51	$74 - $36	$124 - $47	$128 - $51	$178 - $64	$143 - $76	$125 - $79	$951 - $449
Light Trucks	2010 2008	($71) - ($52)	($126) - ($118)	($176) - ($197)	($361) - ($363)	($440) - ($291)	($450) - ($318)	($342) - ($325)	($391) - ($342)	($570) - ($222)	($2,926) - ($2,227)
Total	2010 2008	($39) - ($45)	($83) - ($81)	($71) - ($146)	($288) - ($327)	($316) - ($243)	($322) - ($267)	($163) - ($260)	($248) - ($266)	($445) - ($143)	($1,975) - ($1,778)

Table IX-6j
Comparison of the Calculated Weight Safety-Related Fatality Impacts over the Lifetime of the Vehicles Produced in each Model Year
Total Cost = Total Benefit Alternative
Fatalities Undiscounted, Dollars Discounted at 7%

Fatalities	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	Total
Passenger Cars	2010 2008	5 - 1	10 - 3	15 - 10	13 - 2	20 - 3	19 - 4	22 - 7	18 - 6	13 - 5	0 - 0
Light Trucks	2010 2008	(9) - (12)	(16) - (19)	(18) - (26)	(46) - (46)	(53) - (49)	(59) - (50)	(45) - (44)	(48) - (47)	(63) - (33)	0 - 0
Total	2010 2008	(4) - (11)	(6) - (16)	(3) - (16)	(34) - (44)	(33) - (46)	(40) - (46)	(23) - (37)	(30) - (42)	(50) - (27)	0 - 0
Millions of Dollars											
Passenger Cars	2010 2008	$48 - $8	$89 - $29	$137 - $94	$115 - $18	$177 - $27	$174 - $34	$199 - $66	$164 - $50	$122 - $49	$1,225 - $375
Light Trucks	2010 2008	($82) - ($104)	($137) - ($165)	($159) - ($232)	($407) - ($400)	($465) - ($427)	($518) - ($435)	($399) - ($388)	($421) - ($414)	($555) - ($286)	($3,142) - ($2,851)
Total	2010 2008	($34) - ($96)	($48) - ($137)	($22) - ($138)	($292) - ($382)	($288) - ($399)	($344) - ($401)	($200) - ($322)	($257) - ($364)	($433) - ($238)	($1,918) - ($2,476)

Sensitivity tests

Table IX-2, the table of principal findings, includes sampling-error confidence bounds for the five parameters used in the Volpe model: the statistical uncertainty that is a consequence of having less than a census of data. NHTSA's 2011 preliminary report acknowledged another source of uncertainty, namely that the baseline statistical model can be varied by choosing different control variables or redefining the vehicle classes or crash types, for example. Alternative models produce different point estimates. NHTSA believed it was premature to address that in the preliminary report. "The potential for variation will perhaps be better understood after the public and other agencies have had an opportunity to work with the new database."[576] NHTSA has now garnered 11 more or less plausible alternative techniques that could be construed as sensitivity tests of the baseline model, which were tested or proposed by Charles Farmer (IIHS) or Paul Green (UMTRI) in their peer reviews, Mike Van Auken (DRI) in his public comments, or Tom Wenzel in his parallel research for DOE. See Kahane 2012 for a further discussion of the models and the rationales behind them. The models use NHTSA's databases and regression-analysis approach, but differ from the baseline model in one or more terms or assumptions. NHTSA applied the 11 techniques to the latest databases to generate alternative Volpe-model coefficients. The range of estimates produced by the sensitivity tests gives an idea of the uncertainty inherent in the formulation of the models, subject to the caveat that these 11 tests are, of course, not an exhaustive list of conceivable alternatives. Here are the baseline and alternative results, ordered from the lowest to the highest estimated increase in societal risk per 100-pound reduction for cars weighing less than 3,106 pounds:

[576] Kahane (2011), p. 81.

Table IX-7
Fatality Increase (%) Per 100-Pound Mass Reduction While Holding Footprint* Constant

		Cars < 3,106	Cars ≥ 3,106	CUVs & Minivans	LTVs† < 4,594	LTVs† ≥ 4,594
Baseline estimate		**1.56**	**.51**	**- .37**	**.52**	**- .34**
95% confidence bounds	Lower:	.39	- .59	- 1.55	- .45	- .97
(sampling error)	Upper:	2.73	1.60	.81	1.48	.30
		11 Alternative Models				
1. Track width/wheelbase w. stopped veh data		.25	- .89	- .13	- .09	- .97
2. With stopped-vehicle State data		.97	- .62	- .33	.35	- .80
3. By track width & wheelbase		.97	.24	- .24	- .07	- .58
4. W/O CY control variables		1.53	.43	.04	1.20	.30
5. CUVs/minivans weighted by 2010 sales		1.56	.51	.53	.52	- .35
6. W/O non-significant control variables		1.64	.68	- .46	.35	- .54
7. Incl. muscle/police/AWD cars/big vans		1.81	.49	- .37	.49	- .76
8. Control for vehicle manufacturer		1.91	.75	1.64	.68	- .13
9. Control for veh manufacturer/nameplate		2.07	1.82	1.31	.66	- .13
10. Limited to drivers with BAC=0		2.32	1.06	- .19	.86	- .58
11. Limited to good drivers‡		3.00	1.62	.00	1.09	- .30

*While holding track width and wheelbase constant in alternative model nos. 1 and 3.
†Excluding CUVs and minivans.
‡BAC=0, no drugs, valid license, at most 1 crash and 1 violation during the past 3 years.

For example, in cars weighing less than 3,106 pounds, the baseline estimate associates 100-pound mass reduction, while holding footprint constant, with a 1.56 percent increase in societal fatality risk. The corresponding estimates for the 11 sensitivity tests range from a 0.25 to a 3.00 percent increase. The sensitivity tests illustrate both the fragility and the robustness of the baseline estimates. On the one hand, the variation among the Volpe coefficients is quite large relative to the baseline estimate: in the preceding example of cars < 3,106 pounds, from almost zero to almost double baseline. That is so because the societal effect of mass reduction is small and, as Wenzel has said, it "is overwhelmed by other known vehicle, driver, and crash factors."[577] In other words, a variation in how to model some of those other vehicle, driver, and crash factors – which is exactly what the sensitivity tests do – can appreciably change the estimate of the societal effect of mass reduction.

On the other hand, the variations are not all that large in absolute terms. The ranges of the alternative estimates, at least these alternatives, are about as wide as the sampling-error confidence bounds for the baseline estimates. As a general rule, in the alternative models, as in the baseline models, mass reduction tends to be relatively more harmful in the lighter vehicles, more beneficial in the heavier vehicles. Thus, in all models, the point estimate of the Volpe coefficient is positive for cars < 3,106 pounds, and in all models except one, it is negative for

[577] Wenzel, T. (2011). *Assessment of NHTSA's Report "Relationships Between Fatality Risk, Mass, and Footprint in Model Year 2000-2007 Passenger Cars and LTVs."* (Docket No. NHTSA-2010-0152-0026). Berkeley, CA: Lawrence Berkeley National Laboratory, p. iv.

LTVs ≥ 4,594 pounds. None of these models suggest mass reduction in small cars would be beneficial. All suggest mass reduction in heavy LTVs would be beneficial or, at worst, close to neutral. In general, any judicious combination of mass reductions that maintain footprint and are proportionately higher in the heavier vehicles is unlikely to have a societal effect large enough to be detected by statistical analyses of crash data.

Table IX-8 provides the estimated fatality impacts of the alternative models as a sensitivity analysis. In this table we combine the total fatalities for each model year over the MY 2017-25 model years, and show them for the MY 2010 baseline. All of the sensitivity analyses performed for this analysis are based on the MY 2010 baseline. There was no need to perform sensitivity analyses around two different baselines.

The variations in results from the sensitivity analyses are more or less within the confidence bounds of the 2012 Report (as shown in Table IX-2) ranging from a decrease of 843 fatalities to an increase of 1,905 fatalities. All of the fatality estimates in this table are of undiscounted fatalities.

Table IX-8
Estimated Undiscounted Fatality Increase or Decrease in ( )
over the Lifetime of the Combined 9 Model Years 2017-2025
Passenger Cars and Light Trucks Combined
Preferred Alternative

	Model Year 2010 Baseline
Main Analysis Results	(8)
Sensitivity	
#1	(843)
#2	(686)
#3	(279)
#4	665
#5	657
#6	(114)
#7	(167)
#8	1,687
#9	1,905
#10	385
#11	940

X. NET BENEFITS AND SENSITIVITY ANALYSIS

This chapter compares the costs of technologies needed to make improvements in fuel economy with the potential benefits, expressed in total costs (millions of dollars) from a societal perspective for each model year. The costs do not include CAFE civil penalties estimated to be paid by manufacturers to NHTSA, since these are transfer payments. Thus, the total costs shown in this section do not match the total costs shown in Chapter VII. These are incremental costs and benefits compared to the adjusted baseline of MY 2016. A payback period is calculated, from the consumer's perspective. Finally, sensitivity analyses are also performed on some of the assumptions made in this analysis.

Table X-1 provides the total incremental costs (in millions of dollars) from a societal perspective at a 3 percent discount rate. Table X-2 presents the same set of total incremental costs at a 7 percent discount rate. Table X-3 provides the total benefits at a 3 percent discount rate from a societal perspective for all vehicles produced. Table X-4 presents total benefits at a 7 percent discount rate from a societal perspective for all vehicles produced.

Table X-5 shows the total net benefits (in millions of dollars) from a societal perspective at a 3 percent discount rate for the projected fleet of sales for MY 2017 – MY 2025. Table X-6 is analogous to Table X-5, with use of a 7 percent discount rate.

Total costs follow a predictable pattern with costs rising to reflect the more expensive technologies that manufacturers must apply in order to achieve the CAFE levels that are required under the more aggressive alternatives. With a 3 percent discount rate, total compliance costs for the passenger car fleet under the Total Cost = Total Benefit alternative are 1.5 times greater than those of the Preferred Alternative. In the case a 7 percent discount rate, this ratio increases slightly to 1.6. For the light truck fleet, in the case of a 3 percent discount rate, total compliance costs are 2.5 times higher under the Total Cost = Total Benefit alternative than under the Preferred Alternative; in the case of a 7 percent discount rate, this ratio increases to 2.9.

In Tables X-3 and X-4, lifetime societal benefits follow a similar predictable pattern, with higher benefits associated with the more expensive technologies that are enabled under the more aggressive alternatives. For the combined fleet, the TC=TB alternative produces gross benefits roughly 1.47 times those of the Preferred Alternative under a 3% discount rate and 1.45 times those of the Preferred Alternative under a 7% discount rate.

Tables X-5 and X-6 present the net benefits to society produced by each alternative. Each alternative, including the Preferred Alternative, results in a net benefit to society. In Table X-5, the combined net benefit for passenger cars and light trucks under all nine model years ranges from $247 billion under the 2% Annual Increase alternative to $424 billion under the 7% Annual Increase alternative. Net benefits for the Preferred Alternative (the total under both vehicle types and all model years) are $344 billion at the 3% discount rate.

Table X-1a
Incremental Total Cost – Societal Perspective[578]
Passenger Cars, 3% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$3,491 - $2,607	$5,168 - $4,683	$7,638 - $7,291	$9,601 - $10,810	$12,106 - $13,242	$13,430 - $15,277	$15,119 - $16,605	$18,042 - $19,378	$18,843 - $21,598	$103,438 - $111,490
2% Annual Increase	2010 2008	$1,605 - $1,607	$2,803 - $2,859	$4,270 - $4,244	$5,803 - $6,007	$7,217 - $7,131	$8,036 - $8,071	$9,060 - $9,116	$10,821 - $10,705	$11,058 - $10,939	$60,672 - $60,678
3% Annual Increase	2010 2008	$2,606 - $2,180	$3,894 - $4,167	$6,079 - $5,916	$7,922 - $8,674	$8,907 - $10,121	$10,167 - $11,685	$11,645 - $12,362	$14,084 - $13,701	$14,994 - $14,821	$80,297 - $83,627
4% Annual Increase	2010 2008	$4,164 - $3,145	$5,761 - $5,595	$8,574 - $7,791	$11,189 - $11,269	$13,569 - $13,639	$14,852 - $15,612	$16,440 - $17,455	$18,526 - $20,047	$20,750 - $21,910	$113,825 - $116,463
5% Annual Increase	2010 2008	$5,012 - $3,842	$7,065 - $6,644	$11,417 - $9,169	$14,716 - $14,620	$17,395 - $18,733	$19,669 - $21,332	$22,848 - $24,232	$26,790 - $29,385	$31,262 - $31,810	$156,174 - $159,768
6% Annual Increase	2010 2008	$5,531 - $5,361	$8,018 - $8,602	$13,240 - $11,105	$16,863 - $16,597	$22,173 - $22,413	$24,372 - $29,313	$31,536 - $34,180	$42,338 - $43,766	$42,657 - $49,357	$206,728 - $220,693
7% Annual Increase	2010 2008	$7,847 - $6,806	$10,987 - $11,131	$16,890 - $14,395	$19,740 - $20,165	$24,429 - $28,395	$34,527 - $39,071	$42,017 - $43,210	$50,372 - $56,007	$51,007 - $52,581	$257,816 - $271,761
Max Net Benefits	2010 2008	$8,895 - $9,396	$10,319 - $11,118	$15,851 - $14,538	$17,866 - $17,970	$19,681 - $20,307	$21,194 - $21,259	$23,039 - $22,387	$26,684 - $25,420	$27,075 - $25,554	$170,603 - $167,949
Total Cost = Total Benefit	2010 2008	$9,126 - $14,897	$10,572 - $15,664	$17,021 - $17,382	$19,073 - $20,695	$21,891 - $23,075	$23,719 - $25,237	$28,568 - $27,487	$32,717 - $30,802	$31,287 - $31,239	$193,975 - $206,479

[578] "Societal perspective" includes technology costs and societal costs, but does not include payment of civil penalties by manufacturers in lieu of compliance with the CAFE standards.

Table X-1b
Incremental Total Cost – Societal Perspective
Light Trucks, 3% Discount Rate
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$1,056 - $644	$1,255 - $1,385	$2,889 - $2,543	$3,977 - $3,608	$5,781 - $4,925	$6,227 - $5,717	$6,895 - $6,130	$7,640 - $6,749	$7,510 - $7,811	$43,230 - $39,511
2% Annual Increase	2010 2008	$2,477 - $1,055	$2,495 - $1,624	$3,122 - $2,204	$3,430 - $2,992	$3,769 - $3,563	$4,112 - $4,051	$4,463 - $4,146	$4,901 - $4,485	$4,860 - $4,553	$33,629 - $28,674
3% Annual Increase	2010 2008	$2,885 - $1,374	$2,957 - $2,050	$3,856 - $3,160	$4,975 - $4,432	$5,921 - $5,342	$6,347 - $5,941	$7,041 - $6,280	$7,468 - $6,852	$7,732 - $7,173	$49,182 - $42,605
4% Annual Increase	2010 2008	$3,083 - $2,104	$3,465 - $3,008	$4,535 - $4,648	$6,070 - $6,273	$7,182 - $7,697	$7,751 - $8,330	$8,531 - $8,945	$9,458 - $9,681	$10,616 - $10,101	$60,691 - $60,787
5% Annual Increase	2010 2008	$3,241 - $2,641	$3,736 - $3,869	$5,658 - $6,019	$8,474 - $8,965	$10,564 - $10,708	$11,527 - $12,190	$12,974 - $12,887	$14,691 - $14,575	$15,292 - $14,866	$86,156 - $86,720
6% Annual Increase	2010 2008	$3,601 - $3,552	$4,187 - $4,906	$6,414 - $7,208	$9,364 - $11,731	$12,128 - $13,622	$13,139 - $15,423	$14,617 - $16,199	$17,561 - $18,815	$19,269 - $19,334	$100,281 - $110,791
7% Annual Increase	2010 2008	$4,340 - $3,765	$5,092 - $5,544	$7,419 - $8,306	$11,036 - $12,508	$13,212 - $15,351	$14,138 - $17,401	$15,486 - $19,411	$17,941 - $20,984	$18,662 - $22,339	$107,327 - $125,609
Max Net Benefits	2010 2008	$4,747 - $6,982	$5,094 - $7,671	$7,052 - $8,903	$9,232 - $12,788	$10,967 - $14,149	$11,609 - $14,686	$12,811 - $15,253	$13,603 - $16,435	$14,206 - $15,876	$89,322 - $112,743
Total Cost = Total Benefit	2010 2008	$4,930 - $7,383	$5,269 - $7,996	$6,807 - $9,232	$9,707 - $13,367	$11,357 - $14,762	$11,809 - $15,378	$12,980 - $16,105	$13,890 - $17,092	$14,614 - $16,570	$91,362 - $117,884

Table X-1c
Incremental Total Cost – Societal Perspective
Passenger Cars and Light Trucks Combined, 3% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$4,547 - $3,251	$6,423 - $6,067	$10,528 - $9,834	$13,578 - $14,417	$17,887 - $18,167	$19,657 - $20,994	$22,013 - $22,735	$25,682 - $26,126	$26,353 - $29,409	$146,668 - $151,001
2% Annual Increase	2010 2008	$4,082 - $2,662	$5,298 - $4,484	$7,392 - $6,449	$9,232 - $8,999	$10,987 - $10,694	$12,148 - $12,122	$13,523 - $13,262	$15,722 - $15,190	$15,917 - $15,492	$94,301 - $89,352
3% Annual Increase	2010 2008	$5,490 - $3,554	$6,851 - $6,218	$9,935 - $9,076	$12,897 - $13,106	$14,828 - $15,463	$16,514 - $17,626	$18,686 - $18,642	$21,552 - $20,553	$22,726 - $21,994	$129,479 - $126,232
4% Annual Increase	2010 2008	$7,247 - $5,249	$9,227 - $8,603	$13,109 - $12,439	$17,259 - $17,541	$20,751 - $21,336	$22,603 - $23,942	$24,971 - $26,400	$27,984 - $29,728	$31,365 - $32,011	$174,516 - $177,249
5% Annual Increase	2010 2008	$8,253 - $6,483	$10,801 - $10,513	$17,075 - $15,188	$23,190 - $23,586	$27,959 - $29,440	$31,196 - $33,521	$35,822 - $37,119	$41,481 - $43,961	$46,554 - $46,676	$242,330 - $246,488
6% Annual Increase	2010 2008	$9,132 - $8,913	$12,205 - $13,509	$19,654 - $18,313	$26,228 - $28,328	$34,301 - $36,035	$37,511 - $44,736	$46,152 - $50,379	$59,899 - $62,581	$61,927 - $68,691	$307,009 - $331,484
7% Annual Increase	2010 2008	$12,187 - $10,571	$16,079 - $16,674	$24,309 - $22,701	$30,777 - $32,672	$37,641 - $43,746	$48,665 - $56,472	$57,503 - $62,621	$68,314 - $76,991	$69,669 - $74,920	$365,142 - $397,370
Max Net Benefits	2010 2008	$13,641 - $16,379	$15,412 - $18,788	$22,904 - $23,441	$27,098 - $30,758	$30,647 - $34,455	$32,803 - $35,945	$35,850 - $37,640	$40,287 - $41,856	$41,281 - $41,430	$259,925 - $280,691
Total Cost = Total Benefit	2010 2008	$14,056 - $22,281	$15,841 - $23,660	$23,828 - $26,614	$28,780 - $34,062	$33,248 - $37,837	$35,528 - $40,615	$41,548 - $43,592	$46,606 - $47,894	$45,901 - $47,808	$285,337 - $324,362

Table X-2a
Incremental Total Cost – Societal Perspective[579]
Passenger Cars, 7% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$3,355 - $2,477	$4,965 - $4,447	$7,281 - $6,906	$9,168 - $10,289	$11,514 - $12,655	$12,753 - $14,595	$14,324 - $15,851	$17,123 - $18,522	$17,850 - $20,634	$98,333 - $106,375
2% Annual Increase	2010 2008	$1,540 - $1,516	$2,696 - $2,702	$4,062 - $3,994	$5,502 - $5,682	$6,856 - $6,761	$7,602 - $7,630	$8,526 - $8,604	$10,178 - $10,105	$10,386 - $10,306	$57,350 - $57,301
3% Annual Increase	2010 2008	$2,499 - $2,063	$3,733 - $3,944	$5,783 - $5,578	$7,514 - $8,222	$8,441 - $9,621	$9,617 - $11,102	$10,957 - $11,714	$13,260 - $12,982	$14,112 - $14,034	$75,915 - $79,259
4% Annual Increase	2010 2008	$4,016 - $2,995	$5,551 - $5,323	$8,197 - $7,395	$10,686 - $10,734	$12,930 - $13,029	$14,136 - $14,912	$15,614 - $16,674	$17,596 - $19,172	$19,697 - $20,913	$108,422 - $111,146
5% Annual Increase	2010 2008	$4,827 - $3,664	$6,803 - $6,339	$10,946 - $8,722	$14,099 - $14,004	$16,667 - $18,020	$18,814 - $20,498	$21,872 - $23,271	$25,652 - $28,263	$29,843 - $30,417	$149,523 - $153,198
6% Annual Increase	2010 2008	$5,316 - $5,147	$7,721 - $8,251	$12,717 - $10,624	$16,184 - $15,934	$21,335 - $21,596	$23,434 - $28,209	$30,356 - $32,833	$40,764 - $42,046	$40,845 - $47,037	$198,671 - $211,676
7% Annual Increase	2010 2008	$7,591 - $6,557	$10,642 - $10,734	$16,313 - $13,847	$19,019 - $19,415	$23,575 - $27,366	$33,324 - $37,574	$40,488 - $41,534	$48,484 - $53,763	$48,829 - $50,134	$248,264 - $260,924
Max Net Benefits	2010 2008	$7,784 - $8,700	$9,029 - $9,797	$11,891 - $11,923	$14,665 - $14,443	$16,635 - $16,294	$17,461 - $17,112	$18,539 - $18,246	$21,393 - $20,451	$21,492 - $21,484	$138,889 - $138,449
Total Cost = Total Benefit	2010 2008	$8,822 - $14,398	$10,222 - $15,128	$16,421 - $16,764	$18,352 - $19,928	$21,059 - $22,191	$22,786 - $24,248	$27,436 - $26,401	$31,393 - $29,570	$29,881 - $29,810	$186,372 - $198,439

[579] "Societal perspective" includes technology costs and societal costs, but does not include civil penalties.

Table X-2b
Incremental Total Cost – Societal Perspective
Light Trucks, 7% Discount Rate
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$1,019 - $612	$1,207 - $1,298	$2,759 - $2,381	$3,817 - $3,380	$5,534 - $4,640	$5,940 - $5,386	$6,559 - $5,774	$7,234 - $6,348	$7,090 - $7,365	$41,157 - $37,184
2% Annual Increase	2010 2008	$2,394 - $992	$2,407 - $1,517	$2,990 - $2,055	$3,283 - $2,784	$3,600 - $3,330	$3,908 - $3,791	$4,218 - $3,878	$4,608 - $4,188	$4,559 - $4,239	$31,967 - $26,773
3% Annual Increase	2010 2008	$2,783 - $1,289	$2,846 - $1,915	$3,687 - $2,957	$4,761 - $4,161	$5,649 - $5,037	$6,036 - $5,592	$6,665 - $5,906	$7,049 - $6,442	$7,291 - $6,735	$46,768 - $40,033
4% Annual Increase	2010 2008	$2,979 - $1,995	$3,340 - $2,832	$4,343 - $4,389	$5,824 - $5,937	$6,860 - $7,340	$7,392 - $7,936	$8,118 - $8,510	$8,984 - $9,213	$10,071 - $9,606	$57,910 - $57,758
5% Annual Increase	2010 2008	$3,127 - $2,519	$3,601 - $3,670	$5,437 - $5,720	$8,165 - $8,563	$10,169 - $10,280	$11,082 - $11,705	$12,447 - $12,370	$14,103 - $14,015	$14,659 - $14,251	$82,789 - $83,092
6% Annual Increase	2010 2008	$3,472 - $3,410	$4,036 - $4,686	$6,183 - $6,899	$9,046 - $11,261	$11,710 - $13,105	$12,667 - $14,835	$14,069 - $15,587	$16,907 - $18,137	$18,519 - $18,611	$96,610 - $106,531
7% Annual Increase	2010 2008	$4,201 - $3,613	$4,925 - $5,300	$7,165 - $7,973	$10,665 - $12,041	$12,753 - $14,821	$13,628 - $16,797	$14,898 - $18,758	$17,260 - $20,288	$17,928 - $21,560	$103,423 - $121,150
Max Net Benefits	2010 2008	$4,610 - $6,512	$4,885 - $7,129	$6,688 - $8,250	$8,670 - $10,622	$10,343 - $11,891	$10,919 - $12,296	$11,989 - $12,433	$12,829 - $13,182	$14,026 - $13,003	$84,956 - $95,318
Total Cost = Total Benefit	2010 2008	$4,785 - $7,150	$5,107 - $7,718	$6,570 - $8,884	$9,369 - $12,872	$10,951 - $14,218	$11,378 - $14,797	$12,481 - $15,499	$13,334 - $16,453	$13,994 - $15,904	$87,969 - $113,496

Table X-2c
Incremental Total Cost – Societal Perspective
Combined, 7% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$4,373 - $3,089	$6,172 - $5,745	$10,040 - $9,286	$12,985 - $13,669	$17,047 - $17,295	$18,693 - $19,981	$20,883 - $21,625	$24,356 - $24,871	$24,941 - $27,999	$139,489 - $143,559
2% Annual Increase	2010 2008	$3,934 - $2,508	$5,103 - $4,219	$7,053 - $6,049	$8,786 - $8,466	$10,456 - $10,092	$11,510 - $11,420	$12,745 - $12,482	$14,786 - $14,292	$14,945 - $14,545	$89,318 - $84,074
3% Annual Increase	2010 2008	$5,283 - $3,351	$6,578 - $5,859	$9,470 - $8,535	$12,275 - $12,383	$14,090 - $14,657	$15,653 - $16,694	$17,622 - $17,620	$20,310 - $19,425	$21,403 - $20,769	$122,683 - $119,292
4% Annual Increase	2010 2008	$6,994 - $4,990	$8,891 - $8,155	$12,540 - $11,784	$16,510 - $16,670	$19,790 - $20,369	$21,528 - $22,847	$23,732 - $25,184	$26,579 - $28,385	$29,768 - $30,519	$166,332 - $168,905
5% Annual Increase	2010 2008	$7,955 - $6,183	$10,403 - $10,009	$16,383 - $14,442	$22,264 - $22,568	$26,835 - $28,300	$29,896 - $32,203	$34,319 - $35,640	$39,754 - $42,278	$44,501 - $44,668	$232,312 - $236,290
6% Annual Increase	2010 2008	$8,788 - $8,557	$11,757 - $12,937	$18,899 - $17,523	$25,230 - $27,196	$33,045 - $34,701	$36,101 - $43,044	$44,425 - $48,420	$57,671 - $60,183	$59,364 - $65,647	$295,281 - $318,208
7% Annual Increase	2010 2008	$11,792 - $10,170	$15,567 - $16,034	$23,478 - $21,820	$29,683 - $31,456	$36,328 - $42,187	$46,952 - $54,371	$55,385 - $60,291	$65,744 - $74,051	$66,757 - $71,694	$351,687 - $382,074
Max Net Benefits	2010 2008	$12,394 - $15,212	$13,914 - $16,926	$18,578 - $20,173	$23,334 - $25,066	$26,978 - $28,186	$28,379 - $29,408	$30,528 - $30,679	$34,222 - $33,633	$35,518 - $34,487	$223,845 - $233,768
Total Cost = Total Benefit	2010 2008	$13,607 - $21,548	$15,329 - $22,847	$22,991 - $25,648	$27,721 - $32,800	$32,011 - $36,409	$34,163 - $39,045	$39,917 - $41,901	$44,727 - $46,024	$43,875 - $45,714	$274,341 - $311,935

Table X-3a
Present Value of Lifetime Societal Benefits[580] by Alternative
Passenger Cars, 3% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$12,907 - $10,806	$18,736 - $18,668	$28,873 - $27,786	$35,979 - $38,398	$44,882 - $45,214	$49,850 - $51,915	$56,963 - $56,756	$65,450 - $64,370	$70,184 - $71,111	$383,823 - $385,023
2% Annual Increase	2010 2008	$5,837 - $6,938	$9,334 - $11,448	$14,408 - $15,901	$20,483 - $21,837	$25,159 - $25,879	$28,024 - $29,368	$32,250 - $33,833	$37,921 - $39,561	$40,227 - $42,743	$213,642 - $227,509
3% Annual Increase	2010 2008	$9,919 - $9,455	$14,567 - $16,773	$22,637 - $23,710	$30,754 - $33,073	$35,437 - $37,947	$39,941 - $43,515	$46,372 - $47,564	$55,237 - $52,143	$60,140 - $56,463	$315,004 - $320,643
4% Annual Increase	2010 2008	$13,906 - $13,355	$19,540 - $22,085	$29,969 - $29,907	$39,996 - $40,478	$48,846 - $47,604	$53,826 - $53,705	$60,116 - $59,242	$66,687 - $67,012	$73,837 - $74,047	$406,721 - $407,434
5% Annual Increase	2010 2008	$17,365 - $16,047	$24,279 - $25,387	$36,863 - $34,222	$47,250 - $46,910	$55,294 - $55,843	$60,933 - $61,541	$67,990 - $67,320	$77,140 - $76,642	$86,660 - $84,612	$473,775 - $468,525
6% Annual Increase	2010 2008	$20,141 - $19,577	$27,546 - $29,371	$41,832 - $37,952	$50,211 - $50,491	$59,960 - $59,418	$65,225 - $68,535	$73,709 - $75,196	$85,385 - $85,604	$94,315 - $97,714	$518,324 - $523,858
7% Annual Increase	2010 2008	$24,124 - $23,157	$32,035 - $33,353	$45,415 - $42,565	$53,534 - $54,400	$61,517 - $63,139	$70,425 - $73,626	$77,671 - $79,531	$88,055 - $90,305	$98,386 - $98,130	$551,161 - $558,208
Max Net Benefits	2010 2008	$27,812 - $28,457	$32,030 - $33,766	$44,228 - $40,246	$51,352 - $49,366	$57,354 - $56,328	$61,814 - $60,264	$67,230 - $64,227	$74,694 - $71,187	$80,595 - $76,360	$497,109 - $480,200
Total Cost = Total Benefit	2010 2008	$28,621 - $34,195	$32,625 - $38,340	$45,037 - $43,337	$52,566 - $52,880	$58,957 - $59,629	$64,273 - $65,194	$71,657 - $70,606	$80,198 - $77,820	$85,543 - $84,341	$519,478 - $526,341

[580] These benefits are considered from a "societal perspective" because they include externalities. They are distinguished from a consumer perspective, because consumers generally would not think about the value of carbon dioxide, energy security, etc. This table includes only social benefits; the corresponding social costs are included in Table X-1.

Table X-3b
Present Value of Lifetime Societal Benefits by Alternative
Light Trucks, 3% Discount Rate
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$4,388 - $3,430	$5,868 - $7,976	$14,954 - $14,829	$19,870 - $21,498	$27,579 - $29,219	$30,592 - $33,374	$34,742 - $36,035	$38,691 - $40,324	$40,159 - $44,838	$216,842 - $231,523
2% Annual Increase	2010 2008	$9,939 - $7,528	$10,723 - $10,510	$15,393 - $14,918	$17,403 - $19,141	$19,356 - $22,746	$21,270 - $25,347	$23,726 - $26,818	$26,166 - $28,792	$26,916 - $30,049	$170,892 - $185,849
3% Annual Increase	2010 2008	$11,983 - $10,205	$13,299 - $14,101	$19,689 - $21,375	$24,595 - $27,770	$29,699 - $33,034	$32,616 - $36,078	$36,653 - $38,540	$39,090 - $41,313	$41,457 - $43,688	$249,080 - $266,104
4% Annual Increase	2010 2008	$12,424 - $13,062	$15,080 - $18,041	$22,708 - $27,140	$28,976 - $34,540	$35,597 - $40,576	$38,631 - $43,886	$42,757 - $47,289	$46,959 - $50,252	$51,680 - $52,990	$294,811 - $327,776
5% Annual Increase	2010 2008	$13,587 - $14,886	$16,288 - $21,130	$25,710 - $31,711	$32,799 - $41,217	$40,027 - $47,024	$43,494 - $50,923	$49,223 - $54,129	$53,760 - $57,927	$57,830 - $61,039	$332,719 - $379,986
6% Annual Increase	2010 2008	$15,518 - $17,355	$18,317 - $23,627	$27,050 - $34,101	$34,537 - $44,752	$42,482 - $50,979	$46,264 - $55,322	$51,805 - $57,468	$57,401 - $61,941	$63,747 - $66,600	$357,121 - $412,143
7% Annual Increase	2010 2008	$16,678 - $18,772	$19,817 - $26,200	$29,088 - $36,181	$37,251 - $45,423	$44,825 - $52,959	$48,012 - $57,010	$53,251 - $60,351	$57,780 - $63,487	$62,575 - $68,192	$369,275 - $428,576
Max Net Benefits	2010 2008	$16,794 - $26,116	$19,135 - $29,996	$27,735 - $36,862	$34,273 - $45,119	$41,705 - $51,142	$44,660 - $53,847	$49,478 - $56,135	$52,658 - $58,957	$57,092 - $62,072	$343,531 - $420,245
Total Cost = Total Benefit	2010 2008	$17,491 - $26,847	$19,733 - $30,611	$27,100 - $37,631	$34,841 - $45,375	$42,388 - $51,005	$44,579 - $53,652	$49,320 - $56,245	$52,982 - $58,900	$57,465 - $62,293	$345,900 - $422,557

Table X-3c
Present Value of Lifetime Societal Benefits by Alternative
Passenger Cars and Light Trucks Combined, 3% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$17,295 - $14,236	$24,604 - $26,644	$43,827 - $42,615	$55,849 - $59,896	$72,461 - $74,433	$80,442 - $85,289	$91,704 - $92,791	$104,140 - $104,694	$110,343 - $115,948	$600,666 - $616,546
2% Annual Increase	2010 2008	$15,776 - $14,466	$20,057 - $21,959	$29,801 - $30,818	$37,885 - $40,978	$44,515 - $48,625	$49,295 - $54,715	$55,976 - $60,651	$64,087 - $68,352	$67,143 - $72,792	$384,534 - $413,358
3% Annual Increase	2010 2008	$21,903 - $19,660	$27,865 - $30,874	$42,325 - $45,085	$55,349 - $60,842	$65,136 - $70,981	$72,558 - $79,593	$83,025 - $86,103	$94,326 - $93,456	$101,597 - $100,152	$564,084 - $586,747
4% Annual Increase	2010 2008	$26,329 - $26,416	$34,620 - $40,126	$52,677 - $57,046	$68,972 - $75,018	$84,442 - $88,180	$92,457 - $97,592	$102,873 - $106,531	$113,646 - $117,264	$125,516 - $127,037	$701,532 - $735,211
5% Annual Increase	2010 2008	$30,952 - $30,933	$40,567 - $46,517	$62,573 - $65,934	$80,049 - $88,128	$95,321 - $102,867	$104,428 - $112,464	$117,213 - $121,449	$130,900 - $134,569	$144,490 - $145,651	$806,494 - $848,511
6% Annual Increase	2010 2008	$35,659 - $36,932	$45,863 - $52,998	$68,882 - $72,053	$84,748 - $95,243	$102,443 - $110,396	$111,490 - $123,857	$125,514 - $132,664	$142,786 - $147,544	$158,062 - $164,314	$875,445 - $936,001
7% Annual Increase	2010 2008	$40,802 - $41,930	$51,851 - $59,554	$74,502 - $78,747	$90,785 - $99,823	$106,342 - $116,098	$118,436 - $130,637	$130,922 - $139,882	$145,834 - $153,792	$160,961 - $166,322	$920,436 - $986,784
Max Net Benefits	2010 2008	$44,606 - $54,573	$51,165 - $63,762	$71,963 - $77,108	$85,625 - $94,485	$99,059 - $107,470	$106,475 - $114,111	$116,708 - $120,362	$127,352 - $130,144	$137,687 - $138,432	$840,640 - $900,445
Total Cost = Total Benefit	2010 2008	$46,113 - $61,043	$52,359 - $68,950	$72,137 - $80,968	$87,407 - $98,254	$101,345 - $110,633	$108,852 - $118,846	$120,977 - $126,851	$133,179 - $136,719	$143,009 - $146,634	$865,378 - $948,898

Table X-4a
Present Value of Lifetime Societal Benefits[581] by Alternative
Passenger Cars, 7% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$10,334 - $8,655	$15,012 - $14,957	$23,133 - $22,270	$28,828 - $30,770	$35,972 - $36,237	$39,953 - $41,603	$45,658 - $45,486	$52,455 - $51,588	$56,245 - $56,963	$307,591 - $308,529
2% Annual Increase	2010 2008	$4,677 - $5,557	$7,483 - $9,171	$11,549 - $12,740	$16,408 - $17,496	$20,157 - $20,737	$22,452 - $23,530	$25,841 - $27,112	$30,383 - $31,702	$32,229 - $34,247	$171,179 - $182,292
3% Annual Increase	2010 2008	$7,942 - $7,573	$11,670 - $13,438	$18,135 - $19,002	$24,641 - $26,500	$28,397 - $30,408	$32,005 - $34,866	$37,166 - $38,115	$44,269 - $41,783	$48,191 - $45,232	$252,416 - $256,917
4% Annual Increase	2010 2008	$11,136 - $10,695	$15,657 - $17,693	$24,012 - $23,968	$32,048 - $32,435	$39,147 - $38,150	$43,137 - $43,036	$48,184 - $47,472	$53,447 - $53,696	$59,160 - $59,305	$325,927 - $326,451
5% Annual Increase	2010 2008	$13,908 - $12,850	$19,458 - $20,338	$29,536 - $27,425	$37,857 - $37,576	$44,307 - $44,735	$48,820 - $49,299	$54,476 - $53,930	$61,803 - $61,392	$69,366 - $67,739	$379,531 - $375,284
6% Annual Increase	2010 2008	$16,132 - $15,675	$22,076 - $23,527	$33,519 - $30,413	$40,234 - $40,453	$48,036 - $47,588	$52,251 - $54,856	$59,027 - $60,173	$68,312 - $68,470	$75,414 - $78,069	$414,999 - $419,223
7% Annual Increase	2010 2008	$19,324 - $18,543	$25,675 - $26,712	$36,384 - $34,102	$42,890 - $43,579	$49,291 - $50,549	$56,369 - $58,878	$62,145 - $63,596	$70,433 - $72,158	$78,659 - $78,378	$441,170 - $446,496
Max Net Benefits	2010 2008	$21,104 - $22,376	$24,397 - $25,644	$33,058 - $30,088	$39,268 - $36,256	$44,064 - $41,354	$46,782 - $44,370	$50,172 - $47,796	$56,356 - $52,932	$60,041 - $57,739	$375,241 - $358,554
Total Cost = Total Benefit	2010 2008	$22,925 - $27,356	$26,145 - $30,685	$36,061 - $34,701	$42,096 - $42,336	$47,221 - $47,746	$51,475 - $52,197	$57,373 - $56,534	$64,211 - $62,303	$68,482 - $67,503	$415,988 - $421,362

[581] These benefits are considered from a "societal perspective" because they include externalities. They are distinguished from a consumer perspective, because consumers generally would not think about the value of carbon dioxide, energy security, etc. This table includes only social benefits; the corresponding social costs are included in Table X-2.

Table X-4b
Present Value of Lifetime Societal Benefits by Alternative
Light Trucks, 7% Discount Rate
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$3,483 - $2,717	$4,659 - $6,323	$11,863 - $11,755	$15,773 - $17,051	$21,876 - $23,171	$24,263 - $26,462	$27,545 - $28,570	$30,672 - $31,971	$31,831 - $35,544	$171,965 - $183,564
2% Annual Increase	2010 2008	$7,876 - $5,967	$8,501 - $8,333	$12,207 - $11,826	$13,804 - $15,180	$15,354 - $18,036	$16,871 - $20,097	$18,816 - $21,262	$20,748 - $22,827	$21,338 - $23,821	$135,515 - $147,350
3% Annual Increase	2010 2008	$9,501 - $8,089	$10,548 - $11,181	$15,614 - $16,944	$19,514 - $22,022	$23,555 - $26,195	$25,865 - $28,604	$29,058 - $30,552	$30,987 - $32,753	$32,859 - $34,631	$197,500 - $210,972
4% Annual Increase	2010 2008	$9,850 - $10,355	$11,957 - $14,306	$18,008 - $21,512	$22,990 - $27,389	$28,231 - $32,172	$30,635 - $34,792	$33,899 - $37,484	$37,228 - $39,835	$40,950 - $42,000	$233,747 - $259,845
5% Annual Increase	2010 2008	$10,773 - $11,800	$12,916 - $16,752	$20,389 - $25,134	$26,022 - $32,680	$31,743 - $37,282	$34,487 - $40,369	$39,018 - $42,905	$42,612 - $45,916	$45,828 - $48,356	$263,788 - $301,194
6% Annual Increase	2010 2008	$12,305 - $13,754	$14,527 - $18,729	$21,451 - $27,027	$27,401 - $35,466	$33,690 - $40,400	$36,683 - $43,836	$41,065 - $45,533	$45,484 - $49,068	$50,495 - $52,752	$283,102 - $326,565
7% Annual Increase	2010 2008	$13,224 - $14,883	$15,715 - $20,771	$23,066 - $28,680	$29,545 - $36,017	$35,540 - $41,993	$38,063 - $45,194	$42,203 - $47,828	$45,781 - $50,312	$49,578 - $54,010	$292,716 - $339,687
Max Net Benefits	2010 2008	$13,506 - $20,101	$15,190 - $23,201	$21,984 - $28,917	$27,071 - $34,022	$32,702 - $38,482	$34,834 - $40,591	$38,712 - $41,985	$41,481 - $43,986	$46,103 - $46,417	$271,583 - $317,700
Total Cost = Total Benefit	2010 2008	$13,867 - $21,281	$15,647 - $24,269	$21,490 - $29,835	$27,642 - $35,953	$33,617 - $40,412	$35,347 - $42,504	$39,097 - $44,555	$41,996 - $46,659	$45,532 - $49,342	$274,236 - $334,812

Table X-4c
Present Value of Lifetime Societal Benefits by Alternative
Passenger Cars and Light Trucks Combined, 7% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$13,817 - $11,373	$19,671 - $21,280	$34,996 - $34,025	$44,601 - $47,821	$57,847 - $59,408	$64,216 - $68,065	$73,203 - $74,056	$83,127 - $83,560	$88,076 - $92,506	$479,555 - $492,093
2% Annual Increase	2010 2008	$12,553 - $11,524	$15,984 - $17,504	$23,755 - $24,567	$30,212 - $32,676	$35,511 - $38,773	$39,322 - $43,626	$44,657 - $48,374	$51,131 - $54,529	$53,568 - $58,068	$306,693 - $329,642
3% Annual Increase	2010 2008	$17,443 - $15,662	$22,218 - $24,619	$33,750 - $35,946	$44,155 - $48,523	$51,951 - $56,603	$57,870 - $63,470	$66,224 - $68,667	$75,256 - $74,537	$81,050 - $79,863	$449,916 - $467,889
4% Annual Increase	2010 2008	$20,986 - $21,050	$27,614 - $31,998	$42,020 - $45,481	$55,037 - $59,824	$67,378 - $70,322	$73,771 - $77,828	$82,083 - $84,956	$90,675 - $93,531	$100,109 - $101,305	$559,674 - $586,296
5% Annual Increase	2010 2008	$24,681 - $24,651	$32,374 - $37,090	$49,924 - $52,559	$63,879 - $70,256	$76,051 - $82,017	$83,307 - $89,667	$93,494 - $96,836	$104,415 - $107,308	$115,194 - $116,094	$643,320 - $676,477
6% Annual Increase	2010 2008	$28,436 - $29,429	$36,602 - $42,256	$54,970 - $57,440	$67,635 - $75,919	$81,725 - $87,988	$88,934 - $98,691	$100,092 - $105,706	$113,797 - $117,538	$125,910 - $130,821	$698,101 - $745,788
7% Annual Increase	2010 2008	$32,549 - $33,426	$41,389 - $47,483	$59,450 - $62,782	$72,435 - $79,596	$84,831 - $92,542	$94,433 - $104,072	$104,348 - $111,424	$116,214 - $122,470	$128,237 - $132,388	$733,887 - $786,183
Max Net Benefits	2010 2008	$34,610 - $42,476	$39,587 - $48,846	$55,042 - $59,005	$66,339 - $70,278	$76,766 - $79,836	$81,616 - $84,960	$88,883 - $89,780	$97,837 - $96,917	$106,144 - $104,156	$646,825 - $676,254
Total Cost = Total Benefit	2010 2008	$36,793 - $48,637	$41,792 - $54,954	$57,552 - $64,537	$69,738 - $78,290	$80,838 - $88,158	$86,822 - $94,701	$96,469 - $101,089	$106,207 - $108,963	$114,014 - $116,845	$690,224 - $756,173

Table X-5a
Net Total Benefits[582]
Over the Vehicle's Lifetime – Present Value
Passenger Cars, 3% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$9,416 - $8,199	$13,568 - $13,985	$21,234 - $20,495	$26,378 - $27,589	$32,776 - $31,972	$36,420 - $36,638	$41,844 - $40,151	$47,407 - $44,992	$51,342 - $49,513	$280,386 - $273,534
2% Annual Increase	2010 2008	$4,232 - $5,331	$6,531 - $8,589	$10,138 - $11,656	$14,680 - $15,830	$17,942 - $18,749	$19,989 - $21,298	$23,190 - $24,718	$27,100 - $28,856	$29,169 - $31,804	$152,970 - $166,831
3% Annual Increase	2010 2008	$7,314 - $7,275	$10,673 - $12,606	$16,558 - $17,794	$22,832 - $24,399	$26,530 - $27,826	$29,774 - $31,830	$34,727 - $35,202	$41,153 - $38,442	$45,146 - $41,642	$234,706 - $237,016
4% Annual Increase	2010 2008	$9,742 - $10,209	$13,778 - $16,490	$21,395 - $22,116	$28,807 - $29,209	$35,276 - $33,965	$38,974 - $38,093	$43,676 - $41,787	$48,160 - $46,966	$53,087 - $52,136	$292,896 - $290,972
5% Annual Increase	2010 2008	$12,354 - $12,205	$17,214 - $18,744	$25,446 - $25,053	$32,535 - $32,290	$37,898 - $37,110	$41,265 - $40,209	$45,142 - $43,088	$50,350 - $47,257	$55,398 - $52,801	$317,601 - $308,757
6% Annual Increase	2010 2008	$14,610 - $14,216	$19,528 - $20,769	$28,592 - $26,847	$33,347 - $33,894	$37,787 - $37,005	$40,853 - $39,222	$42,173 - $41,017	$43,047 - $41,837	$51,658 - $48,357	$311,597 - $303,165
7% Annual Increase	2010 2008	$16,277 - $16,351	$21,048 - $22,223	$28,525 - $28,170	$33,794 - $34,235	$37,088 - $34,744	$35,898 - $34,555	$35,654 - $36,321	$37,682 - $34,298	$47,379 - $45,549	$293,345 - $286,447
Max Net Benefits	2010 2008	$18,917 - $19,061	$21,712 - $22,648	$28,376 - $25,708	$33,486 - $31,396	$37,674 - $36,022	$40,620 - $39,004	$44,191 - $41,840	$48,010 - $45,767	$53,520 - $50,806	$326,506 - $312,251
Total Cost = Total Benefit	2010 2008	$19,495 - $19,298	$22,054 - $22,676	$28,016 - $25,954	$33,493 - $32,184	$37,066 - $36,553	$40,554 - $39,957	$43,089 - $43,119	$47,481 - $47,018	$54,256 - $53,103	$325,503 - $319,863

[582] This table is from a societal perspective, thus, civil penalties are deleted from the costs because they are a transfer payment (from manufacturers to the U.S. Treasury).

Table X-5b
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
Light Trucks, 3% Discount Rate
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$3,332 - $2,786	$4,613 - $6,591	$12,064 - $12,286	$15,893 - $17,890	$21,798 - $24,294	$24,365 - $27,657	$27,847 - $29,905	$31,051 - $33,576	$32,648 - $37,026	$173,613 - $192,012
2% Annual Increase	2010 2008	$7,462 - $6,473	$8,228 - $8,886	$12,270 - $12,713	$13,973 - $16,150	$15,587 - $19,183	$17,158 - $21,296	$19,264 - $22,671	$21,265 - $24,307	$22,056 - $25,497	$137,263 - $157,176
3% Annual Increase	2010 2008	$9,099 - $8,830	$10,342 - $12,051	$15,833 - $18,215	$19,619 - $23,337	$23,778 - $27,692	$26,270 - $30,138	$29,612 - $32,260	$31,622 - $34,460	$33,725 - $36,516	$199,899 - $223,499
4% Annual Increase	2010 2008	$9,340 - $10,957	$11,614 - $15,033	$18,173 - $22,492	$22,906 - $28,268	$28,415 - $32,879	$30,879 - $35,556	$34,226 - $38,344	$37,502 - $40,571	$41,064 - $42,889	$234,120 - $266,990
5% Annual Increase	2010 2008	$10,346 - $12,245	$12,552 - $17,261	$20,052 - $25,692	$24,325 - $32,252	$29,464 - $36,316	$31,968 - $38,733	$36,249 - $41,242	$39,070 - $43,351	$42,538 - $46,173	$246,563 - $293,265
6% Annual Increase	2010 2008	$11,917 - $13,803	$14,130 - $18,720	$20,636 - $26,893	$25,173 - $33,021	$30,354 - $37,356	$33,126 - $39,899	$37,188 - $41,269	$39,839 - $43,126	$44,477 - $47,266	$256,840 - $301,352
7% Annual Increase	2010 2008	$12,338 - $15,007	$14,724 - $20,657	$21,669 - $27,875	$26,214 - $32,915	$31,613 - $37,608	$33,874 - $39,609	$37,765 - $40,940	$39,838 - $42,502	$43,913 - $45,853	$261,948 - $302,967
Max Net Benefits	2010 2008	$12,048 - $19,134	$14,041 - $22,325	$20,683 - $27,959	$25,041 - $32,331	$30,738 - $36,993	$33,051 - $39,161	$36,667 - $40,882	$39,055 - $42,521	$42,885 - $46,196	$254,209 - $307,502
Total Cost = Total Benefit	2010 2008	$12,561 - $19,464	$14,464 - $22,615	$20,294 - $28,399	$25,134 - $32,008	$31,031 - $36,242	$32,770 - $38,274	$36,340 - $40,140	$39,092 - $41,808	$42,851 - $45,723	$254,538 - $304,673

Table X-5c
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
Passenger Cars and Light Trucks Combined, 3% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$12,748 - $10,986	$18,181 - $20,576	$33,299 - $32,781	$42,271 - $45,479	$54,574 - $56,266	$60,785 - $64,295	$69,691 - $70,056	$78,458 - $78,568	$83,990 - $86,539	$453,998 - $465,546
2% Annual Increase	2010 2008	$11,693 - $11,804	$14,759 - $17,475	$22,408 - $24,370	$28,653 - $31,980	$33,528 - $37,931	$37,147 - $42,594	$42,453 - $47,389	$48,366 - $53,163	$51,225 - $57,301	$290,233 - $324,006
3% Annual Increase	2010 2008	$16,413 - $16,106	$21,015 - $24,656	$32,391 - $36,009	$42,452 - $47,736	$50,308 - $55,519	$56,044 - $61,967	$64,339 - $67,462	$72,774 - $72,903	$78,871 - $78,157	$434,605 - $460,515
4% Annual Increase	2010 2008	$19,082 - $21,167	$25,393 - $31,523	$39,568 - $44,607	$51,713 - $57,477	$63,691 - $66,844	$69,853 - $73,649	$77,902 - $80,131	$85,662 - $87,536	$94,151 - $95,026	$527,016 - $557,961
5% Annual Increase	2010 2008	$22,700 - $24,450	$29,766 - $36,004	$45,498 - $50,746	$56,859 - $64,542	$67,362 - $73,426	$73,232 - $78,942	$81,391 - $84,330	$89,419 - $90,608	$97,936 - $98,975	$564,164 - $602,023
6% Annual Increase	2010 2008	$26,527 - $28,019	$33,658 - $39,489	$49,227 - $53,740	$58,520 - $66,915	$68,141 - $74,362	$73,979 - $79,121	$79,361 - $82,285	$82,887 - $84,963	$96,136 - $95,623	$568,437 - $604,517
7% Annual Increase	2010 2008	$28,616 - $31,358	$35,773 - $42,879	$50,194 - $56,046	$60,008 - $67,150	$68,701 - $72,352	$69,772 - $74,164	$73,418 - $77,262	$77,521 - $76,800	$91,292 - $91,402	$555,293 - $589,414
Max Net Benefits	2010 2008	$30,965 - $38,194	$35,753 - $44,974	$49,059 - $53,667	$58,527 - $63,727	$68,412 - $73,015	$73,671 - $78,165	$80,858 - $82,722	$87,065 - $88,288	$96,405 - $97,002	$580,715 - $619,754
Total Cost = Total Benefit	2010 2008	$32,057 - $38,762	$36,517 - $45,290	$48,309 - $54,354	$58,627 - $64,192	$68,098 - $72,796	$73,324 - $78,231	$79,429 - $83,259	$86,573 - $88,826	$97,107 - $98,826	$580,042 - $624,536

Table X-6a
Net Total Benefits[583]
Over the Vehicle's Lifetime – Present Value
Passenger Cars, 7% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$6,980 - $6,178	$10,047 - $10,510	$15,852 - $15,365	$19,660 - $20,481	$24,458 - $23,581	$27,200 - $27,008	$31,335 - $29,635	$35,332 - $33,066	$38,395 - $36,329	$209,258 - $202,153
2% Annual Increase	2010 2008	$3,137 - $4,041	$4,786 - $6,468	$7,486 - $8,746	$10,905 - $11,814	$13,301 - $13,976	$14,849 - $15,900	$17,314 - $18,507	$20,205 - $21,597	$21,843 - $23,941	$113,828 - $124,991
3% Annual Increase	2010 2008	$5,442 - $5,511	$7,938 - $9,494	$12,353 - $13,423	$17,127 - $18,279	$19,956 - $20,787	$22,388 - $23,764	$26,209 - $26,401	$31,009 - $28,801	$34,079 - $31,198	$176,501 - $177,658
4% Annual Increase	2010 2008	$7,120 - $7,700	$10,106 - $12,370	$15,815 - $16,573	$21,362 - $21,701	$26,217 - $25,121	$29,001 - $28,125	$32,570 - $30,798	$35,852 - $34,525	$39,463 - $38,392	$217,506 - $215,305
5% Annual Increase	2010 2008	$9,081 - $9,186	$12,656 - $13,999	$18,589 - $18,703	$23,758 - $23,571	$27,641 - $26,715	$30,006 - $28,800	$32,603 - $30,659	$36,152 - $33,129	$39,523 - $37,322	$230,008 - $222,085
6% Annual Increase	2010 2008	$10,816 - $10,528	$14,354 - $15,276	$20,802 - $19,789	$24,050 - $24,518	$26,700 - $25,992	$28,817 - $26,647	$28,671 - $27,340	$27,549 - $26,424	$34,569 - $31,032	$216,329 - $207,547
7% Annual Increase	2010 2008	$11,733 - $11,986	$15,033 - $15,978	$20,071 - $20,255	$23,871 - $24,164	$25,717 - $23,182	$23,045 - $21,304	$21,657 - $22,062	$21,949 - $18,396	$29,830 - $28,244	$192,907 - $185,571
Max Net Benefits	2010 2008	$13,320 - $13,675	$15,368 - $15,848	$21,168 - $18,165	$24,603 - $21,813	$27,428 - $25,060	$29,321 - $27,258	$31,633 - $29,550	$34,963 - $32,481	$38,549 - $36,255	$236,353 - $220,105
Total Cost = Total Benefit	2010 2008	$14,103 - $12,958	$15,923 - $15,556	$19,641 - $17,938	$23,744 - $22,408	$26,161 - $25,555	$28,689 - $27,949	$29,937 - $30,132	$32,819 - $32,733	$38,600 - $37,693	$229,616 - $222,923

583 This table is from a societal perspective, thus, civil penalties are deleted from the costs because they are a transfer payment (from manufacturers to the U.S. Treasury).

Table X-6b
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
Light Trucks, 7% Discount Rate
(Millions of 2010 Dollars)

Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$2,464 - $2,105	$3,453 - $5,025	$9,105 - $9,374	$11,956 - $13,671	$16,342 - $18,531	$18,323 - $21,076	$20,986 - $22,796	$23,439 - $25,623	$24,740 - $28,178	$130,808 - $146,381
2% Annual Increase	2010 2008	$5,482 - $4,975	$6,095 - $6,816	$9,217 - $9,771	$10,521 - $12,396	$11,753 - $14,705	$12,963 - $16,306	$14,598 - $17,384	$16,140 - $18,640	$16,779 - $19,582	$103,547 - $120,577
3% Annual Increase	2010 2008	$6,718 - $6,800	$7,702 - $9,267	$11,927 - $13,987	$14,753 - $17,861	$17,906 - $21,158	$19,829 - $23,011	$22,393 - $24,647	$23,938 - $26,311	$25,568 - $27,896	$150,732 - $170,939
4% Annual Increase	2010 2008	$6,872 - $8,360	$8,617 - $11,474	$13,664 - $17,123	$17,166 - $21,453	$21,371 - $24,832	$23,243 - $26,856	$25,781 - $28,974	$28,244 - $30,622	$30,878 - $32,393	$175,837 - $202,086
5% Annual Increase	2010 2008	$7,646 - $9,281	$9,315 - $13,083	$14,952 - $19,414	$17,857 - $24,117	$21,574 - $27,002	$23,405 - $28,664	$26,572 - $30,536	$28,509 - $31,902	$31,169 - $34,104	$181,000 - $218,101
6% Annual Increase	2010 2008	$8,833 - $10,344	$10,490 - $14,043	$15,268 - $20,129	$18,355 - $24,205	$21,980 - $27,294	$24,016 - $29,000	$26,996 - $29,946	$28,577 - $30,931	$31,977 - $34,142	$186,492 - $220,033
7% Annual Increase	2010 2008	$9,023 - $11,270	$10,790 - $15,471	$15,901 - $20,707	$18,880 - $23,977	$22,787 - $27,172	$24,435 - $28,397	$27,306 - $29,071	$28,521 - $30,023	$31,650 - $32,450	$189,294 - $218,538
Max Net Benefits	2010 2008	$8,896 - $13,589	$10,305 - $16,072	$15,296 - $20,667	$18,402 - $23,400	$22,360 - $26,590	$23,916 - $28,294	$26,723 - $29,552	$28,652 - $30,804	$32,077 - $33,414	$186,627 - $222,381
Total Cost = Total Benefit	2010 2008	$9,082 - $14,130	$10,540 - $16,551	$14,920 - $20,951	$18,273 - $23,081	$22,666 - $26,195	$23,970 - $27,707	$26,616 - $29,056	$28,662 - $30,206	$31,538 - $33,438	$186,266 - $221,316

Table X-6c
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
Passenger Cars and Light Trucks Combined, 7% Discount Rate
(Millions of 2010 Dollars)

Passenger Cars and Light Trucks	Baseline Fleet	MY 2017	MY 2018	MY 2019	MY 2020	MY 2021	MY 2022	MY 2023	MY 2024	MY 2025	9-Year Total
Preferred Alternative	2010 2008	$9,444 - $8,284	$13,500 - $15,535	$24,957 - $24,739	$31,616 - $34,152	$40,800 - $42,112	$45,523 - $48,085	$52,320 - $52,431	$58,771 - $58,689	$63,135 - $64,507	$340,066 - $348,534
2% Annual Increase	2010 2008	$8,620 - $9,016	$10,881 - $13,285	$16,703 - $18,517	$21,426 - $24,211	$25,054 - $28,681	$27,812 - $32,206	$31,912 - $35,892	$36,345 - $40,237	$38,622 - $43,523	$217,375 - $245,568
3% Annual Increase	2010 2008	$12,160 - $12,311	$15,640 - $18,761	$24,279 - $27,411	$31,880 - $36,140	$37,862 - $41,945	$42,217 - $46,776	$48,602 - $51,047	$54,947 - $55,112	$59,647 - $59,094	$327,233 - $348,597
4% Annual Increase	2010 2008	$13,992 - $16,060	$18,723 - $23,844	$29,479 - $33,696	$38,528 - $43,154	$47,588 - $49,952	$52,244 - $54,981	$58,351 - $59,772	$64,096 - $65,146	$70,341 - $70,785	$393,342 - $417,391
5% Annual Increase	2010 2008	$16,727 - $18,467	$21,971 - $27,081	$33,541 - $38,117	$41,615 - $47,688	$49,215 - $53,718	$53,411 - $57,464	$59,175 - $61,195	$64,661 - $65,030	$70,693 - $71,426	$411,008 - $440,187
6% Annual Increase	2010 2008	$19,649 - $20,872	$24,845 - $29,319	$36,071 - $39,917	$42,405 - $48,723	$48,680 - $53,287	$52,833 - $55,647	$55,667 - $57,286	$56,126 - $57,355	$66,546 - $65,174	$402,821 - $427,580
7% Annual Increase	2010 2008	$20,756 - $23,256	$25,823 - $31,449	$35,973 - $40,962	$42,752 - $48,141	$48,504 - $50,355	$47,480 - $49,701	$48,963 - $51,133	$50,470 - $48,419	$61,480 - $60,694	$382,200 - $404,109
Max Net Benefits	2010 2008	$22,216 - $27,264	$25,673 - $31,920	$36,464 - $38,832	$43,005 - $45,212	$49,788 - $51,650	$53,237 - $55,552	$58,356 - $59,101	$63,615 - $63,285	$70,627 - $69,669	$422,980 - $442,486
Total Cost = Total Benefit	2010 2008	$23,185 - $27,089	$26,463 - $32,107	$34,561 - $38,889	$42,017 - $45,489	$48,827 - $51,749	$52,659 - $55,657	$56,553 - $59,188	$61,480 - $62,939	$70,138 - $71,131	$415,883 - $444,239

Breakdown of costs and benefits for the preferred alternative

Table X-7 provides a breakdown of the costs (parenthesized) and benefits for the preferred alternative using a 3 percent and 7 percent discount rate, respectively.

Table X-7[584]
Preferred Alternative
Cost and Benefit Estimates
Passenger Cars and Light Trucks Combined
MY 2017-2025 Combined
(Millions of 2010 Dollars)

Societal Effect	Baseline Fleet	Undiscounted Value	Sum of Present Discounted Values @ 3%	Sum of Present Discounted Values @ 7%
Lifetime Fuel Expenditures (Pretax)	2010 2008	\$577,260 - \$592,122	\$459,059 - \$470,819	\$358,200 - \$367,315
Consumer Surplus from Additional Driving	2010 2008	\$53,178 - \$53,817	\$42,264 - \$42,782	\$32,988 - \$33,398
Refueling Time Value	2010 2008	\$17,088 - \$19,794	\$13,769 - \$15,937	\$10,869 - \$12,575
Petroleum Market Externalities	2010 2008	\$29,626 - \$30,960	\$23,816 - \$24,888	\$18,776 - \$19,622
Maintenance Costs	2010 2008	(\$5,204) - (\$4,938)	(\$5,204) - (\$4,938)	(\$3,877) - (\$3,677)
Congestion Costs	2010 2008	(\$22,347) - (\$22,821)	(\$17,964) - (\$18,346)	(\$14,166) - (\$14,468)
Accident Costs	2010 2008	(\$10,492) - (\$10,725)	(\$8,425) - (\$8,612)	(\$6,639) - (\$6,787)
Noise Costs	2010 2008	(\$416) - (\$425)	(\$334) - (\$341)	(\$263) - (\$269)
Value of Reduced Fatalities	2010 2008	\$52 - \$680	\$20 - \$527	\$5 - \$406
Relative Value Loss (EVs)	2010 2008	(\$91) - (\$570)	(\$91) - (\$570)	(\$40) - (\$247)
CO2	2010 2008	\$59,625 - \$60,718	\$46,881 - \$47,745	\$46,881 - \$47,745

[584] The CAFE model estimates maintenance costs and relative value losses in discounted terms only. In the "undiscounted value" column of Tables X-7, the 3% discounted values for these categories are substituted. CO2 benefits are presented in undiscounted and 3% discounted levels only, in keeping with the application of inter-generational discounting.

CO	2010 2008	\$0 - \$0	\$0 - \$0	\$0 - \$0
VOC	2010 2008	\$674 - \$701	\$550 - \$571	\$440 - \$457
NOX	2010 2008	\$1,280 - \$1,338	\$1,072 - \$1,108	\$880 - \$900
PM	2010 2008	\$8,387 - \$8,434	\$6,839 - \$6,886	\$5,467 - \$5,509
SOX	2010 2008	\$7,070 - \$6,079	\$5,682 - \$4,878	\$4,478 - \$3,841
Total	2010 2008	\$715,690 - \$735,164	\$567,933 - \$583,333	\$454,001 - \$466,321

Payback Period

The "payback period" represents the length of time required for a vehicle buyer to recoup, through savings in fuel use, the higher cost of purchasing a more fuel-efficient vehicle. Thus, only these two factors are considered (purchase price and fuel savings). When a higher CAFE standard requires a manufacturer to improve the fuel economy of some of its vehicle models, the manufacturer's added costs for doing so are generally reflected in higher prices for these models. While buyers of these models pay higher prices to purchase these vehicles, their improved fuel economy lowers the consumer's costs for purchasing fuel to operate them. Over time, buyers may recoup the higher purchase prices they pay for these vehicles in the form of savings in outlays for fuel. The length of time required to repay the higher cost of buying a more fuel-efficient vehicle is referred to as the buyer's payback period.

The length of this payback period depends on the initial increase in a vehicle's purchase price, the improvement in its fuel economy, the number of miles it is driven each year, and the retail price of fuel. We calculated payback periods using the fuel economy improvement and average price increase estimated to result from the standard, the future retail gasoline prices, and estimates of the number of miles vehicles are driven each year as they age. These calculations are taken from a consumer's perspective, not a societal perspective. Thus, only gasoline savings are included on the benefits side of the equation. The price of gasoline includes fuel taxes, since consumers generally only consider and respond to what they pay at the pump, and future savings are discounted to present value using a 3% discount rate or a 7% discount rate. The payback periods are estimated as an average for all manufacturers for the different alternatives. The payback periods for MY 2025 are shown in Table X-8. Discounted at 7%, the payback periods are slightly longer, since the benefits are discounted more.

Table X-8

Payback Period for MY 2025 Average Vehicles
(in years)

Alternative	Discount Rate	Baseline	Passenger Cars	Light Trucks	Combined
Preferred	3%	2010	3.0	1.8	2.6
	3%	2008	3.5	1.7	2.9
1%	3%	2010	2.6	1.4	2.2
	3%	2008	2.2	1.0	1.8
2%	3%	2010	2.8	1.7	2.4
	3%	2008	2.6	1.4	2.2
3%	3%	2010	2.6	1.8	2.3
	3%	2008	2.8	1.6	2.4
4%	3%	2010	3.1	2.0	2.8
	3%	2008	3.0	2.1	2.7
5%	3%	2010	4.1	2.8	3.7
	3%	2008	4.4	2.7	3.8
6%	3%	2010	5.5	3.5	4.8
	3%	2008	5.8	3.4	4.9
7%	3%	2010	6.9	3.9	5.8
	3%	2008	6.5	4.2	5.7
Max Net	3%	2010	3.8	2.7	3.4
	3%	2008	3.8	2.8	3.5
TC=TB	3%	2010	4.2	2.7	3.7
	3%	2008	4.3	2.9	3.8

Alternative	Discount Rate	Baseline	Passenger Cars	Light Trucks	Combined
Preferred	7%	2010	3.1	1.9	2.7
	7%	2008	3.8	1.8	3.1
1%	7%	2010	2.8	1.4	2.3
	7%	2008	2.3	1.0	1.9
2%	7%	2010	2.9	1.7	2.5
	7%	2008	2.7	1.4	2.3
3%	7%	2010	2.7	1.9	2.4
	7%	2008	3.0	1.6	2.5
4%	7%	2010	3.4	2.1	2.9
	7%	2008	3.2	2.2	2.9
5%	7%	2010	4.6	3.0	4.0
	7%	2008	4.9	2.8	4.2
6%	7%	2010	6.1	3.8	5.3
	7%	2008	6.5	3.7	5.5
7%	7%	2010	7.4	4.2	6.3
	7%	2008	7.4	4.7	6.4
Max Net	7%	2010	3.6	2.8	3.3
	7%	2008	3.8	2.7	3.4
TC=TB	7%	2010	4.6	2.9	4.0
	7%	2008	4.7	3.1	4.1

CUMULATIVE IMPACTS

Section 1(b) of Executive Order 13563 Improving Regulatory Planning and Review requires the agencies to take into account to the extent practicable "the costs of cumulative regulations." To adhere to this requirement, we examined the costs of all NHTSA light vehicle final rules with an effective date from MY 2010 or later. In addition, proposed rules which have been published in the Federal Register for light vehicles are also identified and preliminary cost estimates provided. The baseline for the fuel economy cost estimates for this final rule is the 2010 baseline. This analysis does not include potential rulemakings that are identified in the NHTSA priority plan[585], since final decisions have not been made whether those programs or projects will become rulemakings, what alternative will be proposed and the cost estimate for the proposal.

Costs include manufacturing cost per vehicle and fuel costs for safety standards that increase weight and also possible other operational costs. For fuel economy the costs are the per vehicle technology costs plus the costs of fines. These cost estimates are the same whether we use a 3 percent or 7 percent discount rate to discount future benefits or costs because they occur at the time the vehicle is purchased and no discounting is necessary. Instead of using the estimates from previous fuel economy regulatory impact analyses for MY 2011 through MY 2016, the costs provided in this analysis are those from the current Volpe model of costs manufacturers would incur to achieve the MY 2016 CAFE standards. Thus, they are the most up-to-date fuel economy estimates for previous years. The costs are not the same as shown throughout the rest of the analysis, since the baseline assumes that the 2010 standards would have been extended to apply to MYs 2011-25 if the agency had not adopted these higher standards, whereas the rest of the analysis starts with the MY 2016 standards. For safety standards, the cost per affected vehicle includes the most likely cost, in our opinion, from of the range of costs and countermeasures that any vehicle might incur. The cost per average vehicle takes into account voluntary compliance with the rule, and does not consider those vehicles that complied with the rule voluntarily as needing incremental costs, and the average cost for all vehicles that need to meet the rule. For fuel economy, the cost is based on the agency's most up-to-date estimates of the costs of technologies. All costs from previous years are adjusted to 2010 dollars using the implicit price deflator for gross domestic product (GDP).

The results of this analysis show that compared to a MY 2009 baseline, standards that are already final rules and have been proposed (including this rule) are estimated to add costs to the average passenger car and light truck as shown in Table X-9. Based on the final rules and augural rules, the average passenger car will increase in price by $2,236 and the average light

[585] "NHTSA Vehicle Safety and Fuel Economy Rulemaking and Research Priority Plan 2011-2013", March 2011 http://www.nhtsa.gov/Laws+&+Regulations/Vehicles/Vehicle+Safety+Rulemaking+and+Research+Priority+Plan+2009-2011 (last accessed August 1, 2012)

truck will increase in price by $2,186. Tables X-10, X-11, and X-12 provide a breakdown of those costs by model year, by vehicle type, and safety versus fuel economy rules.

Table X-9
Estimated Average Vehicle Increases in Consumer Cost
For Final and Augural Rules
For MY 2025 vehicles compared to MY 2009 vehicles
(in 2010 Economics)

	Safety Standards	Fuel Economy Standards	Total
Passenger Cars	$351	$1,885	$2,236
Light Trucks	$283	$1,903	$2,186

Table X-10
Costs of Passenger Car and Light Truck Safety Rulemakings
That Take Effect in MY 2010 or Later
(With a GVWR of 10,000 lbs. or less, in 2010 economics)

Final	Effective Model Year	Cost Per Affected Vehicle	Average Cost Per Vehicle	Total Industry Cost
FMVSS No. 214; Side Impact Protection[586]	2013	$277[587]	$38	Passenger cars: $355M Light trucks: $263, a total of $618M
FMVSS No. 226 Ejection Mitigation[588]	2017	$54[589]	$31	Passenger cars: $291M Light trucks: $216M, a total of $507M
FMVSS No. 216a Roof Crush Resistance, upgraded standard[590]	2015	$56	$54	Passenger cars: $192M Light trucks: $142M, a total of $334M[591]
FMVSS No. 202a Head Restraints[592]	2011	$7	$6	Passenger cars: $21M Light trucks: $16M, a total of $37M
FMVSS No. 208 Designated seating position	2010	$2.21 for passenger cars and $3.41 for light trucks[593]	$0.036 for passenger cars and $0.018 for light trucks[594]	Passenger cars: $0.349M Light trucks: $0.124M, a total of $0.473M[595]

[586] Docket No. 2007-29134-0004, 72 FR 51907. http://www.regulations.gov/#!documentDetail;D=NHTSA-2007-29134-0004

[587] The average incremental cost per vehicle was estimated to be $33 and the cost per affected vehicle was estimated to be $242 in 2004 economics. When adjusted with Gross Domestic Product (GDP), it resulted in $38 and $276 for the average cost and the affected vehicle cost, respectively, in 2010 economics.

[588] Docket No. 2011-0004-0003, 76 FR 3212. http://www.regulations.gov/#!documentDetail;D=NHTSA-2011-0004-0003

[589] The cost per affected vehicle was estimated to be $53 and the average incremental cost per vehicle was estimated to be $31 in 2009 economics. In 2010 economics, the affected vehicle and the average costs were estimated to be $54 and $31.

[590] Docket No. 2009-0093-0004, 74 FR 22347. http://www.regulations.gov/#!documentDetail;D=NHTSA-2009-0093-0004

[591] With the estimated $54 average vehicle cost, the total cost would be $334M, 192M for passenger cars and $142M for light trucks in 2010 economics.

[592] Docket No. 2004-19807-0001, 69 FR 74848. http://www.regulations.gov/#!documentDetail;D=NHTSA-2004-19807-0001.

[593] The cost per affected vehicles was estimated to be $2 for passenger cars and $3.07 for light trucks in 2005 economics. In 2010 economics, the costs were $2.21 and $3.41 for passenger cars and light trucks, respectively.

[594] When adjusted to the 2010 economics, it resulted in $0.036 for passenger cars and $0.018 for light trucks

FMVSS No. 126 Electronic Stability Control Systems[596]	2011	$532	$100 for passenger cars and $32 for light trucks[597]	Passenger cars: $801M Light trucks: $292M, a total of $1,093M
FMVSS No. 208 5th percentile female FMVSS 208 rule[598]	2013	$0 - $21.40	$0.31 for passenger cars and $0.32 for light trucks	Passenger cars: $2.9M Light trucks: $2.3M, a total cost of $5.2M
Proposed	Estimated Effective Model Year	Cost Per Affected Vehicle	Average Cost Per Vehicle	Total Cost
FMVSS No. 111 Rear Visibility[599]	2015[600]		$121	Passenger cars: $1,150M Light trucks: $855M, a total of $2,005M

[595] The total costs were estimated to be $0.314M for passenger cars and $0.112M for light trucks in 2005 economics. In 2010 economics, the total costs were $0.349M for passenger cars and $0.124M for light trucks
[596] Docket No. 2007-27662-2, 72 FR 17236. http://www.regulations.gov/#!documentDetail;D=NHTSA-2007-27662-0002
[597] The average vehicle costs were estimate to be $90 for average passenger car and $29 for average light trucks in 2005 economics. When adjusted to the 2010 economics, it resulted in $100 for passenger cars and $32 for light trucks.
[598] Docket No. 2005-22323-0002, 71 FR 51768. http://www.regulations.gov/#!documentDetail;D=NHTSA-2005-22323-0002
[599] Docket No. 2010-0162-0034, 75 FR 76186.
[600] Estimated effective date.
[601] The rear visibility cost numbers reflect the likely final rule of 130 degree cameras mounted in the dash. The cost per affected vehicle would be $159 in 2007 economics. The average vehicle cost would be $116 and the incremental total cost would be $1,919 million in 2007 economics based on 16.6 million sales in 2007. When adjusted with the 2010 economics, the cost per affected vehicle was estimated to be $166 and the average cost was estimated to be $121. The total cost was estimated to be $2,005M in 2010 economics.

Table X-11
Fuel Economy Costs of Passenger Cars
Incremental by Model Year
(in 2010 economics)

CAFE	Effective Model Year	Incremental Cost Per Average Vehicle $	Projected Sales in Analysis (millions of vehicles)	Total Industry Cost ($ millions)
Final Rules	2010	No change		$0
	2011	$33	9.3	$306
	2012	$91	9.1	$826
	2013	$129	9.8	$1,260
	2014	$146	10.2	$1,485
	2015	$148	10.6	$1,567
	2016	$202	10.8	$2,180
Final Rule	2017	$85	10.0	$847
	2018	$170	9.9	$1,684
	2019	$151	10.0	$1,507
	2020	$170	10.3	$1,746
	2021	$169	10.5	$1,777
Augural Rule	2022	$84	10.7	$903
	2023	$99	11.0	$1,093
	2024	$192	11.3	$2,168
	2025	$17	11.5	$201

Table X-12
Fuel Economy Costs of Light Trucks
Incremental by Model Year
(in 2010 economics)

CAFE	Effective Model Year	Incremental Cost Per Average Vehicle $	Projected Sales in Analysis (millions of vehicles)	Total Industry Cost ($ millions)
Final Rules	2010	$0	9.0	$0
	2011	$105	6.9	$726
	2012	$123	5.8	$714
	2013	$88	6.0	$526
	2014	$247	5.9	$1,458
	2015	$215	5.8	$1,245
	2016	$162	5.7	$926
Final Rule	2017	$78	5.8	$450
	2018	$69	5.7	$391
	2019	$197	5.6	$1,105
	2020	$209	5.6	$1,171
	2021	$286	5.7	$1,627
Augural Rule	2022	$35	5.7	$200
	2023	$78	5.7	$447
	2024	$69	5.7	$393
	2025	$-58	5.7	$-329

The light truck costs for MY 2025 are negative in Table X-12 ($-58). This appears to be the result of a combination of the achieved level of light truck fuel economy with the 2010 baseline increasing only from 37.4 to 37.6 mpg, the learning curve on costs being applied to the specific technologies used, and multi-year planning. This analysis reports incremental impacts accruing over the useful life of vehicles sold in a given model year, relative to impacts accruing over the useful life of vehicles sold in the preceding model year. Incremental impacts in each model year are attributed to standards applicable in that model year. However, because of multiyear planning effects, an increase in stringency in one model year, if assumed to carry forward indefinitely for purposes of defining a baseline for analysis of standards in the ensuing model year, would have impacts both in earlier model years and in later model years. Therefore, in any given model year, the impacts of CAFE standards could be more precisely attributed to a range of model years around that model year. For example, impacts attributable to the MY 2020 fleet can be attributed to standards applicable through MY 2019, in MY 2020, and (because of multiyear planning effects) after MY 2020. By the same token, the MY 2020 standards produce impacts before MY 2020, in MY 2020, and after MY 2020. However, such accounting would require incremental analysis with a dynamic baseline—analysis NHTSA has not conducted for today's rulemaking. For future rulemakings, NHTSA will give further consideration to the attribution of impacts to CAFE standards applicable in each of a series of model years, and to the practicality of analysis to support alternative approaches to attribution.

Tables X-13 and X-14 show the cumulative safety and fuel economy costs on a per vehicle basis and also total costs for the industry (multiplying average costs per vehicle by projected sales). These cumulative costs are compared to MY 2009 vehicles. The baseline for the fuel economy cost estimates for this final rule is the 2010 baseline.

Table X-13
Cumulative Cost Effects of Recent Passenger Cars Rules and Proposals
(in 2010 economics)

MY	Average Cost per Vehicle, Cumulative Safety and Fuel Economy Costs	Total Cost (in $M's)
2010	$0	$0
2011	$139	$1,040
2012	$229	$1,966
2013	$397	$4,525
2014	$542	$8,291
2015	$865	$14,991
2016	$1,067	$22,511
2017	$1,183	$31,112
2018	$1,353	$41,094
2019	$1,504	$52,613
2020	$1,673	$65,895
2021	$1,843	$81,020
2022	$1,927	$97,121
2023	$2,026	$114,400
2024	$2,218	$134,120
2025	$2,236	$154,237

Table X-14
Cumulative Cost Effects of Recent Light Truck Rules and Proposals
(in 2010 economics)

MY	Average Cost per Vehicle, Cumulative Safety and Fuel Economy Costs	Total Cost (in $M's)
2010	$0	$0
2011	$143	$752
2012	$266	$1,808
2013	$393	$3,741
2014	$640	$6,810
2015	$1,030	$12,049
2016	$1,192	$17,315
2017	$1,301	$23,212
2018	$1,369	$29,190
2019	$1,567	$36,266
2020	$1,776	$44,364
2021	$2,061	$53,982
2022	$2,096	$63,818
2023	$2,175	$74,038
2024	$2,244	$84,659
2025	$2,186	$94,994

Sensitivity Analyses

The agency performed a number of sensitivity analyses to examine important assumptions. All sensitivity analyses were based on the standard setting output of the Volpe model, and – in a departure from the central analysis presented elsewhere in this FRIA – sensitivity analyses are based solely upon the 2010 baseline fleet. We examine sensitivity with respect to the following economic parameters:

1) The price of gasoline: The main analysis uses the Reference Case AEO 2012 Early Release estimate for the price of gasoline. As the AEO 2012 Early Release does not contain Low and High Price Cases, ranges derived from the Low and High Price Cases from the AEO 2011 were utilized in conjunction with the Reference Case AEO 2012 Early Release to study the effect of the Low and High Price Cases on the model results.

2) The rebound effect: The main analysis uses a rebound effect of 10 percent to project increased miles traveled as the cost per mile driven decreases. In the sensitivity analysis, we examine the effect of using a 5, 15, or 20 percent rebound effect instead.

3) The value of CO_2 benefits: The main analysis uses $22 per ton discounted at a 3 percent discount rate to quantify the benefits of reducing CO_2 emissions and $0.199 per gallon to quantify the benefits of reducing fuel consumption. In the sensitivity analysis, we examine the following values and discount rates applied only to the social cost of carbon to value carbon benefits, considering low, high, and very high valuations of approximately $5, $36, and $68 per ton, respectively with regard to the benefits of reducing CO_2 emissions.[602] These are the 2010 values, which increase over time. These values can be translated into cents per gallon by multiplying by 0.0089,[603] giving the following values:

   ($4.91 per ton CO_2) x 0.0089 = $0.044 per gallon discounted at 5%

   ($22.22 per ton CO_2) x 0.0089 = $0.198 per gallon discounted at 3% (used in the main analysis)

   ($36.49 per ton CO_2) x 0.0089 = $0.325 per gallon discounted at 2.5%

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[602] The low, high, and very high valuations of $5, $36, and $67 are rounded for brevity; the exact values are $4.86, $36.13, and $66.88, respectively. While the model uses the unrounded values, the use of unrounded values is not intended to imply that the chosen values are precisely accurate to the nearest cent; rather, they are average levels resulting from the many published studies on the topic.

[603] The molecular weight of Carbon (C) is 12, the molecular weight of Oxygen (O) is 16, thus the molecular weight of CO_2 is 44. 1 gallon of gas weighs 2,819 grams, of that 2,433 grams are carbon. One ton of CO_2/One ton of C (44/12)* 2433grams C/gallon *1 ton/1000kg * 1 kg/1000g = (44 * 2433*1*1) / (12*1*1000 * 1000) = 0.0089. Thus, one ton of CO_2*0.0089 = 1 gallon of gasoline.

And a 95th percentile estimate of

(\$67.55 per ton CO_2) x 0.0089 = \$0.601 per gallon discounted at 3%

4) Global Warming Potential (non-CO_2 GHG benefits): The main analysis does not monetize benefits associated with the reduction of non-CO_2 GHGs (methane, nitrous oxide, HFC-134a). This sensitivity analysis uses a GWP approach to convert non-CO_2 GHGs to CO_2-equivalence to monetize these benefits using the same methods with which the benefits of CO_2 reductions are valued.

   One limitation relevant to the primary benefits analysis is that it does not include the valuation of non-CO_2 GHG impacts (i.e., CH_4, N_2O, and HFCs). The SCC estimates used in this analysis were developed through an interagency process that included EPA, DOT/NHTSA, and other executive branch entities, and concluded in February 2010.[604] The interagency group did not directly estimate the social costs of non-CO_2 GHG emissions when it developed the current social cost of CO_2 values. Moreover, the group determined that it would not transform the CO_2 estimates into estimates for non-CO_2 GHGs using global warming potentials (GWPs), which measure the ability of different gases to trap heat in the atmosphere (i.e., radiative forcing per unit of mass) over a particular timeframe relative to CO_2. Recognizing that non-CO_2 GHG impacts associated with this rulemaking (net reductions in CH_4, N_2O, and HFCs) would provide economic benefits to society, however, the agencies requested comment on a methodology to value such impacts. Several commenters strongly recommended that the agencies value non-CO_2 GHG impacts associated with this final rule. See the preamble IV.C.3 for a summary of the public comments and NHTSA's response.

   One way to approximate the value of marginal non-CO_2 GHG emission reductions in the absence of direct model estimates is to convert the reductions to CO_2-equivalents which may then be valued using the SCC. Conversion to CO_2-e is typically done using the global warming potential (GWP) for the non-CO_2 gas; we refer to this method as the "GWP approach." The GWP is an aggregate measure that approximates the additional energy trapped in the atmosphere over a given timeframe from a perturbation of a non-CO_2 gas relative to CO_2. The time horizon most commonly used is 100 years. One potential problem with utilizing temporally aggregated statistics, such as the GWPs, is that the additional

[604] Technical Support Document: Social Cost of Carbon for Regulatory Impact Analysis Under Executive Order 12866, Interagency Working Group on Social Cost of Carbon, with participation by Council of Economic Advisers, Council on Environmental Quality, Department of Agriculture, Department of Commerce, Department of Energy, Department of Transportation, Environmental Protection Agency, National Economic Council, Office of Energy and Climate Change, Office of Management and Budget, Office of Science and Technology Policy, and Department of Treasury (February 2010). Also available at http://www.epa.gov/oms/climate/regulations/scc-tsd.pdf

radiative forcing from the GHG perturbation is not constant over time and any differences in temporal dynamics between gases will be lost.

While the GWP approach provides an approximation of the monetized value of the non-CO_2 GHG reductions anticipated from this rule, it produces estimates that are less accurate than those obtained from direct model computations for a variety of reasons, including the differences in atmospheric lifetime of non-CO_2 gases relative to CO_2. This is a potentially confounding issue given that the social cost of GHGs is based on a discounted stream of damages—i.e., they are not constant over time—and that are non-linear in temperature.

A limited number of studies in the published literature explore the differences in the social benefit estimates from the GWP approach and direct modeling. One recent working paper (Marten and Newbold, 2011) found that the GWP-weighted benefit estimates for CH_4 and N_2O are likely to be lower than those that would be derived using a directly modeled social cost of these gases for a variety of reasons.[605] This conclusion is reached using the 100 year GWP coefficients as put forth in the IPCC Fourth Assessment Report (CH_4 is 25, N_2O is 298). The GWP reflects only the integrated radiative forcing of a gas over 100 years. In contrast, the directly modeled social cost differs from the GWP because the differences in timing of the warming between gases are explicitly modeled, the non-linear effects of temperature change on economic damages are included, and rather than treating all impacts over a hundred years equally, the modeled social cost applies a discount rate but calculates impacts through the year 2300.

The agencies also undertook a literature search for estimates of the marginal social cost of non-CO_2 GHGs. A range of these estimates are available in published literature (Fankhauser (1994), Kandlikar (1995), Hammitt et al. (1996), Tol et al. (2003), Tol, et al. (2006), Hope (2005) and Hope and Newberry (2006). Most of these estimates are based upon modeling assumptions that are dated and inconsistent. Some of these studies focused on, for example, marginal methane reductions in the 1990s and early 2000s and report estimates for only the single year of interest specific to the study. The assumptions underlying the social cost of non-CO_2 GHG estimates available in the literature differ from those agreed upon by the SCC interagency group and in many cases use older versions of the integrated assessment models. Without additional analysis, the non-CO_2 GHG benefit estimates available in the current literature are not acceptable to use to value the methane reductions finalized in this rulemaking.

[605] Marten, A. and S. Newbold. 2011. "Estimating the Social Cost of Non-CO2 GHG Emissions: Methane and Nitrous Oxide." *NCEE Working Paper Series* #11-01. http://yosemite.epa.gov/ee/epa/eed.nsf/WPNumber/2011-01?opendocument. Accessed May 24, 2012. Docket ID EPA-HQ-OAR-2010-0799.

In the absence of direct model estimates from the interagency analysis, and in the interest of being responsive to comments encouraging us to examine this, NHTSA has conducted a sensitivity analysis using the GWP approach to estimate the benefits associated with reductions of three non-CO_2 GHGs in each calendar year. Estimates for this rulemaking are given below for illustrative purposes and represent the CO_2-e estimate of CH_4, N_2O, and HFC reductions multiplied by the SCC estimates. CO_2-e is calculated using the AR4 100-year GWP of each gas: CH_4 (25), N_2O (298), and HFC-134a (1,430).[606]

5) Military security: The main analysis does not assign a value to the military security benefits of reducing fuel consumption. In the sensitivity analysis, we examine the impact of using a value of 12 cents per gallon instead.

6) Consumer Benefit: The main analysis assumes there is no loss in value to consumers resulting from vehicles that have an increase in price and higher fuel economy. This sensitivity analysis assumes that there is a 25, or 50 percent loss in value to consumers – equivalent to the assumption that consumers will only value the calculated benefits they will achieve at 75, or 50 percent, respectively, of the main analysis estimates.

7) Post-warranty repair costs: The main analysis includes repair costs during the warranty period; post-warranty repair costs are addressed in a sensitivity analysis. The warranty period is assumed to be 5 years for the powertrain and 3 years for the rest of the vehicle. This sensitivity analysis scales the frequency of repair by vehicle survival rates, assumes that per-vehicle repair costs during the post-warranty period are the same as in the in-warranty period, and that repair costs are proportional to incremental direct costs (therefore vehicles with additional components will have increased repair costs).

8) Battery cost: The agency conducted a sensitivity analysis of battery costs for HEV, PHEV and EV technologies. The ranges for battery costs are based on the recommendations from the technical experts in the field of battery energy storage technologies at Department of Energy (DOE) and Argonne National Laboratory (ANL). These ranges of battery costs are developed using the Battery Performance and Cost (BatPaC) model developed by ANL and funded by DOE[607]. The values for these ranges are shown in Table X-15 and are calculated with 95% confidence interval after analyzing the confidence bound using the BatPaC model.

[606] As in the MY 2012-2016 LD rules and in the MY 2014-2018 MD and HD rule, the global warming potentials (GWP) used in this rulemaking are consistent with the 100-year time frame values in the 2007 Intergovernmental Panel on Climate Change (IPCC) Fourth Assessment Report (AR4). At this time, the 100-year GWP values from the 1995 IPCC Second Assessment Report (SAR) are used in the official U.S. GHG inventory submission to the United Nations Framework Convention on Climate Change (UNFCCC) (per the reporting requirements under that international convention) . The UNFCCC recently agreed on revisions to the national GHG inventory reporting requirements, and will begin using the 100-year GWP values from AR4 for inventory submissions in the future. According to the AR4, CH_4 has a 100-year GWP of 25, N_2O has a 100-year GWP of 298, and HFC-134a has a 100-year GWP of 1430.

[607] Section 3.4.3.9 in TSD Chapter 3 has detailed descriptions of the history of the BatPac model and how the agencies used the BatPac model in this analysis.

Table X-15
Suggested Confidence Bounds as Percentages of the Calculated Point Estimate for a Graphite-based Li-ion Battery Using the Default Inputs in BatPaC

		Confidence Interval	
Battery Type	**Cathodes**	**Lower**	**upper**
HEV	LMO, LFP, NCA, NMC	-10%	10%
PHEV, EV	NMC, NCA	-10%	20%
PHEV, EV	LMO, LFP	-20%	35%

ANL also stated that if a simpler approach to defining bounds is desired, +/- 20 percent bounds could be placed on the cost of PHEV and EV batteries. The NHTSA sensitivity analysis uses the bounds that were determined in the in-depth ANL analysis that are shown in the table instead of the simpler and more approximate +/- 20 percent bounds.

In the NPRM central analysis, EPA developed direct manufacturing costs (DMC) for battery systems using ANL's BatPaC model. For this sensitivity analysis, NHTSA scaled these central battery system costs by the percentages shown in Table X-15, per guidance from DOE and ANL experts on reasonable ranges for these costs. Figures X-1 to X-5 shows these battery system DMCs in terms of $/kW for HEV and $/kWh for 20-mile range PHEV (PHEV20), 40-mile range PHEV (PHEV40), 75-mile range EV (EV75), 100-mile range EV (EV100) and 150-mile range EV (EV150). We note that battery system cost varies with vehicle subclasses and driving range. Smaller batteries tend to be relatively more expensive per kWh because the cost for the battery management system, disconnect units and baseline thermal management system is the same from vehicle to vehicle for each type of electrification system, such as HEV, PHEV and EV (but varies between different electrification systems) and this cost is spread over fewer kWh for smaller vehicle. For example, the battery system cost for EVs ranges from $221/kWh for subcompact cars for EV75, to $160/kWh for large trucks for EV150 in MY 2021. Note: the agencies do not apply PHEV or EV technology to large MPVs/minivans or large trucks; however, the estimated costs of such a system are shown here for completeness.

Figure X-1
Battery System Direct Manufacture Cost (DMC) for P2 HEV

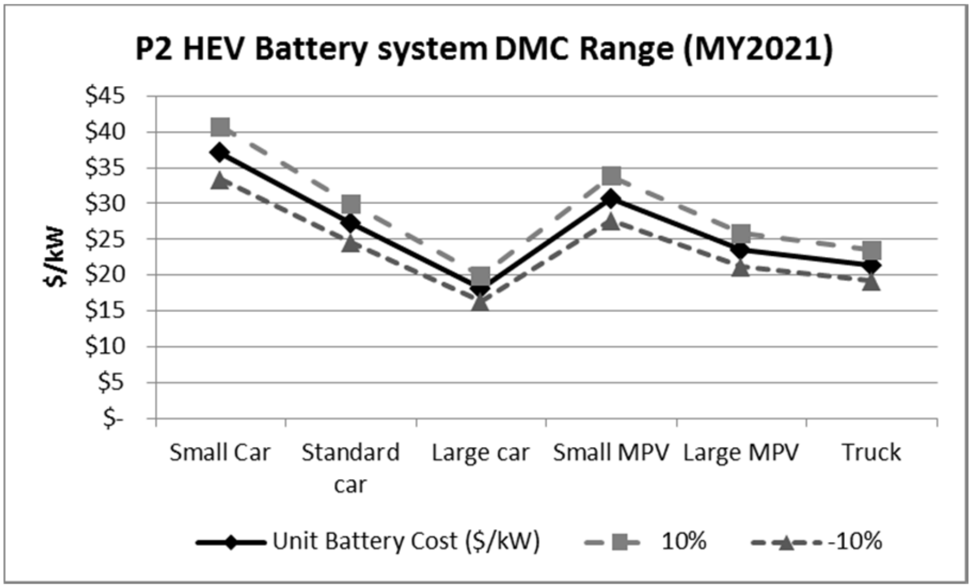


Figure X-2
Battery System Direct Manufacture Cost (DMC) for PHEV20

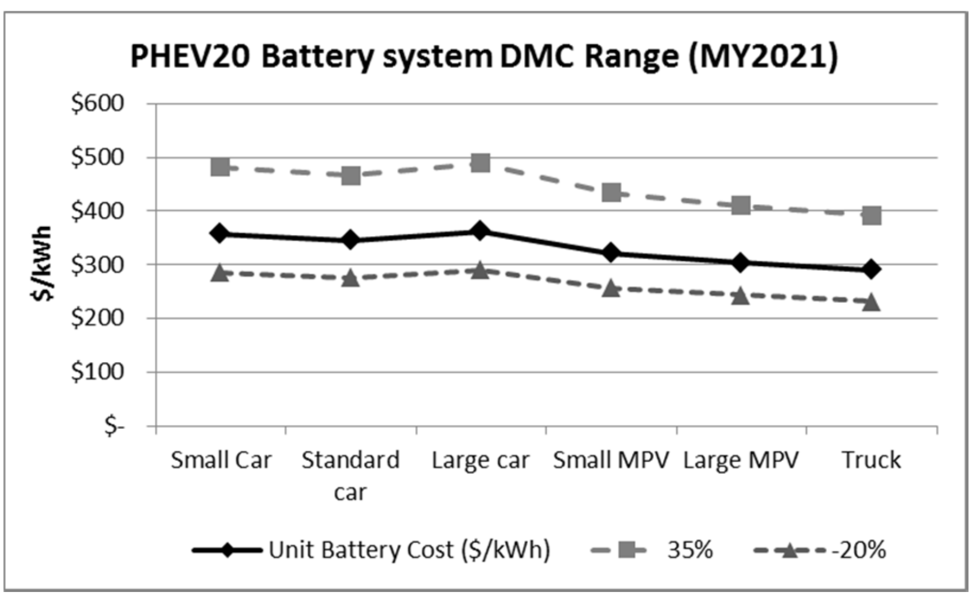


Figure X-3

Battery System Direct Manufacture Cost (DMC) for PHEV40

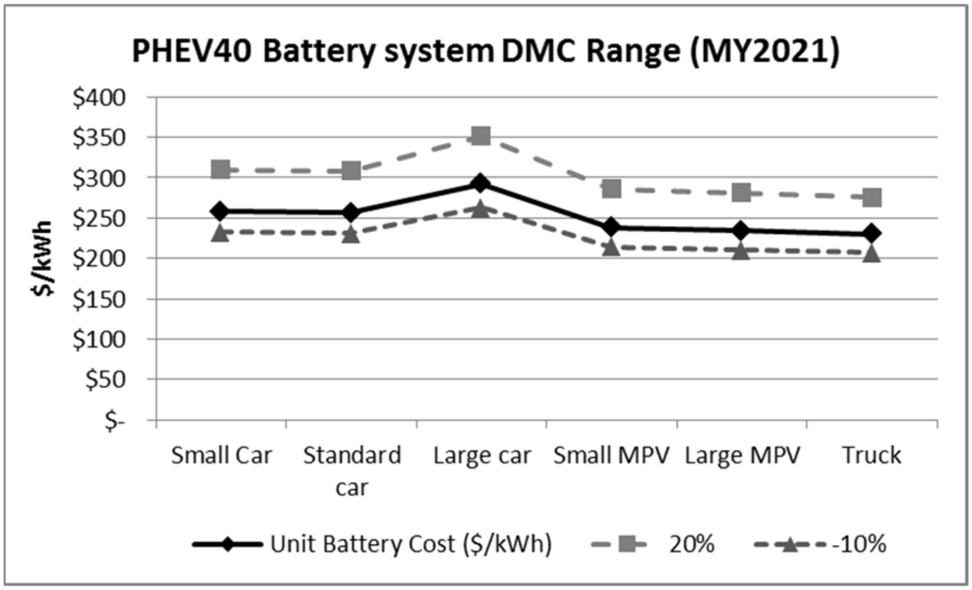


Figure X-4
Battery System Direct Manufacture Cost (DMC) for EV75

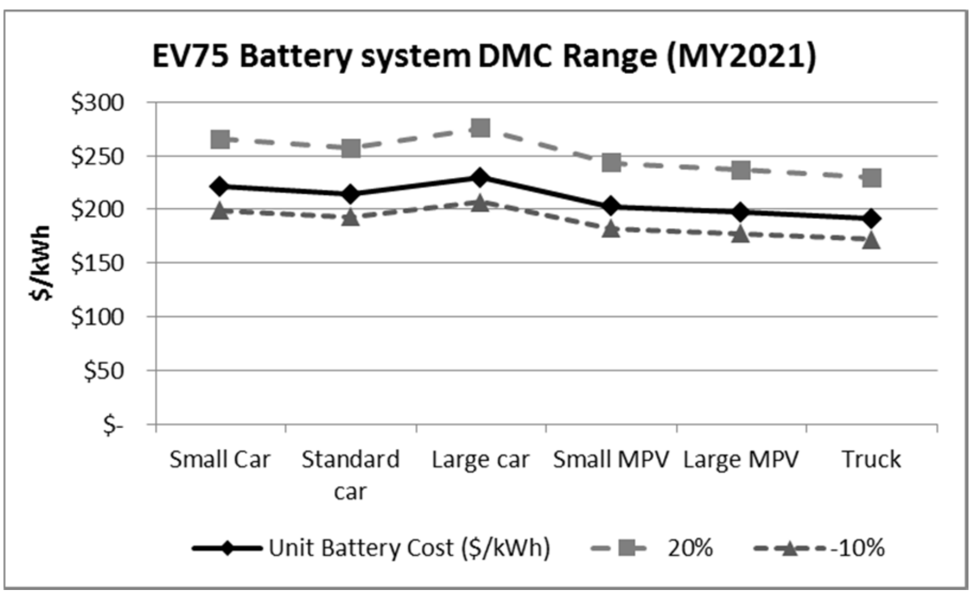
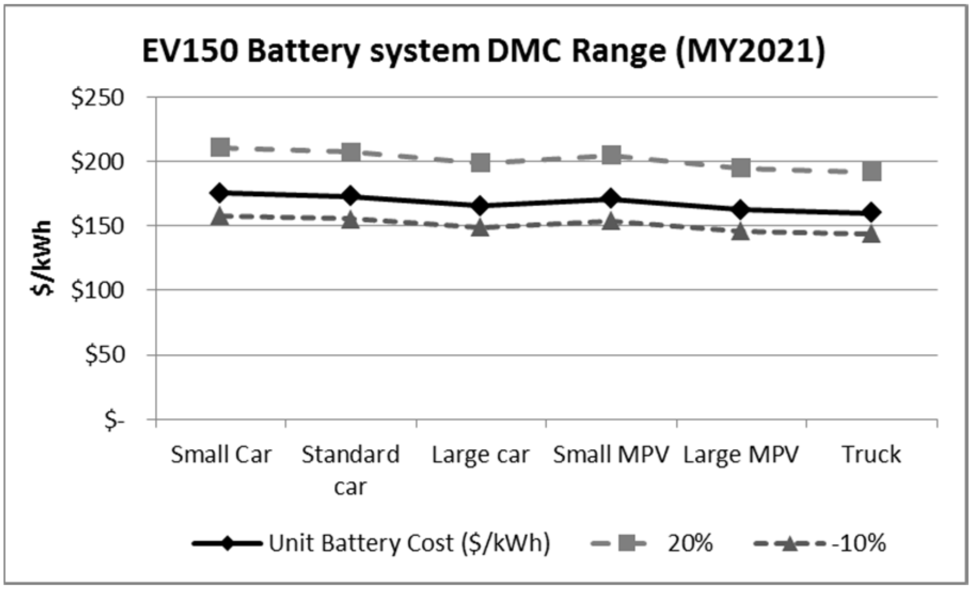


Figure X-5
Battery System Direct Manufacture Cost (DMC) for EV150



For the reader's reference, this sensitivity was conducted using what the agency refers to as "standard setting" analytical runs, in which the agency restricts the operation of the model consistent with statutory requirements related to how the agency may determine maximum feasible CAFE standards (for example, the standard setting runs do not include EVs, because NHTSA may not consider the fuel economy of EVs when setting maximum feasible CAFE standards, nor do they consider PHEVs prior to MY 2020, for the same reason), as compared to the "real-world" analysis, in which the agency attempts to model how manufacturers might respond to the standards (and regulatory alternatives) taking account of all available technologies and compliance flexibilities. NHTSA used the "standard setting" runs for this sensitivity analysis to show the regulatory impact of the battery cost. In the "standard setting" runs, NHTSA included 30-mile range PHEV (PHEV30) only after MY2019 to represent all PHEVs, the cost of which is the average cost of PHEV20 and PHEV40. NHTSA did not apply any EVs in this analysis.

9) Mass reduction cost: Due to the wide range of mass reduction cost as stated in TSD Chapter 3, a sensitivity analysis was performed examining the impact of the cost of vehicle mass reduction to the total technology cost. The direct manufacturing cost (DMC) for mass reduction is represented as a linear function between the unit DMC versus percent of mass reduction as shown in Figure X-6. The slope of this line used for the central analysis is $4.36 (2010$) per pound per percent of mass reduction. The slope of the line is varied ± 40% as the upper and lower bound for this sensitivity study. The values for the range of mass reduction cost are shown in Table X-16.

Table X-16
Bounds for Mass Reduction Direct Manufacturing Cost (2010$)

Sensitivity Bound	Slope of Mass Reduction Line [$/(lb-%MR)	Example Unit Direct Manufacture Cost[1] [$/lb]	Example Total Direct Manufacture Cost[2] [$/lb]
Lower Bound	$2.61	$0.39	$235
NPRM Central Analysis	$4.36	$0.65	$392
Upper Bound	$6.10	$0.92	$549

Notes

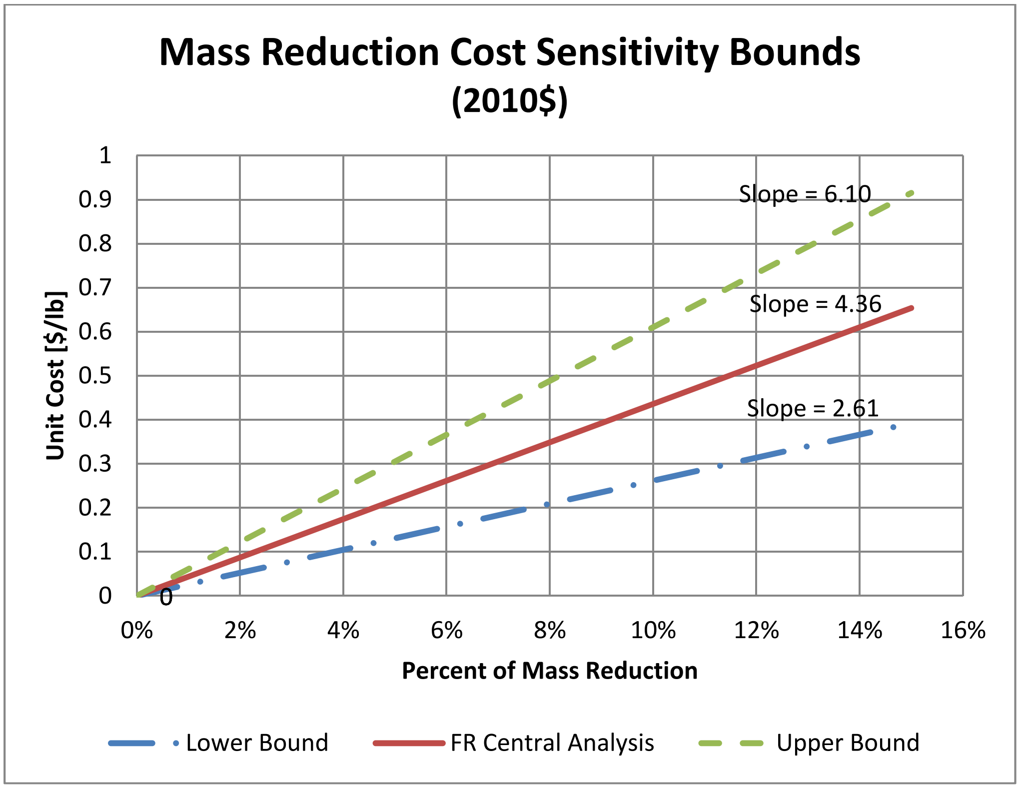
1. Example is based on 15% mass reduction.

   Unit direct manufacturing cost [$/lb]= Slope x Percent of Mass Reduction

2. Example is based on 15% mass reduction for a 4000-lb vehicle.

   Total direct manufacturing cost [$] = Unit Direct Manufacturing Cost x Amount of Mass Reduction

Figure X-6
Direct Manufacturing Cost for Mass Reduction (2010$)



10) Market-driven response: The baseline for the central analysis is based on the MY 2016 CAFE standards and assumes that manufacturers will make no changes in the fuel economy from that level through MY 2025. A sensitivity analysis was performed to simulate potential increases in fuel economy over the compliance level required if MY 2016 standards were to remain in place. The assumption is that the market would drive manufacturers to put technologies into their vehicles that they believe consumers would value and be willing to pay for. Using parameter values consistent with the central analysis, the agency simulated a market-driven response baseline by applying a payback period of one year for purposes of calculating the value of future fuel savings when simulating whether manufacturers would apply additional technology to an already CAFE-compliant fleet. In other words we assumed that manufacturers that were above their MY 2016 CAFE level would compare the cost to consumers to the fuel savings in the first year of operation and decide to voluntarily apply those technologies to their vehicles when benefits for the first year exceeded costs for the consumer. For a manufacturer's fleet that that has not yet achieved compliance with CAFE standards, the agency continued to apply a five-year payback period. In other words, for this sensitivity analysis the agency assumed that manufacturers that have not yet met CAFE standards for future model years will apply technology as if buyers were willing to pay for the technologies as long as the fuel savings throughout the first five years of vehicle

ownership exceeded their costs. Once having complied with those standards, however, manufacturers are assumed to consider making further improvements in fuel economy as if buyers were only willing to pay for fuel savings to be realized during the first year of vehicle ownership. The 'market-drive response' analysis assumes manufacturers will overcomply if additional technology is sufficiently cost effective. Because this assumption has a greater impact under the baseline standards, its application reduces the incremental costs, effects, and benefits attributable to the new standards. This does not mean costs, effects, and benefits would actually be smaller with a market-driven response; rather it means costs, effects, and benefits would be at least as great, but would be partially attributable not to the new standards, but instead to the market.

11) Transmission shift optimization technology disabled: As part of the simulation work for the final rule, ANL attempted to replicate the shift optimizer technology but produced different results than those of Ricardo, particularly in the application of shift optimization to naturally aspirated engines. Because of this uncertainty in effectiveness values, NHTSA conducted a sensitivity case analysis with transmission shift optimizer technology disabled.

Above we discuss how we mathematically determined market demand, but a potential rationale for more market demand follows: For years, consumers have been learning about the benefits that accrue to them from owning and operating vehicles with greater fuel efficiency. Consumer demand has thus shifted towards such vehicles, not only because of higher fuel prices but also because many consumers are learning about the value of purchases based not only on initial costs but also on the total cost of owning and operating a vehicle over its lifetime. This type of learning is expected to continue before and during the model years affected by this rule, particularly given the new fuel economy labels that clarify potential economic effects and should therefore reinforce that learning.[608] Therefore, some increase in the demand for, and production of, more fuel efficient vehicles is incorporated as a market driven response in this sensitivity analysis.

Varying each of the above 11 parameters in isolation results in a variety of economic scenarios. These are listed in Table X-17 below along with the preferred alternative.

12) The agency performed two additional sensitivity analyses presented in Tables X-20 and X-21. First, the agency analyzed the impact that having a retail price equivalent (RPE) factor of 1.5 for all technologies would have on the various alternatives instead of using the indirect

[608] A recent Consumer Reports study supports the noted increase in consumer learning and consequent desire for more fuel-efficient vehicles. See "High Gas Prices Motivate Drivers to Change Direction," *Consumer Reports,* May 2012, *available at:* http://www.consumerreports.org/content/cro/en/cars/fuel-economy-survey-high-gas-prices-impact-drivers.html (last accessed August 1, 2012)

cost markup (ICM) methodology. The ICM methodology results in an overall markup factor of 1.2 to 1.25 compared to the RPE markup factor from variable cost of 1.5. Next, the agency conducted a separate sensitivity analysis using values that were derived from the 2011 NAS report.[2] This analysis used an RPE markup factor of 1.5 for non-electrification technologies, which is consistent with the NAS estimation for technologies manufactured by suppliers, and a RPE markup factor of 1.33 for electrification technologies (HEV, PHEV and EV); three types of learning which include no learning for mature technologies, 1.25 percent annual learning for evolutionary technologies, and 2.5 percent annual learning for revolutionary technologies; technology cost estimates for 52 percent (33 out of 63) technologies; and technology effectiveness estimates for 56 percent (35 out of 63) of technologies. Cost learning was applied to technology costs in a manner similar to how cost learning is applied in the central analysis for many technologies which have base costs which are applicable to recent or near-term future model years. As noted above, the cost learning factors used for the sensitivity case are different than the values used in the central analysis. For the other inputs in the sensitivity case, where the NAS study has inconsistent information or lacks projections, NHTSA used the same input values that were used in the central analysis.

13) Table X-22 separately examines the sensitivity of the benefits of reducing criteria pollutants and vehicle safety to alternate values of statistical life.

Table X-17
Sensitivity Analyses

Name	Fuel Price	Discount Rate	Rebound Effect	SCC	Military Security
Reference	Reference	3%	10%	\$22	0¢/gal
High Fuel Price	High	3%	10%	\$22	0¢/gal
Low Fuel Price	Low	3%	10%	\$22	0¢/gal
5% Rebound Effect	Reference	3%	5%	\$22	0¢/gal
15% Rebound Effect	Reference	3%	15%	\$22	0¢/gal
20% Rebound Effect	Reference	3%	20%	\$22	0¢/gal
12¢/gal Military Security Value	Reference	3%	10%	\$22	12¢/gal
\$5/ton CO_2 Value	Reference	3%	10%	\$5	0¢/gal
\$36/ton CO_2 Value	Reference	3%	10%	\$36	0¢/gal
\$68/ton CO_2 Value	Reference	3%	10%	\$68	0¢/gal
Global Warming Potential	Reference	3%	10%	\$22	0¢/gal
50% Consumer Benefit	Reference	3%	10%	\$22	0¢/gal
75% Consumer Benefit	Reference	3%	10%	\$22	0¢/gal
Post-Warranty Repair Costs	Reference	3%	10%	\$22	0¢/gal
Low Battery Cost	Reference	3%	10%	\$22	0¢/gal
High Battery Cost	Reference	3%	10%	\$22	0¢/gal
Low Cost Mass Reduction	Reference	3%	10%	\$22	0¢/gal
High Cost Mass Reduction	Reference	3%	10%	\$22	0¢/gal
Market-Driven Response	Reference	3%	10%	\$22	0¢/gal
No Shift Optimization	Reference	3%	10%	\$22	0¢/gal

Table X-18 presents the achieved fuel economy, per-vehicle price increase, total benefits, total cost, lifetime fuel savings, and the lifetime reductions in CO_2 emissions that would result under the standards from the economic scenarios. For the achieved fuel economy and per-vehicle price increase, the table presents only the model year 2025 results, since this model year showed the greatest impacts. For net benefits, fuel savings, and CO_2 emissions reductions, the table presents totals over the nine model years, rather than their values for MY 2025, to reflect the total impact of the standards that would result from the various economic assumptions. To derive a valid comparison between the baseline and the sensitivity analyses, all runs were based on a 3% discount rate using the central standard setting data runs. Thus, the preferred mpg levels and baseline are slightly different than the main analysis. Costs include both technology costs and fine payments.

Table X-19 presents the percentage changes from the Preferred Alternative economic assumptions for the items in Table X-18. From these tables, we conclude the following regarding the impact of varying the economic parameters among the considered values:

1) Varying the economic assumptions has almost no impact on achieved mpg. The mass reduction cost sensitivities, battery cost reduction sensitivities[609], market-based baseline sensitivity, and no shift optimization sensitivity cases are the only instances in which achieved mpg differs from the reference case of the Preferred Alternative. None of these alter the outcome by more than 0.3 mpg for either fleet.
2) Varying the economic assumptions has, at most, a small impact on per-vehicle costs, with only the no shift optimization variation affecting the per-vehicle cost by more than 10 percent from the central analysis level. Similarly, fuel saved and CO_2 emissions reductions vary only slightly across the sensitivity cases, where the only substantial impact results from the market-driven baseline sensitivity in which voluntary overcompliance reduces the number of gallons of fuel saved as well as the quantity of CO_2 emissions by just under 28 percent.
3) The category most affected by variations in the economic parameters considered in these sensitivity analyses is net benefits. The sensitivity analyses examining the AEO low and high fuel price scenarios demonstrate the potential to negatively impact net benefits by up to 38 percent or to increase them by about 32 percent relative to those of the Preferred Alternative. Other large impacts on net benefits occurred with the \$68/ton CO_2 valuation, in which net benefits increased by nearly 22 percent, the market-driven baseline, which reduces net benefits by close to 32 percent, and (as expected) the 50 and 75 percent consumer fuel savings valuation cases, which decrease net benefits by approximately 52 and 26 percent, respectively.

[609] The difference resulting from changes in battery cost are less that 0.05 mpg, therefore are imperceptible in Table X-12 and round to 0% in Table X-13.

4) Even if consumers value the benefits achieved at 50% of the main analysis assumptions, total benefits still exceed costs, with net benefits greater than $135 billion.

Regarding the lower fuel savings and CO_2 emissions reductions predicted by the sensitivity analysis as fuel price increases, which initially may seem counterintuitive, we note that there are some counterbalancing factors occurring. As fuel price increases, people will drive less and so fuel savings and CO_2 emissions reductions may decrease.

Table X-18a
Sensitivity Analyses
(mpg, Per-Vehicle Cost, Total Benefits, Total Cost, Fuel Saved, & CO_2 Emissions Reduced)
Passenger Cars

Economic Assumptions	MY 2025 Achieved mpg	MY 2025 Per-Vehicle Cost	MY 2017-2025 Net Benefits, Discounted 3%, in Millions of $	MY 2017-2025 Fuel Saved, in Millions of Gallons	MY 2017-2025 CO2 Emissions Reduced, in mmT
Passenger Cars					
Preferred	54.1	$1,578	$293,062	109,852	2,384
High Fuel Price	54.2	$1,623	$385,879	102,888	2,234
Low Fuel Price	53.8	$1,498	$180,822	112,798	2,449
5% Rebound Effect	54.1	$1,578	$306,879	113,226	2,458
15% Rebound Effect	54.1	$1,578	$290,962	106,478	2,310
20% Rebound Effect	54.1	$1,578	$283,004	103,105	2,237
12¢/gal Military Security Value	54.1	$1,578	$308,923	109,852	2,384
$5/ton CO2 Value	54.1	$1,578	$274,982	109,852	2,384
$36/ton CO2 Value	54.1	$1,578	$317,760	109,852	2,384
$68/ton CO2 Value	54.1	$1,578	$364,833	109,852	2,384
Global Warming Potential	54.1	$1,578	$299,023	109,852	2,384
50% Consumer Benefit	54.1	$1,578	$141,150	109,852	2,384
75% Consumer Benefit	54.1	$1,578	$220,035	109,852	2,384
Post-Warranty Repair Costs	54.1	$1,578	$286,038	109,852	2,384
Low Battery Cost	54.1	$1,570	$299,128	109,869	2,384
High Battery Cost	54.1	$1,591	$298,490	109,831	2,384
Low Cost Mass Reduction	54.1	$1,551	$300,244	109,931	2,386

High Cost Mass Reduction	54.1	$1,600	$297,339	109,826	2,384
Market-Driven Baseline	54.4	$1,618	$216,774	86,564	1,878
No Shift Optimization	53.9	$1,626	$283,476	107,957	2,340

Table X-18b
Sensitivity Analyses
(mpg, Per-Vehicle Cost, Total Benefits, Total Cost, Fuel Saved, & CO_2 Emissions Reduced)
Light Trucks

Economic Assumptions	MY 2025 Achieved mpg	MY 2025 Per-Vehicle Cost	MY 2017-2025 Net Benefits, Discounted 3%, in Millions of $	MY 2017-2025 Fuel Saved, in Millions of Gallons	MY 2017-2025 CO2 Emissions Reduced, in mmT
Light Trucks					
Preferred	39.3	$1,226	$175,793	61,984	1,333
High Fuel Price	39.3	$1,331	$242,737	60,886	1,312
Low Fuel Price	39.1	$1,132	$118,820	68,407	1,479
5% Rebound Effect	39.3	$1,226	$182,716	64,149	1,380
15% Rebound Effect	39.3	$1,226	$175,216	59,818	1,286
20% Rebound Effect	39.3	$1,226	$171,466	57,653	1,239
12¢/gal Military Security Value	39.3	$1,226	$184,284	61,984	1,333
$5/ton CO2 Value	39.3	$1,226	$165,604	61,984	1,333
$36/ton CO2 Value	39.3	$1,226	$189,482	61,984	1,333
$68/ton CO2 Value	39.3	$1,226	$215,721	61,984	1,333
Global Warming Potential	39.3	$1,226	$179,017	61,984	1,333
50% Consumer Benefit	39.3	$1,226	$91,951	61,984	1,333
75% Consumer Benefit	39.3	$1,226	$135,458	61,984	1,333
Post-Warranty Repair Costs	39.3	$1,226	$173,514	61,984	1,333
Low Battery Cost	39.3	$1,225	$178,979	61,984	1,333
High Battery Cost	39.3	$1,226	$178,953	61,984	1,333
Low Cost Mass Reduction	39.4	$1,194	$183,675	63,111	1,355

High Cost Mass Reduction	39.1	$1,165	$176,659	60,497	1,299
Market-Driven Baseline	39.3	$985	$103,943	37,887	818
No Shift Optimization	39.2	$1,392	$171,545	60,623	1,300

Table X-18c
Sensitivity Analyses
(mpg, Per-Vehicle Cost, Total Benefits, Total Cost, Fuel Saved, & CO_2 Emissions Reduced)
Passenger Cars and Light Trucks Combined

Economic Assumptions	MY 2025 Achieved mpg	MY 2025 Per-Vehicle Cost	MY 2017-2025 Net Benefits, Discounted 3%, in Millions of $	MY 2017-2025 Fuel Saved, in Millions of Gallons	MY 2017-2025 CO2 Emissions Reduced, in mmT
Passenger Cars and Light Trucks					
Preferred	48.1	$1,461	$468,855	171,836	3,717
High Fuel Price	48.2	$1,526	$628,616	163,775	3,545
Low Fuel Price	47.8	$1,376	$299,642	181,205	3,928
5% Rebound Effect	48.1	$1,461	$489,595	177,374	3,838
15% Rebound Effect	48.1	$1,461	$466,178	166,297	3,597
20% Rebound Effect	48.1	$1,461	$454,469	160,758	3,476
12¢/gal Military Security Value	48.1	$1,461	$493,208	171,836	3,717
$5/ton CO2 Value	48.1	$1,461	$440,586	171,836	3,717
$36/ton CO2 Value	48.1	$1,461	$507,241	171,836	3,717
$68/ton CO2 Value	48.1	$1,461	$580,554	171,836	3,717
Global Warming Potential	48.1	$1,461	$478,040	171,836	3,717
50% Consumer Benefit	48.1	$1,461	$233,100	171,836	3,717
75% Consumer Benefit	48.1	$1,461	$355,494	171,836	3,717
Post-Warranty Repair Costs	48.1	$1,461	$459,553	171,836	3,717
Low Battery Cost	48.1	$1,456	$478,107	171,853	3,718
High Battery Cost	48.1	$1,470	$477,443	171,815	3,717
Low Cost Mass Reduction	48.1	$1,432	$483,919	173,042	3,741

High Cost Mass Reduction	48.0	$1,455	$473,998	170,323	3,683
Market-Driven Baseline	48.2	$1,408	$320,717	124,451	2,696
No Shift Optimization	47.9	$1,635	$455,021	168,580	3,640

Table X-19a
Sensitivity Analyses – Percentage Change from the Reference Case
Passenger Cars

Economic Assumptions	MY 2025 Achieved mpg	MY 2025 Per-Vehicle Cost	MY 2017-2025 Net Benefits, Discounted 3%, in Millions of $	MY 2017-2025 Fuel Saved, in Millions of Gallons	MY 2017-2025 CO2 Emissions Reduced, in mmT
Passenger Cars					
Preferred	Base	Base	Base	Base	Base
High Fuel Price	0.3%	2.9%	31.7%	-6.3%	-6.3%
Low Fuel Price	-0.6%	-5.1%	-38.3%	2.7%	2.7%
5% Rebound Effect	0.0%	0.0%	4.7%	3.1%	3.1%
15% Rebound Effect	0.0%	0.0%	-0.7%	-3.1%	-3.1%
20% Rebound Effect	0.0%	0.0%	-3.4%	-6.1%	-6.2%
12¢/gal Military Security Value	0.0%	0.0%	5.4%	0.0%	0.0%
$5/ton CO2 Value	0.0%	0.0%	-6.2%	0.0%	0.0%
$36/ton CO2 Value	0.0%	0.0%	8.4%	0.0%	0.0%
$68/ton CO2 Value	0.0%	0.0%	24.5%	0.0%	0.0%
Global Warming Potential	0.0%	0.0%	2.0%	0.0%	0.0%
50% Consumer Benefit	0.0%	0.0%	-51.8%	0.0%	0.0%
75% Consumer Benefit	0.0%	0.0%	-24.9%	0.0%	0.0%
Post-Warranty Repair Costs	0.0%	0.0%	-2.4%	0.0%	0.0%
Low Battery Cost	0.0%	-0.5%	2.1%	0.0%	0.0%
High Battery Cost	0.0%	0.8%	1.9%	0.0%	0.0%
Low Cost Mass Reduction	0.0%	-1.7%	2.5%	0.1%	0.1%
High Cost Mass Reduction	0.1%	1.4%	1.5%	0.0%	0.0%

Market-Driven Baseline	0.6%	2.6%	-26.0%	-21.2%	-21.2%
No Shift Optimization	-0.3%	3.1%	-3.3%	-1.7%	-1.8%

Table X-19b
Sensitivity Analyses – Percentage Change from the Reference Case
Light Trucks

Economic Assumptions	MY 2025 Achieved mpg	MY 2025 Per-Vehicle Cost	MY 2017-2025 Net Benefits, Discounted 3%, in Millions of $	MY 2017-2025 Fuel Saved, in Millions of Gallons	MY 2017-2025 CO2 Emissions Reduced, in mmT
Light Trucks					
Preferred	Base	Base	Base	Base	Base
High Fuel Price	0.1%	8.6%	38.1%	-1.8%	-1.6%
Low Fuel Price	-0.6%	-7.7%	-32.4%	10.4%	10.9%
5% Rebound Effect	0.0%	0.0%	3.9%	3.5%	3.5%
15% Rebound Effect	0.0%	0.0%	-0.3%	-3.5%	-3.5%
20% Rebound Effect	0.0%	0.0%	-2.5%	-7.0%	-7.0%
12¢/gal Military Security Value	0.0%	0.0%	4.8%	0.0%	0.0%
$5/ton CO2 Value	0.0%	0.0%	-5.8%	0.0%	0.0%
$36/ton CO2 Value	0.0%	0.0%	7.8%	0.0%	0.0%
$68/ton CO2 Value	0.0%	0.0%	22.7%	0.0%	0.0%
Global Warming Potential	0.0%	0.0%	1.8%	0.0%	0.0%
50% Consumer Benefit	0.0%	0.0%	-47.7%	0.0%	0.0%
75% Consumer Benefit	0.0%	0.0%	-22.9%	0.0%	0.0%
Post-Warranty Repair Costs	0.0%	0.0%	-1.3%	0.0%	0.0%
Low Battery Cost	0.0%	0.0%	1.8%	0.0%	0.0%
High Battery Cost	0.0%	0.0%	1.8%	0.0%	0.0%
Low Cost Mass Reduction	0.2%	-2.6%	4.5%	1.8%	1.7%
High Cost Mass Reduction	-0.5%	-5.0%	0.5%	-2.4%	-2.5%

Market-Driven Baseline	0.1%	-19.6%	-40.9%	-38.9%	-38.7%
No Shift Optimization	-0.2%	13.6%	-2.4%	-2.2%	-2.5%

Table X-19c
Sensitivity Analyses – Percentage Change from the Reference Case
Passenger Cars and Light Trucks Combined

Economic Assumptions	**MY 2025 Achieved mpg**	**MY 2025 Per-Vehicle Cost**	**MY 2017-2025 Net Benefits, Discounted 3%, in Millions of $**	**MY 2017-2025 Fuel Saved, in Millions of Gallons**	**MY 2017-2025 CO2 Emissions Reduced, in mmT**
Passenger Cars and Light Trucks					
Preferred	Base	Base	Base	Base	Base
High Fuel Price	0.2%	4.5%	34.1%	-4.7%	-4.6%
Low Fuel Price	-0.6%	-5.8%	-36.1%	5.5%	5.7%
5% Rebound Effect	0.0%	0.0%	4.4%	3.2%	3.2%
15% Rebound Effect	0.0%	0.0%	-0.6%	-3.2%	-3.2%
20% Rebound Effect	0.0%	0.0%	-3.1%	-6.4%	-6.5%
12¢/gal Military Security Value	0.0%	0.0%	5.2%	0.0%	0.0%
$5/ton CO2 Value	0.0%	0.0%	-6.0%	0.0%	0.0%
$36/ton CO2 Value	0.0%	0.0%	8.2%	0.0%	0.0%
$68/ton CO2 Value	0.0%	0.0%	23.8%	0.0%	0.0%
Global Warming Potential	0.0%	0.0%	2.0%	0.0%	0.0%
50% Consumer Benefit	0.0%	0.0%	-50.3%	0.0%	0.0%
75% Consumer Benefit	0.0%	0.0%	-24.2%	0.0%	0.0%
Post-Warranty Repair Costs	0.0%	0.0%	-2.0%	0.0%	0.0%
Low Battery Cost	0.0%	-0.4%	2.0%	0.0%	0.0%
High Battery Cost	0.0%	0.6%	1.8%	0.0%	0.0%
Low Cost Mass Reduction	0.1%	-1.9%	3.2%	0.7%	0.7%
High Cost Mass Reduction	-0.1%	-0.4%	1.1%	-0.9%	-0.9%

Market-Driven Baseline	0.4%	-3.6%	-31.6%	-27.6%	-27.5%
No Shift Optimization	-0.3%	12.0%	-3.0%	-1.9%	-2.1%

Table X-20a
Achieved mpg level, MY 2025
Comparing Different Cost Mark-up Methodologies
(3% Discount Rate)

	ICM Method (Main Analysis Costs)	**RPE Method (Main Analysis Costs)**	**Difference (mpg)**
Passenger Cars			
Preferred Alternative	54.07	53.92	0.16
Max Net Benefits	56.52	56.42	0.10
Light trucks			
Preferred Alternative	39.29	39.14	0.15
Max Net Benefits	43.66	43.56	0.10

Table X-20b
Achieved mpg level, MY 2025
Comparing ICM Method with Main Analysis Costs vs. NAS Costs
(3% Discount Rate)

	ICM Method (Main Analysis Costs)	**ICM Method (NAS Cost Estimates)**	**Difference (mpg)**
Passenger Cars			
Preferred Alternative	54.07	52.78	1.29
Max Net Benefits	56.52	55.32	1.20
Light trucks			
Preferred Alternative	39.29	37.71	1.58
Max Net Benefits	43.66	43.27	0.39

Table X-21
Sensitivity Analyses
(Achieved mpg, Per-Vehicle Cost, Net Benefits, Fuel Saved, & CO_2 Emissions Reduced)

Cost Method and Set of Cost Estimates	MY 2025 Achieved mpg	Average MY 2025 Per-Vehicle Technology Cost	MY 2017-2025 Net Benefits, Discounted 3%, in Millions of $	MY 2017-2025 Fuel Saved, in Millions of Gallons	MY 2017-2025 CO2 Emissions Reduced, in mmT
Passenger Cars					
ICM w/Main Analysis Costs	54.07	$1,578	$293,062	109,852	2,384
RPE w/Main Analysis Costs	53.92	$1,943	$273,307	107,200	2,325
ICM w/NAS Costs	52.78	$2,103	$242,912	100,496	2,155
Light trucks					
ICM w/Main Analysis Costs	39.29	$1,226	$175,793	61,984	1,333
RPE w/Main Analysis Costs	39.14	$1,491	$181,243	65,083	1,397
ICM w/NAS Costs	37.71	$1,375	$154,597	56,337	1,217

Sensitivity Analysis, Value of Statistical Life

The value associated with preventing a fatality is measured by the Value of a Statistical Life (VSL), defined as the value of preventing one random fatality among a population at risk. The Office of Management and Budget (OMB) reviews and approves regulations issued from numerous agencies including DOT, EPA, OSHA, CPSC, etc., and issues guidance for agencies to use in analyzing the impacts of their regulations. Although OMB guidance generally seeks to ensure a level of consistency in the issues addressed by various regulatory agencies, OMB has not established a common VSL for use across all government agencies. Instead, OMB recommends that each agency develop and justify its own VSL. As a result, different agencies assign different values to saving a life in their regulations.

The Department of Transportation (DOT) has issued a series of guidance memos for the various modes within the department. In February 2008, DOT established a VSL of $5.8 million with supplementary calculations at $3.2 million and $8.4 million in recognition of uncertainty found over a range of studies (these figures are measured in 2007 dollars). NHTSA typically adds the economic cost of crashes to the VSL of about $300,000 to determine the comprehensive cost of fatal crashes. These economic costs include medical costs, legal costs, insurance administration costs, property damage, travel delay costs, etc. In March 2009 DOT issued updated guidance establishing a VSL of $6.0 million for 2009. Adjusting the economic cost portion to 2009 economics as well produced a comprehensive costs of $6.32 million for the central analysis, and supplemental comprehensive costs of $3.72 and $8.92 million. These values were used in the NPRM, which was based on 2009 economics. The Final Rule is based on 2010 economics. Adjusting these comprehensive values for 2010 economics produces estimates of $6.34 million for the central value, with alternative values of $3.74 million and $8.94 million.[610]

Within the CAFE FRIA, VSL is used for two different purposes, once to value benefits-per-ton from reducing emissions of criteria pollutants in Chapter VIII, and once to value potential safety impacts in Chapter IX. The potential safety impacts calculation is discussed outside the Volpe model, in order to emphasize the uncertainty surrounding this issue. It is examined separately and put in context of the overall net benefits derived from the Volpe model.

The benefits-per-ton values for reducing emissions of criteria pollutants were derived by EPA for use by both EPA and NHTSA in this rulemaking activity. These estimates were based on an estimate of VSL derived previously by EPA and reported in its *Guidelines for Preparing Economic Analyses* (see Technical Support Document, Section 4.B.11.b.).[611] This estimate is $6.3 million in 2000 dollars, which corresponds to $7.79 million when expressed in 2009 dollars, which was used in the sensitivity analysis for the NPRM. EPA has adjusted this value to $7.98 million to reflect 2010 economics. NHTSA agreed to use the estimates of per-ton benefits from reducing air pollutant emissions derived by EPA in this rulemaking, despite their reliance on a VSL estimate higher than that endorsed by DOT.

[610] Note that these represent a simple average of comprehensive values calculated for crashworthiness and crash avoidance countermeasures. Fatality impacts result from both mass reduction and the rebound effect. The interaction of these two sources affects both crashworthiness and crash avoidance, although the portions of each impact are uncertain. Therefore, a simple average of the two estimates is used. Since the two values differ by less than 1%, the impact is not significant in any case.

[611] U.S. Environmental Protection Agency (U.S. EPA). 2000. Guidelines for Preparing Economic Analyses. EPA 240-R-00-003. National Center for Environmental Economics, Office of Policy Economics and Innovation. Washington, DC.

As noted in the DOT guidance, however, the uncertainty surrounding the VSL is notable, and should be recognized in regulatory analyses. Accordingly, NHTSA has prepared this sensitivity analysis, which examines the values of both safety mortality impact and mortality benefits from reducing criteria pollutant emissions under the complete range of DOT VSL values, as well as the EPA value. Table X-22 summarizes these estimates. The fatality impacts examined were derived from the scenario representing the real world scenario (credits allowed), with voluntary over-compliance and a 2010 baseline. As noted in the safety section, mass reduction within all scenarios was specifically targeted towards certain vehicle types in order to attempt to remain safety neutral over the 2017-2025 model year lifetimes. In this particular scenario, this produced a combined total of 17 fatalities prevented over the 2017-2025 period.

Table X-22
Sensitivity Analysis of Alternate VSLs
Preferred Alternative

Assumed VSL (2010 Dollars)	Source	Value of Fatality Impacts, 2017-2025, 3% Discount Rate ($millions)	Value of Mortality Benefits from Reduced Emissions of Criteria Air Pollutants ($millions)[612]
$3.74 million	DOT Lower Estimate	$51 savings	$960
$6.34 million	DOT Central Estimate	$86 savings	$1630
$7.98 million	EPA VSL Estimate	$109 savings	$2100
$8.94 million	DOT Upper Estimate	$122 savings	$2300

As mentioned above, the safety impacts are highly uncertain and are not used in the Volpe model. Although the criteria pollutants benefits are used in the Volpe model, their impact is small.

Sensitivity Analysis for Maximum Net Benefit and Total Costs = Total Benefits Alternatives

In the tables above, the preferred alternative is the baseline and sensitivity analyses are compared to the preferred alternative. For the maximum net benefits and total cost = total benefit alternatives, it is more likely that the mpg level will be more affected by different assumptions that affect costs and benefits, due to the methodology used to determine the mpg level of those alternatives. Thus, this analysis compares MY 2025 passenger car, light truck and combined mpg levels for different sensitivity analyses (see Tables X-23a and X-23b) at a 3% discount rate.

[612] All numbers derived from 2025 impacts from EIS Table 4.2.1-8-B2, which reflects the real world scenario (credits allowed), with voluntary over-compliance and a 2010 baseline under a 3% discount rate. Laden et al (2006) values were used for this sensitivity examination.

Table X-23a
Sensitivity Analysis for Maximum Net Benefits Alternative

Maximum Net Benefit	**Passenger Car mpg**	**Light Truck mpg**	**Combined mpg**
Reference	56.5	43.7	51.5
7% Discount Rate	54.2	43.9	50.3
High Fuel Price	56.7	43.5	51.5
Low Fuel Price	56.0	43.5	51.1
5% Rebound Effect	56.5	43.7	51.5
15% Rebound Effect	56.5	43.7	51.5
20% Rebound Effect	56.5	43.7	51.5
12¢/gal Military Security Value	56.5	43.7	51.5
$5/ton CO2 Value	56.5	43.7	51.5
$36/ton CO2 Value	56.5	43.7	51.5
$68/ton CO2 Value	56.5	43.7	51.5
Global Warming Potential	56.5	43.7	51.5
50% Consumer Benefit	56.5	43.7	51.5
75% Consumer Benefit	56.5	43.7	51.5
Post-Warranty Repair Costs	56.5	43.7	51.5
Low Battery Cost	56.5	43.7	51.5
High Battery Cost	56.5	43.7	51.5
Low Cost Mass Reduction	56.5	43.7	51.5
High Cost Mass Reduction	56.6	43.6	51.5
RPE w/Main Analysis Costs	56.4	43.6	51.4
ICM w/NAS Costs	55.3	43.3	50.6

Market-Driven Baseline	56.4	43.5	51.3
No Shift Optimization	56.2	43.3	51.1

Table X-23b
Sensitivity Analysis for Total Cost = Total Benefit Alternative

Maximum Net Benefit	**Passenger Car mpg**	**Light Truck mpg**	**Combined mpg**
Reference	58.1	43.8	52.4
7% Discount Rate	58.1	43.8	52.4
High Fuel Price	58.6	43.7	52.7
Low Fuel Price	57.7	43.7	52.1
5% Rebound Effect	58.1	43.8	52.4
15% Rebound Effect	58.1	43.8	52.4
20% Rebound Effect	58.1	43.8	52.4
12¢/gal Military Security Value	58.1	43.8	52.4
\$5/ton CO2 Value	58.1	43.8	52.4
\$36/ton CO2 Value	58.1	43.8	52.4
\$68/ton CO2 Value	58.1	43.8	52.4
Global Warming Potential	58.1	43.8	52.4
50% Consumer Benefit	58.1	43.8	52.4
75% Consumer Benefit	58.1	43.8	52.4
Post-Warranty Repair Costs	58.1	43.8	52.4
Low Battery Cost	58.1	43.8	52.4
High Battery Cost	58.1	43.8	52.4
Low Cost Mass Reduction	58.1	43.8	52.4
High Cost Mass Reduction	58.1	43.7	52.4
RPE w/Main Analysis Costs	58.1	43.6	52.3
ICM w/NAS Costs	57.2	43.6	51.8

Market-Driven Baseline	58.1	43.7	52.4
No Shift Optimization	57.7	43.4	52.0

XI. FLEXIBILITIES IN MEETING THE STANDARD

A. The CO_2 Credits and Fuel Consumption Improvement Values for Air Conditioning Efficiency, Off-cycle Reductions, and Full-size Pickup Trucks

In addition to the existing statutory provisions that add various flexibilities to the CAFE program, today's final rule establishes several changes to the procedures for purposes of calculating CAFE levels used to determine manufacturers' compliance with CAFE standards. These changes provide incentives to apply specific technologies based on their potential to achieve fuel economy improvements not observed under current fuel economy test procedures, as well as "game changing" technologies for light trucks. These changes, discussed briefly here, are presented in detail in Section IV.I of the preamble to today's final rule and in Chapter 5 of the Joint TSD.

For the MYs 2012-2016 rule, EPA provided an option for manufacturers to generate credits for complying with GHG standards by incorporating efficiency-improving vehicle technologies that would reduce CO_2 and fuel consumption from air conditioning (A/C) operation. EPA also provided another credit generating option for vehicle operation that is not captured by the Federal Test Procedure (FTP) and Highway Fuel Economy Test (HFET), collectively known as the "two-cycle" test procedure. EPA referred to these credits as "off-cycle credits." See 76 FR 74937, 74998, 75020.

For the MYs 2017-2025 rule, EPA proposed to modify fuel economy calculation procedures such that if a vehicle employs technologies designated as improving A/C efficiency or otherwise reducing off-cycle fuel consumption, the vehicle will, for purposes of CAFE, receive a higher fuel economy rating than would otherwise be the case. See id. and 76 FR 74995-998. For this final rule, under its EPCA authority, EPA is allowing manufacturers to generate fuel consumption improvement values for purposes of CAFE compliance based on the use of A/C efficiency and the other off-cycle technologies. These fuel consumption improvement values will not apply to compliance with the CAFE program for MYs 2012-2016. Also, any reductions in leakage of HFCs from air conditioning systems, which are generally unrelated to fuel consumption reductions, will not apply to compliance with the CAFE program, and will continue to apply only to the EPA GHG program.

NHTSA expects that, because of the increases to calculated fuel economy values available for improvements to the efficiency of A/C systems (up to 0.000563 gal/mi for cars and 0.000810 gal/mi for trucks),[613] manufacturers will take technological steps to maximize these benefits.

[613] Note that these are gallons per mile and not miles per gallon. The actual miles per gallon improvement depends upon the baseline mpg of the vehicle.

Since we project that all manufacturers will adopt these A/C improvements to their maximum extent, we have also accounted for expected A/C efficiency improvements in determining the maximum feasible CAFE standards. Other (non-A/C) off-cycle improvements in fuel consumption may also be eligible to apply towards compliance with the CAFE standards, as discussed above; however, with two exceptions (for the two-cycle benefits of stop-start and active aerodynamic improvements – technologies which we expect manufacturers to adopt widely and whose benefits can be reliably quantified), these off-cycle improvements are not incorporated in the stringency of the standards.

EPA, in coordination with NHTSA, is also introducing for MYs 2017-2025 a new incentive for certain advanced technologies used in full-sized pickup trucks. Under its EPCA authority for CAFE, EPA is establishing fuel economy improvement values for manufacturers that hybridize a significant quantity of their full-size pickup trucks, or that use other technologies that significantly improve the fuel economy of these full-sized pickup trucks. We discuss each of these types of incentives in detail in the Preamble and in Chapter 5 of the Joint TSD.

XII. PROBABILISTIC UNCERTAINTY ANALYSIS

OMB Circular A-4 directs agencies to conduct formal probabilistic uncertainty analysis of complex rules where there are large, multiple uncertainties whose analysis raises technical challenges or where effects cascade and where the impacts of the rule exceed $1 billion. CAFE meets all of these criteria. This chapter identifies and quantifies the major uncertainties in the final regulatory impact analysis and estimates the probability distribution of the benefits, costs, and net benefits of the compliance options selected for the final MYs 2017-2021 passenger car and light truck CAFE standards and augural MYs 2022-2025 standards. Throughout the course of the main analysis, input values were selected from a variety of often conflicting sources. Best estimates were selected based on the preponderance of data and analyses available, but there is inevitably a level of uncertainty in these selections, particularly given the time frame of the rulemaking. Some of these inputs contributed less to the overall variations of the outcomes, and, thus, are less significant. Some inputs depend on others or are closely related (*e.g.*, oil import externalities), and thus can be combined. With the vast number of uncertainties embedded in this regulatory analysis, this uncertainty analysis identifies only the major independent uncertainty factors having appreciable variability and impact on the end results and quantifies them by probability distributions. The values of these uncertainties are then randomly selected and fed back into the CAFE Compliance and Effects model (CAFE model) to determine the net benefits using the Monte Carlo statistical simulation technique.[614] The simulation technique induces the probabilistic outcomes accompanied with degrees of probability or plausibility. This facilitates a more informed decision-making process, because it provides additional information about the degree to which a particular outcome is likely. Using single point estimates for a large number of variables in an analysis provides a very limited view of the potential results, and provides no measure of confidence in the estimated outcome beyond the assertion that it is the "most likely." The likelihood of correctly estimating the exact total costs and benefits of a program as complex as CAFE, over such a long time frame, is small. But by using Monte Carlo simulations to explicitly consider the uncertainty around the important inputs to the analysis, decision-makers are able to see the probabilities associated with a large range of outcomes and develop confidence in achieving acceptable levels of net benefit from the existing program specification, even without perfect information about future conditions.

The analysis is based on the actual processes used to derive net benefits as described in the previous chapters. As with the sensitivity analyses discussed in Chapter X, NHTSA utilized the 2010 baseline fleet for the entirety of the uncertainty analysis. Each variable (*e.g.*, cost of a particular technology) in the simulation model represents an uncertainty factor that would

[614] See, for example, Morgan, MG, Henrion, M, and Small M, "Uncertainty: A Guide to Dealing with Uncertainty in Quantitative Risk and Policy Analysis," Cambridge University Press, 1990.

potentially alter the modeling outcomes if its value was changed. We assume that most of these variables are independent of each other, although similar technology costs are sampled in such a way that they are simultaneously at similar points in their respective cost distributions, even if the distributions themselves are different. For example, a single technology cost might be sampled as three variables based on the platform to which it is applied (*e.g.*, midsize passenger car, or small light truck). The distributions of cost would be different because larger vehicles often have higher incremental technology costs. However, it is more likely that a single technology's cost would be simultaneously higher than expected (in the central analysis) for each of the vehicle classes to which it is applied than be higher than expected for some classes and lower than expected for others. The sample design of technology costs for the final rule's Monte Carlo analysis attempts to account for such similarities. The confidence intervals around the costs and benefits of technologies reflect independent levels of uncertainty regarding costs and benefits, rather than linked probabilities dependent on higher or lower quality versions of a specific technology.

The uncertainties of these variables are described by appropriate probability distribution functions based on available data. If data are not sufficient or not available, agency staff used professional judgment to estimate the probability distributions of these uncertainty factors. A complete description of the formulas and methods used in the CAFE model is available on NHTSA's website.[615]

After defining and quantifying the major uncertainty factors, the next step is to run the simulation model many times to obtain a distribution of results rather than single-value estimates. In each run of the model, the 2012–2016 CAFE standards are held constant after 2016 in the baseline run, and then the final (and augural) standards of this rule are implemented in 2017 under the policy alternative runs. This policy environment is identical for each run in the simulation to ensure that variation in outcomes is a product of the relationship between the standards and the values of the underlying uncertainties in each case, rather than simultaneous changes in both uncertainties and the policy environment. The simulation process was run repeatedly for approximately 30,000 trials under each discount rate scenario (three and seven percent). Each complete run is a trial, and each trial represents a randomly generated instance of each included variable based on its probability distribution. The relevant variables in the

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[615] 2017–2025 CAFE Compliance and Effects Modeling System Documentation, Volpe Center, U.S. Dept. of Transportation, August 2012,. *Available at* http://www.nhtsa.gov/fuel-economy (last accessed Jul. 13, 2012).

simulation model then take on the selected values from the trial, and the model simulates CAFE compliance, costs, and benefits.

Simulation Models and Uncertainty Factors

A Monte Carlo simulation was conducted using the CAFE modeling system that was developed to estimate the impacts of higher CAFE requirements described in previous chapters. The purpose of the Monte Carlo simulation was to consider simultaneous variation in the values of chosen uncertainty parameters and its resulting impact on key output metrics—fuel savings and net benefits, for example. Net benefits are the difference between (1) the total dollar value that would be saved in fuel costs and other benefits and (2) the total costs of the rule.

The agency reviewed the inputs and relationships that drive the CAFE model to determine the factors that are the major sources of uncertainty. Several factors were identified as potentially contributing to uncertainty to the estimated impacts of higher CAFE standards, although not all were ultimately selected to be run in the simulation. In particular, the social cost of damages caused by criteria pollutant and greenhouse gas emissions have been omitted from the analysis, the latter based on guidance from the interagency working group that developed the cost estimates used in the central analysis. The list of included uncertainties is:

(1) Technology costs;

(2) Technology effectiveness;

(3) Fuel prices;

(4) Manufacturers' decision to produce vehicles with fuel economies higher than the levels mandated by CAFE standards;

(5) Average vehicle miles traveled per vehicle;

(6) The passenger car share of the new vehicle market;

(7) The value of oil consumption externalities and;

(8) The rebound effect.

Technology Costs

The costs incurred by manufacturers to modify their vehicles to meet new CAFE levels are assumed to be passed on to consumers in the form of higher new car prices. These technology costs are the primary determinant of the overall cost of improving fuel economy.

Sixty-five different technologies were examined as possible methods to comply with higher CAFE standards. These technologies were described in Chapter V earlier in this analysis. The agency used what were deemed the most likely cost values in the main analysis. For the uncertainty analysis, the agency modeled the plausible range of costs individually for each technology using beta distributions with mode values equal to the corresponding technology costs used in the central analysis. The beta distribution was chosen to represent the higher probability implicit in the central values, but also recognizing that alternative values recommended by the National Academy of Sciences (NAS) would have some probability of occurring. For a variety of reasons discussed elsewhere in this analysis, the agency selected central values that differ from the NAS recommendations. However, one purpose of an uncertainty analysis is to identify plausible alternate assumptions and reflect the possibility that these alternative values could occur. The agency calculated the ratio of total MY 2025 costs under the central values used in this analysis and compared them to the alternate values based on NAS recommendations, and found that NAS recommended values were 1.45 times the central values.[616] The agency created a beta model based on a mode equal to the central value, with the tails defined based on the average confidence intervals found in the NAS study. This confidence interval (18.6%) was added to the NAS relative cost. There were no confidence intervals provided in the FEV reports,[617] which defines the mode value, so the lower tail was defined as the absolute value of the difference between the NAS value and its upper confidence interval subtracted from the central values.

This effectively assigned a confidence interval to the central values of 27%. Within these parameters, the agency chose alpha and beta values of 1.8 and 3.14, respectively, to assign a 5% probability that values chosen would be equal to or greater than the NAS costs. The use of beta distributions with the above parameters allow for a range of technology costs less than those used in the central analysis, in-between those of the central analysis and those of the NAS study, and above those of the NAS study, with the greatest weight assigned around the central NPRM values. It should be noted that while, on average, the NAS recommended values for technology

[616] This factor reflects differences in direct technology cost estimates, indirect cost markups, and rates of learning. It thus represents the full range of assumptions that influence cost estimates.
[617] It should be noted that, although the FEV cost study did not determine formal uncertainty ranges or confidence intervals, FEV did conduct sensitivity analysis for some of the technologies for which they estimated costs, focusing on potential changes in labor and burden rates, material costs, and mark-ups such as engineering, profit, and end-item scrappage. This analysis found, for example, that a 20 percent decrease in labor rates would yield a 3 percent decrease in the cost of HEV technology.

costs are greater than the central NPRM values, there are cases on individual technologies where the NAS values are less than the central NPRM values. In these cases, the beta curve is reversed (beta values of 3.14 and 1.8 are used) to keep the mode at the central NPRM value and assign 5% probability that the value chosen would be equal to or less than the NAS cost.

Technology Effectiveness

The modifications adopted by manufacturers to enable their vehicles to meet new CAFE levels will improve fuel efficiency and reduce the cost of operating the more efficient vehicles. The effectiveness of each technology determines how large an impact it will have towards enabling manufacturers to meet the higher CAFE standards, and will thus determine how much additional improvement is needed and which additional technologies will be required to achieve full compliance. In selecting the likely path that manufacturers will choose to meet CAFE, the CAFE model tests the interaction of technology costs and effectiveness to achieve an optimal (cost-minimizing) technological solution. Technology effectiveness is thus a primary determinant of the overall cost and benefit of improving fuel economy.

As noted above, sixty-five different technologies were examined as possible methods to comply with higher CAFE standards. These technologies were described in Chapter V earlier in this analysis. Chapter V also summarizes the estimated range of effectiveness for these technologies. The agency used what were deemed the most likely effectiveness values in the main analysis. For the uncertainty analysis, the central NPRM value and the NAS-recommended value for effectiveness were used in establishing a range for variation. In many cases, the values were the same. In this case, a normal distribution was used and, as had been done in previous uncertainty analysis for CAFE rule-making, technology complexity was used to determine the standard deviation for the distribution. The determination of complexity was by agency expert professional judgment, and divided into low-complexity, medium-complexity and high-complexity. The technologies in each category and the standard deviation for each are shown in the table below.

Low Complexity	**Medium Complexity**	**High Complexity**
Standard Deviation = 14.5%	Standard Deviation = 29%	Standard Deviation = 43.5%
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	Discrete Variable Valve Lift (DVVL) on SOHC	Plug-in Hybrid - 30 mi range

Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	Cylinder Deactivation on SOHC	Plug-in Hybrid
6-Speed Manual/Improved Internals	Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	Electric Vehicle (Early Adopter) - 75 mile range
High Efficiency Gearbox (Manual)	Discrete Variable Valve Lift (DVVL) on DOHC	Electric Vehicle (Early Adopter) - 100 mile range
Improved Auto. Trans. Controls/Externals	Continuously Variable Valve Lift (CVVL)	Electric Vehicle (Early Adopter) - 150 mile range
6-Speed Trans with Improved Internals (Auto)	Cylinder Deactivation on DOHC	Electric Vehicle (Broad Market) - 150 mile range
High Efficiency Gearbox (Auto or DCT)	Stoichiometric Gasoline Direct Injection (GDI)	Fuel Cell Vehicle
Shift Optimizer	Cylinder Deactivation on OHV	
Mass Reduction - Level 1	Variable Valve Actuation - CCP and DVVL on OHV	
Mass Reduction - Level 2	Stoichiometric Gasoline Direct Injection (GDI) on OHV	
Mass Reduction - Level 3	Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	
Low Rolling Resistance Tires - Level 3	Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	
Secondary Axle Disconnect	Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	
	Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	
	Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	
	Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	
	Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	
	Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	

	Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	
	Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	
	Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	
	Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	
	6-speed DCT	
	8-Speed Trans (Auto or DCT)	
	Mass Reduction - Level 4	
	Mass Reduction - Level 5	

In cases where the NAS value did not equal the central NPRM value, a beta distribution was used to give a distribution which had 20% probability of being outside of the range between the NAS value and the central NPRM value. The beta parameters used were 1.2 and 1.055 for cases where the NAS value was less than the central NPRM value, and 1.1 and 1.411 for cases where the central NPRM value was less than the NAS value.

Fuel Prices

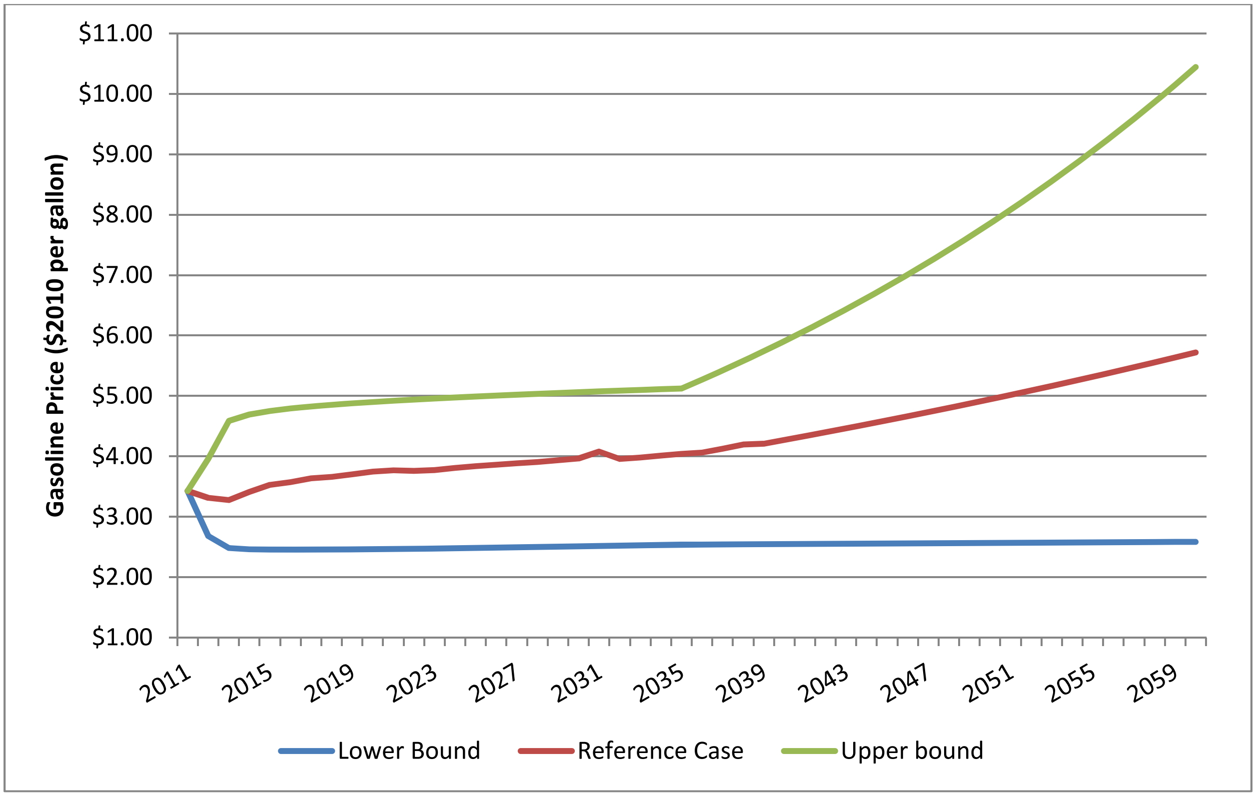
Higher CAFE standards will result in reduced gasoline consumption, which will translate into lower vehicle operating costs for consumers. The value of fuel saved is a direct function of fuel prices. Fuel prices are thus a primary determinant of the overall social benefit that will result from improving fuel economy.

Forecasting gasoline prices over a long period of time is a deeply uncertain process, and this analysis attempts to measure impacts that occur over the approximately the next 50 years, because vehicles sold in MY 2025 that reach their full useful life will not be retired until after 2060.;. In the main analysis, the agency utilized fuel price projections from the Energy Information Administration's (EIA) Annual Energy Outlook 2012 (AEO) Early Release. The main analysis is based on the AEO 2012 Early Release Reference Case scenario, which represents EIA's current best estimate of future fuel prices. For the uncertainty analysis, the Agency examined two other scenarios based on the AEO 2012 Early Release, the Low Oil Price scenario (LOP) and the High Oil Price scenario (HOP).[618] The LOP scenario was chosen to allow for the possibility that the EIA's Reference Case predictions could overestimate the price of gasoline in the future. However, previous escalation in the price of gasoline resulted in prices that exceeded those estimated by EIA for their reference case. To reflect the possibility of significantly higher prices, the agency selected the HOP case, which gives the highest gasoline price forecasts among all AEO scenarios.

From these forecast fuel prices, a set of distributions were made for each year (up to 2100) for each fuel type (gasoline, diesel, ethanol-85, electricity). The Reference case, LOP and HOP were, for each fuel, fit to a curve to supply a less jagged target (this reduced the annual variation in the projections, but preserved the long-term trend which was most relevant to this analysis), and a beta distribution was fit to each year for each fuel. This distribution used the curve-fitted Reference case as the mode and was calibrated to give approximately 12.5% probability that the chosen fuel price would be lower than LOP or higher than HOP. From here, a single random value is chosen to represent the percentile of each (annual) beta distribution, tracing out a full time series of fuel prices for each random draw.

[618] The AEO 2012 Early Release does not include low and high fuel price scenarios; ranges for the low and high scenarios were derived using an estimate of the relationship between World Oil Price and the average price of gasoline (and diesel).

Figure XII-1
Bounding Fuel Price Cases in Monte Carlo Sampling



Addressing Uncertainty about the Supply of Fuel Economy Beyond the Levels Mandated by the Standards

The CAFE model implicitly includes the capability to apply appropriate amounts of technology under varying fuel price cases by including a variable that represents manufacturers' assumption about consumer willingness-to-pay for fuel economy technology. This willingness-to-pay is characterized as the payback period for fuel economy technology investments, meaning the number of years' worth of fuel savings necessary to balance the cost of the new technology. In the central analysis, the model alters that variable to be zero once a manufacturer reaches compliance (or decides to pay fines, if they have historically done so). This means that no additional technology is added beyond the standards in the baseline, or in any of the other regulatory scenarios. For the central analysis, which uses a single fuel price projection and economic and technological parameter values consistent with it, the zero-year payback assumption is generally consistent with the collection of other assumptions. For example, assuming a one-year payback period (instead of zero) after compliance with 2016 standards in the central analysis only adds about 1 MPG to MY 2025 fuel economy in the baseline. However, under more extreme fuel prices, the zero-year payback assumption begins to create internally inconsistent results.

To address this limitation, NHTSA has included the length of the payback period (that manufacturers assume consumers desire) in the uncertainty analysis. Assuming some non-zero payback period ensures that when fuel prices are very high, manufacturers will continue to add cost-effective fuel economy technologies even when the standards are not sufficient to force these additions. As one might expect, higher fuel prices and longer payback periods result in more fuel economy technology being added beyond the level mandated by the standards, while lower fuel prices and shorter payback periods result in less.

The cases that most challenge internal consistency are naturally found at the extremes, low-price-long-payback, for example. In the low-price-long-payback case, the fuel savings would still be very low, technology would still not be very attractive, and only a small amount of additional fuel economy technology (if any at all) would be added to vehicles already in compliance. So one could credibly argue that there is uncertainty about the degree to which manufacturers understand consumers' willingness-to-pay for fuel economy and add slightly more than would be demanded.

Similarly, under the high-price-short-payback draws, fuel prices are high enough to make some technology additions occur in the baseline, but maybe not the ideal amount under those conditions because manufacturers assumed a shorter payback period than consumers have with high fuel prices. Since there is uncertainty about manufacturers' ability to perfectly respond to consumer preferences, these draws produce results that are still plausible (if less probable than others).

The payback period itself is drawn from a Poisson distribution with lambda = .85. This places slightly higher probability on the central analysis value of zero, with steeply decreasing probabilities afterward.

Average Vehicle Miles Travelled Per Vehicle

One of the most influential inputs to the CAFE model is the annual VMT schedule, which defines the baseline vehicle mile travelled by the average vehicle at each age of its life. Although the mileage accumulation schedule is based on the 2009 NHTS, a very large sample of households, it is still only one sample. NHTSA included uncertainty about this mileage accumulation schedule in the uncertainty analysis by sampling first-year VMT from a probability distribution and then applied the annual percentage reductions from the central analysis in each subsequent year of the vehicle's life.

NHTSA fit a distribution to the observed first-year VMT in the 2009 NHTS, then empirically estimated the sampling distribution of mean first-year VMT. Each instance of average first-year VMT in the Monte Carlo simulation is drawn from a probability distribution that was fit to the estimated sampling distribution of the mean (using separate distributions for passenger cars and light trucks). The probability distribution for the average first year passenger car VMT is normal, with a mean of 13,216 miles and a standard deviation of 108.3 miles. The distribution of average first year light truck VMT is also normal, with a mean of 14,757 miles and a standard deviation of 129 miles. Although these distributions produce small deviations from the mean, the increases (or decreases) in first-year VMT ultimately impact VMT at every age of the vehicle's life. As in the central analysis, NHTSA incorporates the impact of fleet vehicle operations on average VMT by averaging their estimated usage into the value obtained by the random draw.

The Passenger Car Share of the New Vehicle Market

The agencies rely on outputs from the Energy Information Administration's NEMS model to derive estimates of total annual light-duty vehicle sales and sales by regulatory class for all future model years. Continuing to use the static market forecast based on the NEMS run that underlies the central analysis could lead to implausible results under varying combinations of input parameters, because changing the values of any of the factors that influence that forecast would be likely to change the forecast as well. To address this limitation, NHTSA investigated the transportation module in NEMS to better understand the underlying equation that takes total new vehicle sales and distributes them to vehicle classes. The annual share of passenger cars in NEMS is determined by a difference equation that considers the historic car share, per capita income, fuel price, average car horsepower, average car weight, vehicle fuel economy, and an autocorrelation coefficient to account for time series influences.

Since all of those variables are either implicitly included in the CAFE model, or simulated as part of the Monte Carlo analysis, NHTSA was able to address uncertainty about the passenger car share of the new vehicle market by adding a new relationship to the model rather than adding a new uncertainty parameter to the sample. NHTSA used the NEMS run that informs the central analysis to develop a approximation of the relationship between passenger car share and the variables described above. Incorporating this relationship into the CAFE model ensures that the passenger car share in any trial is consistent with the other values drawn for that trial, and that the resulting passenger car share is consistent with the logic used to develop the passenger car share in the central analysis. This endogenous relationship only appears in the version of the CAFE model that was used for the Monte Carlo analysis — the central analysis still relies upon a static forecast for both the main analysis and all sensitivity runs.

Oil Consumption Externalities

Reduced fuel consumption can benefit society by lowering the world market price for oil, reducing the threat of petroleum supply disruptions, reducing the cost of military operations related to the security of international oil production, distribution, and maintenance and operation of the strategic petroleum reserve. These benefits are called "externalities" because they are not reflected directly in the market price of fuel. A full description of these externalities is included in Chapter VIII under "Other Economic Benefits from Reducing Petroleum Use." These factors increase the net social benefits from reduced fuel consumption. Although they represent a relatively small portion of overall social benefits, there is a significant level of uncertainty as to their values.[619]

Monopsony costs represent the reduced value of payments from U.S. oil purchasers to foreign oil suppliers that results when lower U.S. oil demand reduces the world price of petroleum, beyond

[619] For reasons noted in Chapter VIII, the agency opted not to conduct uncertainty analysis surrounding the military security externality. While there is uncertainty regarding the value of the military security externality, the agency believes that U.S. military expenditures are unlikely to be directly influenced by this rule.

the savings from reduced purchases of petroleum itself.[620] However, consistency with NHTSA's use of estimates of the *global* benefits from reducing emissions of CO_2 and other greenhouse gases in this analysis requires the use of a global perspective for assessing their net value. From this perspective, reducing these payments simply results in a transfer of resources from foreign oil suppliers to U.S. purchasers (or more properly, in a savings in the value of resources previously transferred from U.S. purchasers to foreign producers), and provides no real savings in resources to the global economy. Thus NHTSA's analysis of the benefits from adopting higher CAFE standards for MY 2017-2025 cars and light trucks excludes the reduced value of monopsony payments by U.S. oil consumers that might result from lower fuel consumption by these vehicles, and they are likewise not included in the uncertainty analysis.

The second component of external economic costs imposed by U.S. petroleum imports arises because an increase in oil prices triggered by a disruption in the supply of imported oil reduces the level of output that the U.S. economy can produce. The reduction in potential U.S. economic output depends on the extent and duration of the increases in petroleum product prices that result from a disruption in the supply of imported oil, as well as on whether and how rapidly these prices return to pre-disruption levels. Even if prices for imported oil return completely to their original levels, however, economic output will be at least temporarily reduced from the level that would have been possible without a disruption in oil supplies. It is estimated that each gallon of fuel saved that results in a reduction in U.S. petroleum imports (either crude petroleum or refined fuel) will reduce the expected costs of oil supply disruptions to the U.S. economy by \$0.097 to \$0.297, with the actual value most likely to be \$0.197 per gallon. The uncertainty analysis draws samples from a normal distribution with a mean of \$0.197 and a standard deviation of \$0.05, developed so that the upper and lower bounds of the estimated range occur two standard deviations from the mean.

The Rebound Effect

By reducing the amount of gasoline used and, thus, the cost of operating a vehicle, higher CAFE standards are expected to result in a slight increase in annual miles driven per vehicle. This "rebound effect" impacts net societal benefits because the increase in miles driven offsets a

[620] The reduction in payments from U.S. oil purchasers to domestic petroleum producers is not included as a benefit, since it represents a transfer that occurs entirely within the U.S. economy.

portion of the gasoline savings that results from more fuel-efficient vehicles. Although consumers derive value from this extra driving, it also leads to increases in crashes, congestion, noise, and pollution costs associated with driving. As Table XII-1 illustrates, most recent estimates of the magnitude of the rebound effect for light duty vehicles fall in the range of 15-20 percent (*i.e.*, increasing vehicle use will offset 15-20 percent of the fuel savings resulting from an improvement in fuel economy), but studies also show that the rebound effect has been gradually decreasing over time. On this basis, the agency employed a rebound effect of 10 percent in the main analysis. A more complete discussion of the rebound effect is included in Chapter VIII. For the uncertainty analysis, a range of 5 to 30 percent was used and employed in a slightly skewed beta distribution which produced a mean of approximately 14.2 percent. The skewed distribution reflects the agency's belief that the more credible studies that differ from the 10 percent value chosen for the main analysis fall below this value (*i.e.*, are more negative) and differ by more substantial margins than the upper range of credible values. Table XII-2 summarizes the economic parameters used in the uncertainty analysis.

Table XII-1
Summary Statistics for Estimates of the Rebound Effect

Category of Estimates	Number of Studies	Number of Estimates	Range		Distribution		
			Low	High	Median	Mean	Std. Dev.
All Estimates	22	66	7%	75%	22%	23%	14%
Published Estimates	17	50	7%	75%	22%	24%	14%
U.S. Time-Series Data	7	34	7%	45%	14%	18%	9%
Household Survey Data	13	23	9%	75%	31%	31%	16%
Pooled U.S. State Data	2	9	8%	58%	22%	25%	14%
Constant Rebound Effect (1)	15	37	7%	75%	20%	23%	16%
Variable Rebound Effect: (1)	10	29	10%	45%	23%	23%	10%

Table XII-2
Economic Parameters in the Monte Carlo Analysis

Discount Rates (%)	0.03, 0.07
Fuel Path Randomization Parameter	
Uniform distribution range	(0,1)
Rebound Effect Randomization Parameters	
Beta Distribution, Alpha Shape	1.50
Beta Distribution, Beta Shape	3.00
Scale	-0.25
Base	-0.05
Price Shock Randomization Parameters	
Normal Distribution, Mean	$0. 197
Normal Distribution, Standard Deviation	$0.05
Payback Period Uncertainty	
Poisson Distribution, lambda shape	0.85

Modeling Results – Trial Draws

Because of the complexity of the CAFE model, the computer time required to perform the uncertainty analysis was significant. The uncertainty analysis conducted a total of 60,000 trials (30,000 for each discount rate). Figures XII-2 through XII-11 graphically illustrate the draw results for a selected sample of the 137 variables (65 technology effectiveness rates, 65 technology costs, fuel price series, oil import externalities, length of payback period for additional fuel savings, first-year VMT (by regulatory class), and the rebound effect) that were examined.

Although the full uncertainty ranges for all technologies are presented in Table XII-3 and XII-4, the agency chose to graphically highlight a subset of these technologies in Figure XII-2 through XII-7. These technologies were selected for illustrative purposes due to their high penetration rates and due to their importance as enablers of the preferred alternative.

Figure XII-2
Monte Carlo Draw Profile, Combined Fleet, Costs

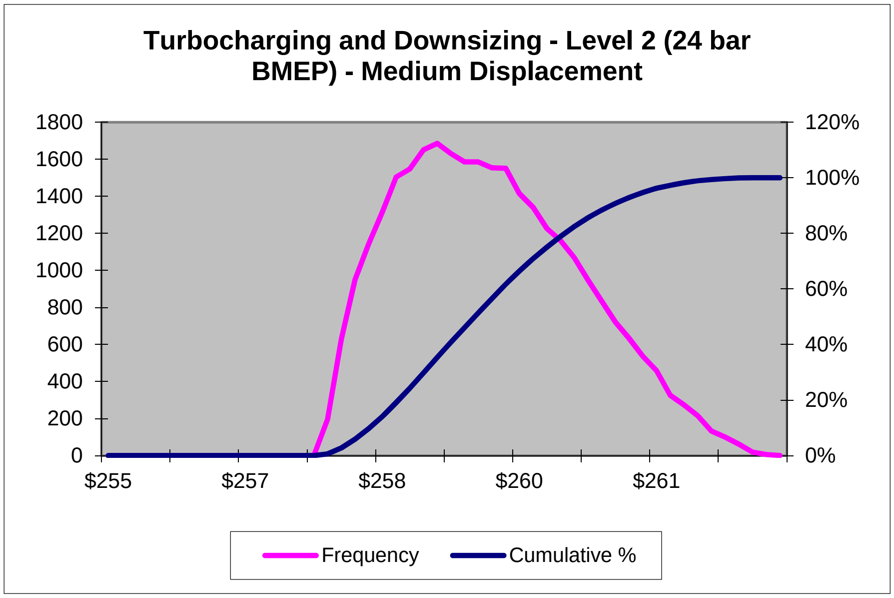


Figure XII-3
Monte Carlo Draw Profile, Combined Fleet, Effectiveness

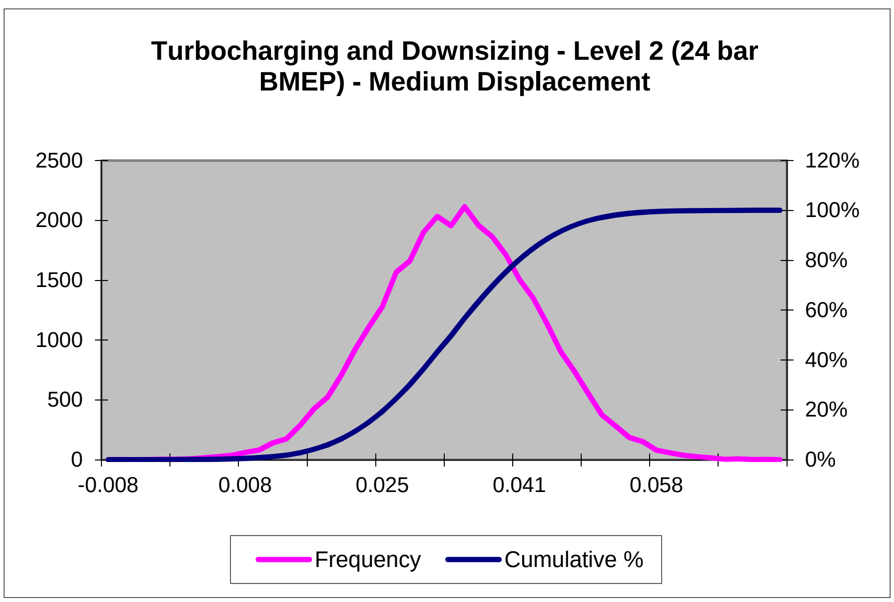


Figure XII-4
Monte Carlo Draw Profile, Combined Fleet, Costs

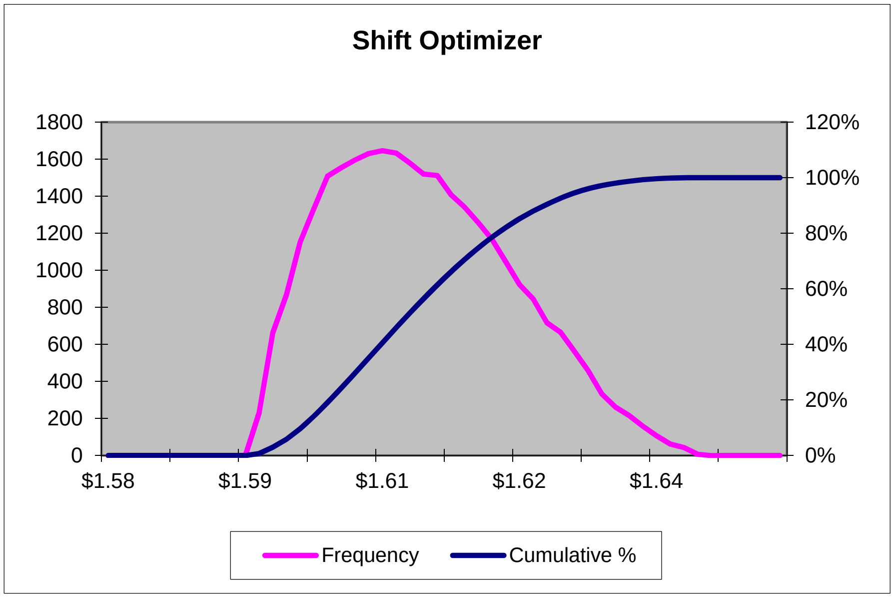


Figure XII-5
Monte Carlo Draw Profile, Combined Fleet, Effectiveness

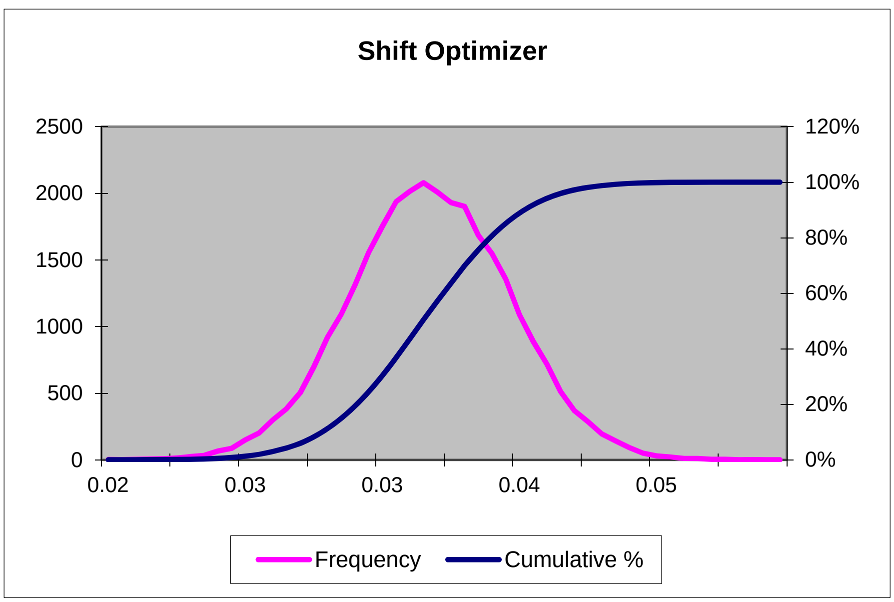


Figure XII-6
Monte Carlo Draw Profile, Combined Fleet, Costs

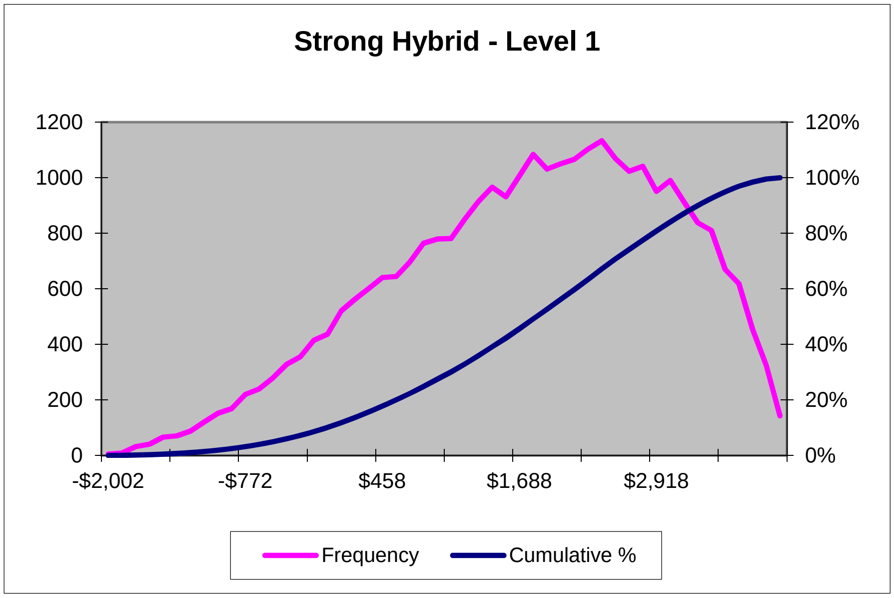


Figure XII-7
Monte Carlo Draw Profile, Combined Fleet, Effectiveness

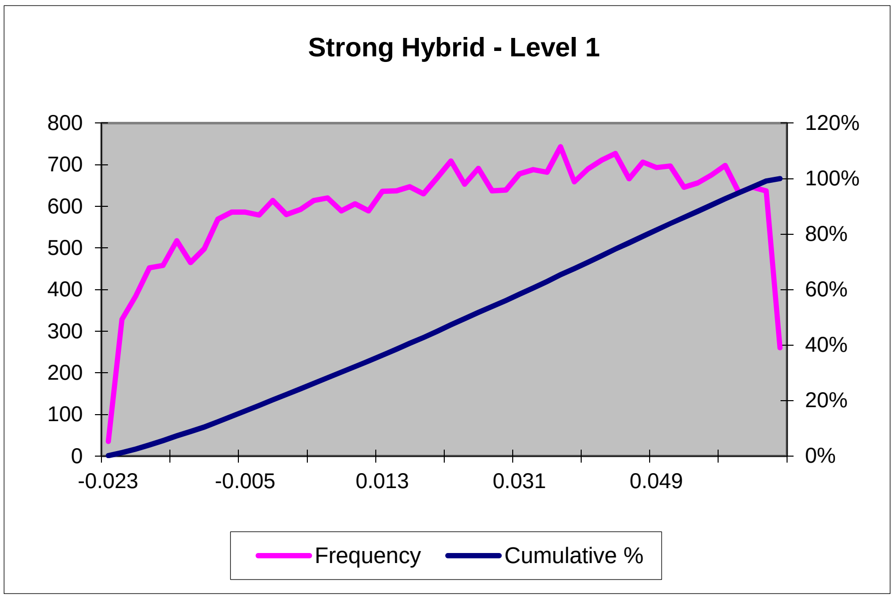


Figure XII-8
Monte Carlo Draw Profile
Pretax Fuel Price Path

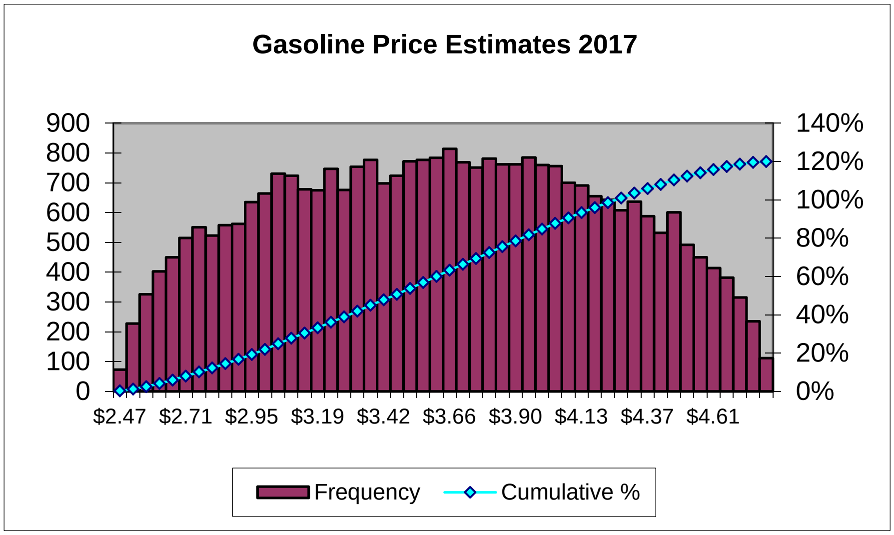


Figure XII-9
Monte Carlo Draw Profile

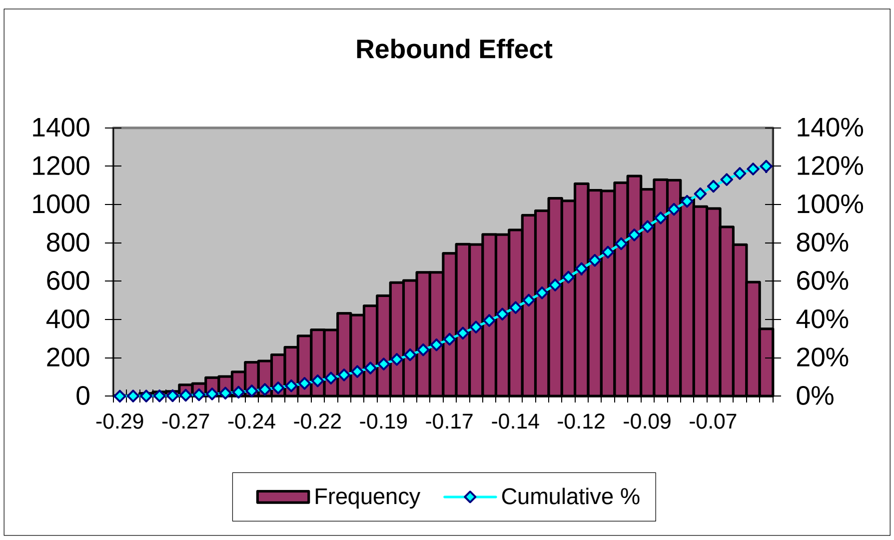


Figure XII-10
Monte Carlo Draw Profile

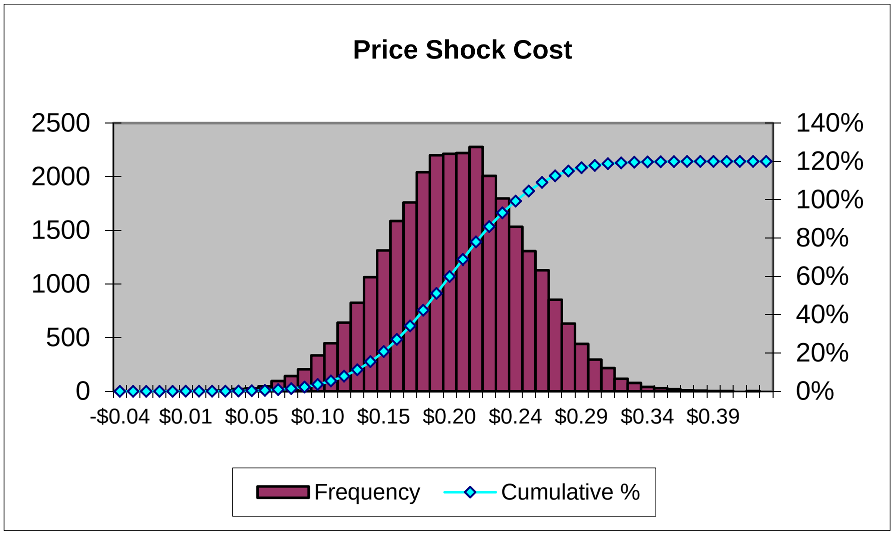


Table XII-3
Monte Carlo Draw Results, Combined Fleet, Technology Costs

Technology	Distribution	α Shape Parameter	β Shape Parameter	Low Value	Mode[621]	High Value
Low Friction Lubricants - Level 1	Beta	1.8	3.14	2.7386283	4.0237939	7.4375884
Engine Friction Reduction - Level 1	Beta	1.8	3.14	14.547884	15.124497	16.656161
Low Friction Lubricants and Engine Friction Reduction - Level 2	Beta	1.8	3.14	13.708552	15.710183	21.027129
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	Beta	1.8	3.14	41.923728	46.342552	58.080304
Discrete Variable Valve Lift (DVVL) on SOHC	Beta	1.8	3.14	33.064626	40.769137	61.234684
Cylinder Deactivation on SOHC	Beta	1.8	3.14	-74.25367	32.472016	315.96822
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	Beta	1.8	3.14	41.923728	46.342552	58.080304
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	Beta	1.8	3.14	38.563648	44.259545	59.389596
Discrete Variable Valve Lift (DVVL) on DOHC	Beta	1.8	3.14	33.064626	40.769137	61.234684
Continuously Variable Valve Lift (CVVL)	Beta	1.8	3.14	61.546277	65.630618	76.479883
Cylinder Deactivation on DOHC	Beta	1.8	3.14	-74.25367	32.472016	315.96822
Stoichiometric Gasoline Direct Injection (GDI)	Beta	1.8	3.14	58.8416	67.11349	89.08617
Cylinder Deactivation on OHV	Beta	1.8	3.14	105.31028	207.75485	479.87909
Variable Valve Actuation - CCP and DVVL on OHV	Beta	1.8	3.14	50.936136	51.929593	54.568521
Stoichiometric Gasoline Direct Injection (GDI) on OHV	Beta	3.14	1.8	53.222227	67.11349	72.343029
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	Beta	3.14	1.8	376.70283	493.60136	537.60927

[621] Note, for the Low, High and Mode values: These values are only given as estimates. They were generated from averages over all tech classes from MY 2016 data. Rather than the values shown here, the model receives as inputs an index where 1.0 = the mode value.

Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	Beta	3.14	1.8	-209.89942	19.393554	105.71376
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	Beta	3.14	1.8	524.71386	620.78767	656.95586
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	Beta	1.8	3.14	13.964956	26.056443	58.175144
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	Beta	1.8	3.14	230.03571	262.37389	348.27402
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	Beta	1.8	3.14	387.75822	442.26886	587.06586
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	Beta	1.8	3.14	264.93308	302.17709	401.10862
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	Beta	1.8	3.14	264.93308	302.17709	401.10862
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	Beta	1.8	3.14	264.93308	302.17709	401.10862
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	Beta	1.8	3.14	467.50209	524.74778	676.80991
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	Beta	1.8	3.14	467.50209	524.74778	676.80991
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	Beta	3.14	1.8	-344.95423	-299.9334	-282.98474
Advanced Diesel - Small Displacement	Beta	1.8	3.14	835.62872	888.61543	1029.3644
Advanced Diesel - Medium Displacement	Beta	3.14	1.8	846.37148	854.96969	858.2066
Advanced Diesel - Large Displacement	Beta	1.8	3.14	1651.4607	1709.9917	1865.4681
6-Speed Manual/Improved Internals	Beta	1.8	3.14	234.95286	279.1927	396.70729
High Efficiency Gearbox (Manual)	Beta	1.8	3.14	218.90336	250.86616	335.76917
Improved Auto. Trans. Controls/Externals	Beta	1.8	3.14	52.382421	62.245633	88.445352
6-Speed Trans with Improved Internals (Auto)	Beta	1.8	3.14	-180.87206	-39.063067	337.62517
6-speed DCT	Beta	3.14	1.8	-61.336479	-60.49875	-60.183376
8-Speed Trans (Auto or DCT)	Beta	1.8	3.14	184.89548	210.88789	279.93171
High Efficiency Gearbox (Auto or DCT)	Beta	1.8	3.14	218.90336	250.86616	335.76917
Shift Optimizer	Beta	1.8	3.14	1.4557074	1.66826	2.232865

Electric Power Steering	Beta	1.8	3.14	87.391493	109.41991	167.93417
Improved Accessories - Level 1	Beta	1.8	3.14	68.504232	88.988519	143.40107
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	Beta	3.14	1.8	53.15804	54.173585	54.555899
12V Micro-Hybrid (Stop-Start)	Beta	1.8	3.14	119.24381	387.04024	1098.3898
Integrated Starter Generator	Beta	1.8	3.14	711.89927	975.84914	1676.9811
Strong Hybrid - Level 1	Beta	3.14	1.8	-1959.6721	2445.0574	4103.2729
Conversion from SHEV1 to SHEV2	Beta	1.8	3.14	1123.7961	1276.3205	1681.4723
Strong Hybrid - Level 2	Beta	3.14	1.8	-1849.0735	2441.335	4056.5129
Plug-in Hybrid - 30 mi range	Beta	3.14	1.8	5335.4639	9909.2228	11631.071
Mass Reduction - Level 1	Beta	1.8	3.14	-0.8142845	0.0542583	2.3613749
Mass Reduction - Level 2	Beta	1.8	3.14	-0.3709052	0.2907176	2.0481907
Mass Reduction - Level 3	Beta	1.8	3.14	0.0095596	0.4806218	1.7319076
Mass Reduction - Level 4	Beta	1.8	3.14	0.2816568	0.5237698	1.1668964
Mass Reduction - Level 5	Beta	1.8	3.14	0.5213845	0.7332778	1.2961312
Low Rolling Resistance Tires - Level 1	Beta	1.8	3.14	-3.0180253	6.7063232	32.537179
Low Rolling Resistance Tires - Level 2	Beta	3.14	1.8	52.703973	73.162117	80.86384
Low Rolling Resistance Tires - Level 3						
Low Drag Brakes	Beta	1.8	3.14	64.370593	73.769555	98.736083
Secondary Axle Disconnect	Beta	1.8	3.14	82.193257	97.669622	138.7796
Aero Drag Reduction, Level 1	Beta	1.8	3.14	36.696475	48.917138	81.378972
Aero Drag Reduction, Level 2	Beta	1.8	3.14	131.17966	164.44371	252.80326

Table XII-4

Monte Carlo Draw Results, Combined Fleet, Fuel Economy Improvement Rates

Technology	Distribution	Indexed Mean	Std Dev (in 0:1 range)	α Shape Parameter	β Shape Parameter	Low Value	Mode	High Value
Low Friction Lubricants - Level 1	Beta			1.2	1.0549956	0.004375	0.0066054	0.0072188
Engine Friction Reduction - Level 1	Beta			1.2	1.0549956	0.0113021	0.0231732	0.0264375
Low Friction Lubricants and Engine Friction Reduction - Level 2	Beta			1.1	1.4108074	0.0101395	0.0133455	0.0265157
Variable Valve Timing (VVT) - Coupled Cam Phasing (CCP) on SOHC	Normal	1	0.145					
Discrete Variable Valve Lift (DVVL) on SOHC	Normal	1	0.29					
Cylinder Deactivation on SOHC	Normal	1	0.29					
Variable Valve Timing (VVT) - Intake Cam Phasing (ICP)	Normal	1	0.145					
Variable Valve Timing (VVT) - Dual Cam Phasing (DCP)	Normal	1	0.29					
Discrete Variable Valve Lift (DVVL) on DOHC	Normal	1	0.29					
Continuously Variable Valve Lift (CVVL)	Normal	1	0.29					
Cylinder Deactivation on DOHC	Normal	1	0.29					
Stoichiometric Gasoline Direct Injection (GDI)	Normal	1	0.29					
Cylinder Deactivation on OHV	Normal	1	0.29					

Variable Valve Actuation - CCP and DVVL on OHV	Normal	1	0.29					
Stoichiometric Gasoline Direct Injection (GDI) on OHV	Normal	1	0.29					
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Small Displacement	Normal	1	0.29					
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Medium Displacement	Normal	1	0.29					
Turbocharging and Downsizing - Level 1 (18 bar BMEP) - Large Displacement	Normal	1	0.29					
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Small Displacement	Normal	1	0.29					
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Medium Displacement	Normal	1	0.29					
Turbocharging and Downsizing - Level 2 (24 bar BMEP) - Large Displacement	Normal	1	0.29					
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Small Displacement	Normal	1	0.29					
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Medium Displacement	Normal	1	0.29					
Cooled Exhaust Gas Recirculation (EGR) - Level 1 (24 bar BMEP) - Large Displacement	Normal	1	0.29					
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Small Displacement	Normal	1	0.29					
Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Medium Displacement	Normal	1	0.29					

Cooled Exhaust Gas Recirculation (EGR) - Level 2 (27 bar BMEP) - Large Displacement	Normal	1	0.29					
Advanced Diesel - Small Displacement	Beta			1.1	1.4108074	0.0357976	0.0479829	0.0980408
Advanced Diesel - Medium Displacement	Beta			1.1	1.4108074	0.0357976	0.0479829	0.0980408
Advanced Diesel - Large Displacement	Beta			1.1	1.4108074	0.0357976	0.0405367	0.0600053
6-Speed Manual/Improved Internals	Normal	1	0.145					
High Efficiency Gearbox (Manual)	Normal	1	0.145					
Improved Auto. Trans. Controls/Externals	Normal	1	0.145					
6-Speed Trans with Improved Internals (Auto)	Normal	1	0.145					
6-speed DCT	Normal	1	0.29					
8-Speed Trans (Auto or DCT)	Normal	1	0.29					
High Efficiency Gearbox (Auto or DCT)	Normal	1	0.145					
Shift Optimizer	Normal	1	0.145					
Electric Power Steering	Beta			1.1	1.4108074	0.0107917	0.0130838	0.0225
Improved Accessories - Level 1	Beta			1.2	1.0549956	0.00875	0.0120124	0.0129095
Improved Accessories - Level 2 (w/ Alternator Regen and 70% efficient alternator)	Beta			1.2	1.0549956	0.002625	0.01954	0.0241912
12V Micro-Hybrid (Stop-Start)	Beta			1.1	1.4108074	0.0170219	0.0202968	0.03375

Integrated Starter Generator	Beta			1.1	1.4108074	0.0555699	0.060814	0.0823572
Strong Hybrid - Level 1	Beta			1.2	1.0549956	-0.0216179	0.0415055	0.058863
Conversion from SHEV1 to SHEV2	Beta			1.1	1.4108074	0.1118695	0.1233505	0.1705154
Strong Hybrid - Level 2	Beta			1.2	1.0549956	-0.0245667	0.0084411	0.0175175
Plug-in Hybrid - 30 mi range	Normal	1	0.435					
Mass Reduction - Level 1	Normal	1	0.145					
Mass Reduction - Level 2	Normal	1	0.145					
Mass Reduction - Level 3	Normal	1	0.145					
Mass Reduction - Level 4	Normal	1	0.29					
Mass Reduction - Level 5	Normal	1	0.29					
Low Rolling Resistance Tires - Level 1	Beta			1.1	1.4108074	0.016625	0.0177751	0.0225
Low Rolling Resistance Tires - Level 2	Beta			1.2	1.0549956	0.0169643	0.0216479	0.0229358
Low Rolling Resistance Tires - Level 3	Normal	1	0.145					
Low Drag Brakes	Beta			1.1	1.4108074	0.007	0.007832	0.01125
Secondary Axle Disconnect	Normal	1	0.145					
Aero Drag Reduction, Level 1	Beta			1.2	1.0549956	0.013125	0.0231252	0.025875
Aero Drag Reduction, Level 2	Beta			1.1	1.4108074	0.0214944	0.0244414	0.0365482

Modeling Results – Output

Tables XII-5, XII-6, and XII-7 summarize the modeling results for fuel saved, total costs, societal benefits, and net benefits for passenger cars and trucks, respectively, under a 7% discount rate. They also indicate the probability that net benefits exceed zero. Tables XII-8, XII-9, and XII-10 summarize these same results under a 3 percent discount rate. These results are also illustrated in Figures XII-11 through XII-14 for the combined fleet under the Preferred Alternative at the 7 percent discount rate for MY 2025. Although not shown here, the general shapes of the resulting output distributions are similar for the light trucks, for the 3 percent discount rate, and for other model years as well. The following discussions summarize the range of results presented in these tables for the combined passenger car and light truck fleets across both the 7 percent (typically the lower range) and 3 percent (typically upper range) discount rates.[622]

Fuel Savings:[623] The analysis indicates that MY 2017 vehicles (both passenger cars and light trucks) will experience between -166 million and 20,142 million gallons of fuel savings over their useful lifespan. Negative fuel savings imply greater fuel consumption under the standards than in the baseline (for the same trial). MY 2018 vehicles will experience between 494 million and 34,380 million gallons of fuel savings over their useful lifespan. MY 2019 vehicles will experience between 743 million and 56,991 million gallons of fuel savings over their useful lifespan. MY 2020 vehicles will experience between 559 million and 77,193 million gallons of fuel savings over their useful lifespan. MY 2021 vehicles will experience between 732 million and 99,094 million gallons of fuel savings over their useful lifespan. MY 2022 vehicles will experience between 911 million and 108,747 million gallons of fuel savings over their useful lifespan. MY 2023 vehicles will experience between 972 million and 120,468 million gallons of fuel savings over their useful lifespan. MY 2024 vehicles will experience between 964 million and 134,279 million gallons of fuel savings over their useful lifespan. MY 2025 vehicles will experience between 1032 million and 144,463 million gallons of fuel savings over their useful lifespan.

Over the combined lifespan of the nine model years, between -627 and 805,278 million gallons of fuel will be saved.

[622] In a few cases the upper range results were obtained from the 7% rate and the lower range results were obtained from the 3% rate. While this may seem counterintuitive, it results from the random selection process that is inherent in the Monte Carlo technique.
[623] Note that Chapter XII of the PRIA erroneously listed fuel savings 1,000 times greater than expected. This error was fixed for the FRIA.

Total Costs: The analysis indicates that owners of MY 2017 passenger cars and light trucks will pay between -$47 million and $6,800 million in higher vehicle prices to purchase vehicles with improved fuel efficiency. MY 2018 owners will pay between -$43 million and $9,020 million more. MY 2019 owners will pay between -$66 million and $15,119 million more. MY 2020 owners will pay between $99 million and $19,516 million more. MY 2021 owners will pay between $106 million and $26,253 million more. MY 2022 owners will pay between $25 million and $29,752 million more. MY 2023 owners will pay between $26 million and $39,275 million more. MY 2024 owners will pay between -$76 million and $48,809 million more. MY 2025 owners will pay between -$40 million and $51,977 million more.

Across all nine model years combined, owners will pay between $0.2 billion and $246.5 billion in higher vehicle prices to purchase vehicles with improved fuel efficiency.

Net of Societal Costs and Benefits: The analysis indicates that changes to passenger cars and light trucks to meet the CAFE standards for each of the nine model years covered by this rule will produce overall net societal costs and benefits in the following ranges:

- MY 2017: Between -$229 million and $22,544 million
- MY 2018: Between $470 million and $37,580 million
- MY 2019: Between $716 million and $62,293 million
- MY 2020: Between $398 million and $86,184 million
- MY 2021: Between $679 million and $109,215 million
- MY 2022: Between $921 million and $120,015 million
- MY 2023: Between $970 million and $134,972 million
- MY 2024: Between $991 million and $149,797 million
- MY 2025: Between $1,002 million and $162,174 million

Over the combined lifespan of the nine model years, net social benefits valued between $5.9 billion and $884.8 billion will be produced.

Net Benefits: The uncertainty analysis indicates that the net impact of the higher CAFE requirements for MY 2017 passenger cars and light trucks will be between a net cost of $1,021 million and a net benefit of $18,396 million. Assuming a 7 percent discount rate, there is a 99.6 percent certainty that changes made to the MY 2017 passenger car fleet to achieve the CAFE standards will produce a net benefit. For light trucks, this value is 97.2 percent. Assuming a 3 percent discount rate, these values are 99.9 percent and 97.4 percent, respectively.

The net impact of the higher CAFE requirements for MY 2018 will be between a net cost of $717 million and a net benefit of $31,733 million. Assuming a 7 percent discount rate, there is a 98.5 percent certainty that changes made to the MY 2018 passenger car fleet to achieve the CAFE standards will produce a net benefit. For light trucks, this value is 100 percent. Assuming a 3 percent discount rate, these values are 99.7 percent and 100 percent, respectively.

The net impact of the higher CAFE requirements for MY 2019 will be between a net cost of $1,622 million and a net benefit of $53,503 million. Assuming a 7 percent discount rate, there is a 97.8 percent certainty that changes made to the MY 2019 passenger car fleet to achieve the CAFE standards will produce a net benefit. For light trucks, this value is 100 percent. Assuming a 3 percent discount rate, these values are 99.3 percent and 100 percent, respectively.

The net impact of the higher CAFE requirements for MY 2020 will be between a net cost of $1,947 million and a net benefit of $86,184 million. Assuming a 7 percent discount rate, there is a 97.4 percent certainty that changes made to the MY 2020 passenger car fleet to achieve the CAFE standards will produce a net benefit. For light trucks, this value is 100 percent. Assuming a 3 percent discount rate, these values are 99.0 percent and 100 percent, respectively.

The net impact of the higher CAFE requirements for MY 2021 will be between a net cost of $4,774 million and a net benefit of $95,398 million. Assuming a 7 percent discount rate, there is a 96.8 percent certainty that changes made to the MY 2021 passenger car fleet to achieve the CAFE standards will produce a net benefit. For light trucks, this value is 100 percent. Assuming a 3 percent discount rate, these values are 99.0 percent and 100 percent, respectively.

The net impact of the higher CAFE requirements for MY 2022 will be between a net cost of $6,817 million and a net benefit of $104,740 million. Assuming a 7 percent discount rate, there is a 96.3 percent certainty that changes made to the MY 2022 passenger car fleet to achieve the CAFE standards will produce a net benefit. For light trucks, this value is 100 percent. Assuming a 3 percent discount rate, these values are 98.8 percent and 100 percent, respectively.

The net impact of the higher CAFE requirements for MY 2023 will be between a net cost of $12,900 million and a net benefit of $119,058 million. Assuming a 7 percent discount rate, there is a 93.9 percent certainty that changes made to the MY 2023 passenger car fleet to achieve the CAFE standards will produce a net benefit. For light trucks, this value is 100 percent. Assuming a 3 percent discount rate, these values are 97.7 percent and 100 percent, respectively.

The net impact of the higher CAFE requirements for MY 2024 will be between a net cost of $18,421 million and a net benefit of $132,130 million. Assuming a 7 percent discount rate, there is a 89.6 percent certainty that changes made to the MY 2024 passenger car fleet to achieve the CAFE standards will produce a net benefit. For light trucks, this value is 100 percent. Assuming a 3 percent discount rate, these values are 95.2 percent and 100 percent, respectively.

The net impact of the higher CAFE requirements for MY 2025 will be between a net cost of $21,051 million and a net benefit of $143,774 million. Assuming a 7 percent discount rate, there is an 88.9 percent certainty that changes made to the MY 2025 passenger car fleet to achieve the CAFE standards will produce a net benefit. For light trucks, this value is 100 percent. Assuming a 3 percent discount rate, these values are 94.6 percent and 100 percent, respectively.

Over all nine model years, the higher CAFE standards will produce a net impact ranging from a net cost of $69.3 billion to a net benefit of $774.7 billion. There is at least a 99.5 percent certainty that higher CAFE standards will produce a net societal benefit in each of the combined fleet model years covered by this rule.

Keeping with our presentation conventions when both costs and benefits are presented on the same table and combined, costs are displayed as parenthesized values to aid the reader in following the summation logic.

Table XII-5
UNCERTAINTY ANALYSIS RESULTS, PASSENGER CARS
(7% Discount Rate)

Item	Mean	Low	High
MY 2017			
Fuel Saved (mill. gall)	6,094	-35	12,822
Total Cost ($mill.)	($2,879)	(-$5)	($6,353)
Social Benefits ($mill.)	$7,051	-$49	$14,547
Net Benefits ($mill.)	$4,166	-$1,143	$11,330
% Certainty Net Ben. > 0	99.6%		
MY 2018			
Fuel Saved (mill. gall)	8,718	-7	18,919
Total Cost ($mill.)	($4,340)	($24)	($8,196)
Social Benefits ($mill.)	$9,548	-$118	$20,187
Net Benefits ($mill.)	$5,193	-$2,509	$15,316
% Certainty Net Ben. > 0	98.5%		
MY 2019			
Fuel Saved (mill. gall)	13,317	56	27,286
Total Cost ($mill.)	($6,335)	($18)	($12,296)
Social Benefits ($mill.)	$14,277	-$249	$28,780
Net Benefits ($mill.)	$7,767	-$4,117	$22,105
% Certainty Net Ben. > 0	97.8%		
MY 2020			
Fuel Saved (mill. gall)	17,151	-199	34,855
Total Cost ($mill.)	($8,298)	($68)	($14,617)
Social Benefits ($mill.)	$18,272	-$342	$37,350
Net Benefits ($mill.)	$9,709	-$5,192	$29,759

% Certainty Net Ben. > 0	97.4%		
MY 2021			
Fuel Saved (mill. gall)	20,522	-283	41,831
Total Cost ($mill.)	($10,310)	($107)	($20,891)
Social Benefits ($mill.)	$21,563	-$587	$44,153
Net Benefits ($mill.)	$10,903	-$7,790	$34,320
% Certainty Net Ben. > 0	96.8%		
Item	Mean	Low	High
MY 2022			
Fuel Saved (mill. gall)	22,858	112	45,533
Total Cost ($mill.)	($11,599)	($122)	($23,709)
Social Benefits ($mill.)	$23,998	-$316	$48,215
Net Benefits ($mill.)	$11,962	-$10,926	$37,758
% Certainty Net Ben. > 0	96.3%		
MY 2023			
Fuel Saved (mill. gall)	25,251	66	50,648
Total Cost ($mill.)	($13,168)	($146)	($29,662)
Social Benefits ($mill.)	$26,118	-$1,712	$53,547
Net Benefits ($mill.)	$12,417	-$19,390	$42,110
% Certainty Net Ben. > 0	93.9%		
MY 2024			
Fuel Saved (mill. gall)	28,533	-54	55,300
Total Cost ($mill.)	($15,993)	($74)	($36,930)
Social Benefits ($mill.)	$29,101	-$3,869	$57,986
Net Benefits ($mill.)	$12,514	-$32,331	$45,247

% Certainty Net Ben. > 0	89.6%		
MY 2025			
Fuel Saved (mill. gall)	30,718	-446	59,285
Total Cost ($mill.)	($16,918)	(-$13)	($38,633)
Social Benefits ($mill.)	$30,767	-$8,651	$61,616
Net Benefits ($mill.)	$13,198	-$41,163	$48,328
% Certainty Net Ben. > 0	88.9%		

Table XII-6
UNCERTAINTY ANALYSIS RESULTS, LIGHT TRUCKS
(7% Discount Rate)

Item	Mean	Low	High
MY 2017			
Fuel Saved (mill. gall)	1,107	-1,509	4,680
Total Cost ($mill.)	($430)	(-$708)	($1,692)
Social Benefits ($mill.)	$1,301	-$1,867	$5,492
Net Benefits ($mill.)	$870	-$1,307	$4,198
% Certainty Net Ben. > 0	97.2%		
MY 2018			
Fuel Saved (mill. gall)	3,507	-507	8,350
Total Cost ($mill.)	($643)	(-$615)	($1,964)
Social Benefits ($mill.)	$4,593	-$530	$10,471
Net Benefits ($mill.)	$3,949	-$184	$9,648
% Certainty Net Ben. > 0	100.0%		
MY 2019			
Fuel Saved (mill. gall)	8,113	369	17,890
Total Cost ($mill.)	($1,460)	(-$535)	($3,734)
Social Benefits ($mill.)	$10,524	$571	$22,122
Net Benefits ($mill.)	$9,019	$393	$20,606
% Certainty Net Ben. > 0	100.0%		
MY 2020			
Fuel Saved (mill. gall)	11,879	428	25,755
Total Cost ($mill.)	($2,292)	(-$379)	($6,368)
Social Benefits ($mill.)	$15,456	$640	$31,275
Net Benefits ($mill.)	$13,078	$441	$28,903

% Certainty Net Ben. > 0	100.0%		
MY 2021			
Fuel Saved (mill. gall)	16,828	172	35,962
Total Cost ($mill.)	($3,349)	(-$310)	($8,790)
Social Benefits ($mill.)	$21,936	$439	$44,408
Net Benefits ($mill.)	$18,469	$269	$40,986
% Certainty Net Ben. > 0	100.0%		
Item	Mean	Low	High
MY 2022			
Fuel Saved (mill. gall)	18,815	265	39,098
Total Cost ($mill.)	($3,659)	(-$312)	($9,689)
Social Benefits ($mill.)	$24,612	$2	$48,176
Net Benefits ($mill.)	$20,813	$139	$44,390
% Certainty Net Ben. > 0	100.0%		
MY 2023			
Fuel Saved (mill. gall)	21,994	284	43,902
Total Cost ($mill.)	($4,098)	(-$251)	($10,824)
Social Benefits ($mill.)	$29,009	$76	$54,509
Net Benefits ($mill.)	$24,741	-$158	$50,443
% Certainty Net Ben. > 0	100.0%		
MY 2024			
Fuel Saved (mill. gall)	24,935	518	49,093
Total Cost ($mill.)	($4,506)	(-$371)	($12,845)
Social Benefits ($mill.)	$33,148	$692	$61,436
Net Benefits ($mill.)	$28,445	$347	$56,938

% Certainty Net Ben. > 0	100.0%		
MY 2025			
Fuel Saved (mill. gall)	28,102	777	53,978
Total Cost ($mill.)	($4,815)	(-$465)	($15,492)
Social Benefits ($mill.)	$37,660	$866	$66,344
Net Benefits ($mill.)	$32,627	$569	$61,515
% Certainty Net Ben. > 0	100.0%		

Table XII-7
UNCERTAINTY ANALYSIS RESULTS, PASSENGER CARS AND LIGHT TRUCKS
(7% Discount Rate)

Item	Mean	Low	High
MY 2017			
Fuel Saved (mill. gall)	7,201	-130	15,775
Total Cost ($mill.)	($3,309)	(-$47)	($6,800)
Social Benefits ($mill.)	$8,352	-$171	$17,945
Net Benefits ($mill.)	$5,036	-$1,021	$13,899
% Certainty Net Ben. > 0	99.7%		
MY 2018			
Fuel Saved (mill. gall)	12,225	494	26,877
Total Cost ($mill.)	($4,983)	($43)	($9,020)
Social Benefits ($mill.)	$14,140	$470	$29,848
Net Benefits ($mill.)	$9,142	-$717	$24,006
% Certainty Net Ben. > 0	100.0%		
MY 2019			
Fuel Saved (mill. gall)	21,431	743	44,448
Total Cost ($mill.)	($7,796)	($66)	($15,119)
Social Benefits ($mill.)	$24,800	$716	$49,374
Net Benefits ($mill.)	$16,787	-$1,622	$40,674
% Certainty Net Ben. > 0	100.0%		
MY 2020			
Fuel Saved (mill. gall)	29,029	559	60,125
Total Cost ($mill.)	($10,589)	($99)	($19,516)
Social Benefits ($mill.)	$33,728	$398	$68,247
Net Benefits ($mill.)	$22,787	-$1,947	$58,180

% Certainty Net Ben. > 0	99.9%		
MY 2021			
Fuel Saved (mill. gall)	37,349	732	77,035
Total Cost ($mill.)	($13,659)	($106)	($26,253)
Social Benefits ($mill.)	$43,499	$679	$86,347
Net Benefits ($mill.)	$29,372	-$4,774	$72,828
% Certainty Net Ben. > 0	99.9%		
Item	Mean	Low	High
MY 2022			
Fuel Saved (mill. gall)	41,674	911	84,434
Total Cost ($mill.)	($15,258)	($25)	($29,752)
Social Benefits ($mill.)	$48,610	$921	$94,784
Net Benefits ($mill.)	$32,775	-$6,817	$79,879
% Certainty Net Ben. > 0	99.9%		
MY 2023			
Fuel Saved (mill. gall)	47,245	972	93,472
Total Cost ($mill.)	($17,265)	($26)	($39,275)
Social Benefits ($mill.)	$55,127	$970	$106,531
Net Benefits ($mill.)	$37,158	-$12,900	$91,037
% Certainty Net Ben. > 0	99.8%		
MY 2024			
Fuel Saved (mill. gall)	53,468	964	103,982
Total Cost ($mill.)	($20,499)	(-$76)	($48,809)
Social Benefits ($mill.)	$62,250	$991	$118,049
Net Benefits ($mill.)	$40,958	-$18,421	$100,862

% Certainty Net Ben. > 0	99.5%		
MY 2025			
Fuel Saved (mill. gall)	58,820	1,032	111,686
Total Cost ($mill.)	($21,733)	(-$40)	($51,977)
Social Benefits ($mill.)	$68,427	$1,002	$127,583
Net Benefits ($mill.)	$45,825	-$21,051	$109,697
% Certainty Net Ben. > 0	99.6%		

Combining MY 2017-2025

Total Benefits at 7% discount rate: Societal benefits will total $6.0 billion to $698.7 billion, with a mean estimate of $358.9 billion.

Total Costs at 7% discount rate: Costs will total between $0.2 billion and $246.5 billion, with a mean estimate of $115.1 billion.

Table XII-8
UNCERTAINTY ANALYSIS RESULTS, PASSENGER CARS
(3% Discount Rate)

Item	Mean	Low	High
MY 2017			
Fuel Saved (mill. gall)	7,753	-43	16,333
Total Cost ($mill.)	($2,879)	(-$5)	($6,353)
Social Benefits ($mill.)	$8,789	-$60	$18,231
Net Benefits ($mill.)	$5,901	-$648	$14,908
% Certainty Net Ben. > 0	99.9%		
MY 2018			
Fuel Saved (mill. gall)	11,097	-8	24,090
Total Cost ($mill.)	($4,340)	($24)	($8,196)
Social Benefits ($mill.)	$11,893	-$148	$25,285
Net Benefits ($mill.)	$7,534	-$1,604	$20,410
% Certainty Net Ben. > 0	99.7%		
MY 2019			
Fuel Saved (mill. gall)	16,965	73	34,786
Total Cost ($mill.)	($6,335)	($18)	($12,296)
Social Benefits ($mill.)	$17,789	-$308	$36,080
Net Benefits ($mill.)	$11,222	-$2,959	$29,296
% Certainty Net Ben. > 0	99.3%		
MY 2020			
Fuel Saved (mill. gall)	21,865	-264	44,479
Total Cost ($mill.)	($8,298)	($68)	($14,617)
Social Benefits ($mill.)	$22,775	-$441	$46,859
Net Benefits ($mill.)	$14,122	-$3,990	$39,143

% Certainty Net Ben. > 0	99.0%		
MY 2021			
Fuel Saved (mill. gall)	26,166	-371	53,436
Total Cost ($mill.)	($10,310)	($107)	($20,891)
Social Benefits ($mill.)	$26,868	-$748	$55,435
Net Benefits ($mill.)	$16,089	-$6,546	$45,395
% Certainty Net Ben. > 0	99.0%		
Item	Mean	Low	High
MY 2022			
Fuel Saved (mill. gall)	29,156	144	58,226
Total Cost ($mill.)	($11,599)	($122)	($23,709)
Social Benefits ($mill.)	$29,906	-$409	$60,560
Net Benefits ($mill.)	$17,722	-$9,215	$49,861
% Certainty Net Ben. > 0	98.8%		
MY 2023			
Fuel Saved (mill. gall)	32,224	86	64,808
Total Cost ($mill.)	($13,168)	($146)	($29,662)
Social Benefits ($mill.)	$32,555	-$2,030	$67,323
Net Benefits ($mill.)	$18,673	-$17,159	$55,594
% Certainty Net Ben. > 0	97.7%		
MY 2024			
Fuel Saved (mill. gall)	36,440	-78	70,884
Total Cost ($mill.)	($15,993)	($74)	($36,930)
Social Benefits ($mill.)	$36,304	-$4,495	$73,015
Net Benefits ($mill.)	$19,515	-$31,218	$59,948

% Certainty Net Ben. > 0	95.2%		
MY 2025			
Fuel Saved (mill. gall)	39,267	-577	76,120
Total Cost ($mill.)	($16,918)	(-$13)	($38,633)
Social Benefits ($mill.)	$38,416	-$9,845	$77,724
Net Benefits ($mill.)	$20,631	-$41,679	$64,078
% Certainty Net Ben. > 0	94.6%		

Table XII-9
UNCERTAINTY ANALYSIS RESULTS, LIGHT TRUCKS
(3% Discount Rate)

Item	Mean	Low	High
MY 2017			
Fuel Saved (mill. gall)	1,425	-1,948	6,036
Total Cost ($mill.)	($430)	(-$708)	($1,692)
Social Benefits ($mill.)	$1,640	-$2,359	$6,940
Net Benefits ($mill.)	$1,209	-$1,800	$5,647
% Certainty Net Ben. > 0	97.4%		
MY 2018			
Fuel Saved (mill. gall)	4,522	-655	10,794
Total Cost ($mill.)	($643)	(-$615)	($1,964)
Social Benefits ($mill.)	$5,805	-$667	$13,318
Net Benefits ($mill.)	$5,162	-$321	$12,495
% Certainty Net Ben. > 0	100.0%		
MY 2019			
Fuel Saved (mill. gall)	10,464	472	23,137
Total Cost ($mill.)	($1,460)	(-$535)	($3,734)
Social Benefits ($mill.)	$13,296	$724	$28,135
Net Benefits ($mill.)	$11,776	$592	$26,587
% Certainty Net Ben. > 0	100.0%		
MY 2020			
Fuel Saved (mill. gall)	15,329	554	33,365
Total Cost ($mill.)	($2,292)	(-$379)	($6,368)
Social Benefits ($mill.)	$19,533	$806	$39,800
Net Benefits ($mill.)	$17,125	$625	$37,373

% Certainty Net Ben. > 0	100.0%		
MY 2021			
Fuel Saved (mill. gall)	21,730	221	46,611
Total Cost ($mill.)	($3,349)	(-$310)	($8,790)
Social Benefits ($mill.)	$27,729	$570	$56,562
Net Benefits ($mill.)	$24,222	$405	$53,057
% Certainty Net Ben. > 0	100.0%		
Item	Mean	Low	High
MY 2022			
Fuel Saved (mill. gall)	24,313	344	50,735
Total Cost ($mill.)	($3,659)	(-$312)	($9,689)
Social Benefits ($mill.)	$31,124	-$3	$61,414
Net Benefits ($mill.)	$27,276	$138	$57,521
% Certainty Net Ben. > 0	100.0%		
MY 2023			
Fuel Saved (mill. gall)	28,442	369	57,102
Total Cost ($mill.)	($4,098)	(-$251)	($10,824)
Social Benefits ($mill.)	$36,705	$92	$69,568
Net Benefits ($mill.)	$32,377	-$30	$65,370
% Certainty Net Ben. > 0	100.0%		
MY 2024			
Fuel Saved (mill. gall)	32,272	671	63,891
Total Cost ($mill.)	($4,506)	(-$371)	($12,845)
Social Benefits ($mill.)	$41,969	$876	$78,509
Net Benefits ($mill.)	$37,197	$562	$73,854

% Certainty Net Ben. > 0	100.0%		
MY 2025			
Fuel Saved (mill. gall)	36,405	1,011	70,444
Total Cost ($mill.)	($4,815)	(-$465)	($15,492)
Social Benefits ($mill.)	$47,715	$1,100	$84,998
Net Benefits ($mill.)	$42,605	$803	$80,003
% Certainty Net Ben. > 0	100.0%		

Table XII-10
UNCERTAINTY ANALYSIS RESULTS, PASSENGER CARS AND LIGHT TRUCKS
(3% Discount Rate)

Item	Mean	Low	High
MY 2017			
Fuel Saved (mill. gall)	9,179	-166	20,142
Total Cost ($mill.)	($3,309)	(-$47)	($6,800)
Social Benefits ($mill.)	$10,429	-$229	$22,544
Net Benefits ($mill.)	$7,110	-$562	$18,396
% Certainty Net Ben. > 0	99.9%		
MY 2018			
Fuel Saved (mill. gall)	15,619	637	34,380
Total Cost ($mill.)	($4,983)	($43)	($9,020)
Social Benefits ($mill.)	$17,698	$592	$37,580
Net Benefits ($mill.)	$12,695	$65	$31,733
% Certainty Net Ben. > 0	100.0%		
MY 2019			
Fuel Saved (mill. gall)	27,429	959	56,991
Total Cost ($mill.)	($7,796)	($66)	($15,119)
Social Benefits ($mill.)	$31,084	$903	$62,293
Net Benefits ($mill.)	$22,997	-$455	$53,503
% Certainty Net Ben. > 0	100.0%		
MY 2020			
Fuel Saved (mill. gall)	37,194	716	77,193
Total Cost ($mill.)	($10,589)	($99)	($19,516)
Social Benefits ($mill.)	$42,307	$496	$86,184
Net Benefits ($mill.)	$31,247	-$399	$75,938

% Certainty Net Ben. > 0	100.0%		
MY 2021			
Fuel Saved (mill. gall)	47,896	943	99,094
Total Cost ($mill.)	($13,659)	($106)	($26,253)
Social Benefits ($mill.)	$54,597	$862	$109,215
Net Benefits ($mill.)	$40,310	-$2,155	$95,398
% Certainty Net Ben. > 0	100.0%		
Item	Mean	Low	High
MY 2022			
Fuel Saved (mill. gall)	53,468	1,174	108,747
Total Cost ($mill.)	($15,258)	($25)	($29,752)
Social Benefits ($mill.)	$61,030	$1,158	$120,015
Net Benefits ($mill.)	$44,998	-$3,345	$104,740
% Certainty Net Ben. > 0	100.0%		
MY 2023			
Fuel Saved (mill. gall)	60,665	1,256	120,468
Total Cost ($mill.)	($17,265)	($26)	($39,275)
Social Benefits ($mill.)	$69,260	$1,224	$134,972
Net Benefits ($mill.)	$51,050	-$11,945	$119,058
% Certainty Net Ben. > 0	100.0%		
MY 2024			
Fuel Saved (mill. gall)	68,712	1,252	134,279
Total Cost ($mill.)	($20,499)	(-$76)	($48,809)
Social Benefits ($mill.)	$78,273	$1,260	$149,797
Net Benefits ($mill.)	$56,712	-$12,965	$132,130

% Certainty Net Ben. > 0	99.8%		
MY 2025			
Fuel Saved (mill. gall)	75,673	1,326	144,463
Total Cost ($mill.)	($21,733)	(-$40)	($51,977)
Social Benefits ($mill.)	$86,131	$1,276	$162,174
Net Benefits ($mill.)	$63,237	-$16,623	$143,774
% Certainty Net Ben. > 0	99.8%		

Combining MY 2017-2025

Total Benefits at 3% discount rate: Societal benefits will total $7.5 billion to $884.8 billion, with a mean estimate of $330.4 billion.

Total Costs at 3% discount rate: Costs will total between $0.2 billion and $246.5 billion, with a mean estimate of $115.1 billion.

FIGURE XII-11
Model Output Profile

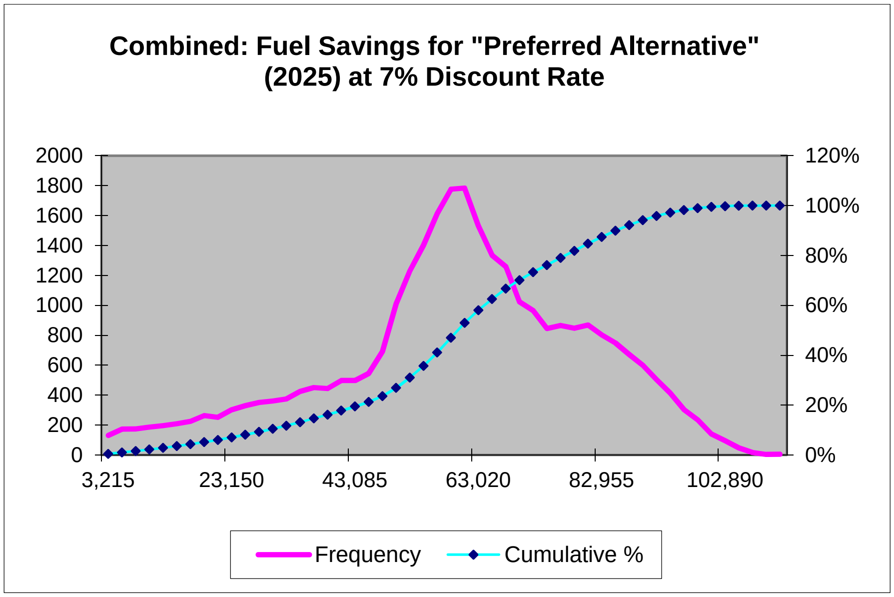


FIGURE XII-12
Model Output Profile

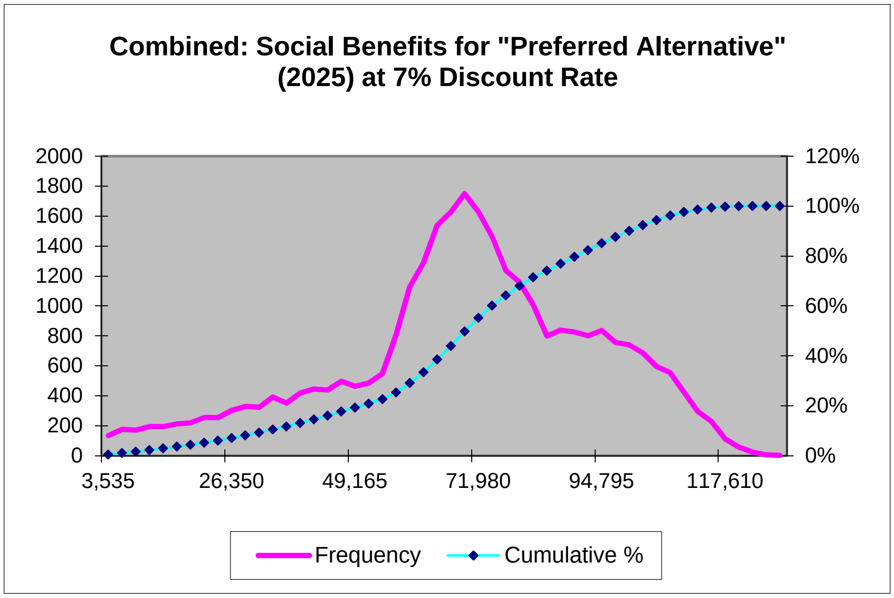


FIGURE XII-13
Model Output Profile

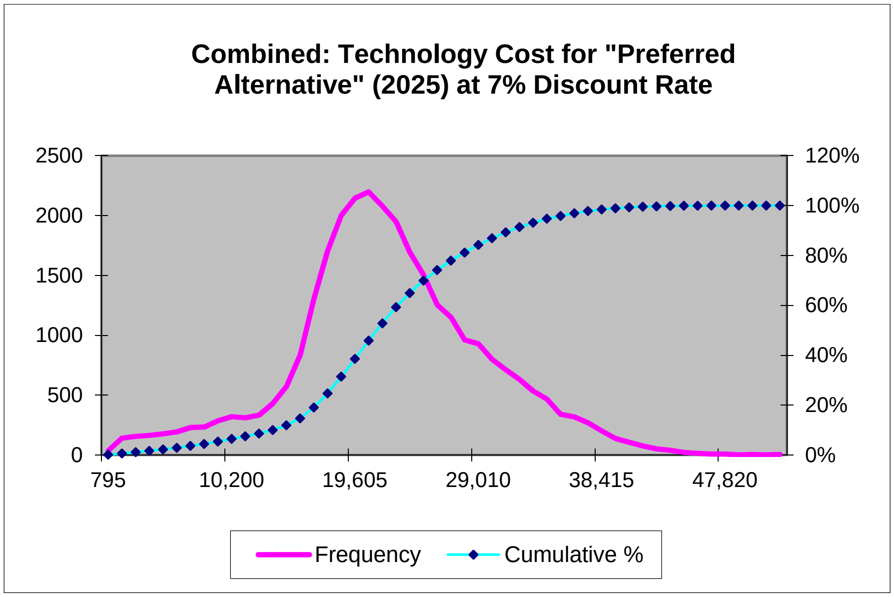
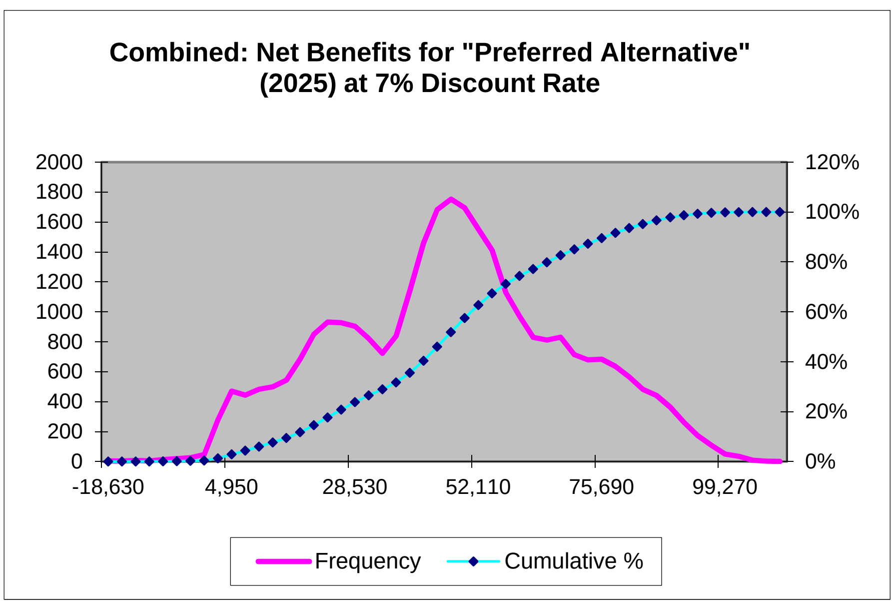


FIGURE XII-14
Model Output Profile



XIII. REGULATORY FLEXIBILITY ACT AND UNFUNDED MANDATES REFORM ACT ANALYSIS

A. Regulatory Flexibility Act

The Regulatory Flexibility Act of 1980 (5 U.S.C §601 et seq.) requires agencies to evaluate the potential effects of their proposed and final rules on small business, small organizations and small Government jurisdictions.

5 U.S.C §603 requires agencies to prepare and make available for public comments initial and final regulatory flexibility analysis (RFA) describing the impact of proposed and final rules on small entities. Section 603(b) of the Act specifies the content of a RFA. Each RFA must contain:

1. A description of the reasons why action by the agency is being considered;
2. A succinct statement of the objectives of, and legal basis for a final rule;
3. A description of and, where feasible, an estimate of the number of small entities to which the final rule will apply;
4. A description of the projected reporting, recording keeping and other compliance requirements of a final rule including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record;
5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap or conflict with the final rule;
6. Each final regulatory flexibility analysis shall also contain a description of any significant alternatives to the final rule which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the final rule on small entities.

1. Description of the reason why action by the agency is being considered

NHTSA is issuing this final rule to improve vehicle fuel economy.

2. Objectives of, and legal basis for, the final rule

The Energy Independence and Security Act (EISA) mandates the setting of separate standards for passenger cars and for light trucks at levels sufficient to ensure that the average fuel economy of the combined fleet of all passenger cars and light trucks sold by all manufacturers in the U.S. in model year 2020 equals or exceeds 35 miles per gallon.

3. Description and estimate of the number of small entities to which the final rule will apply

The final rule will affect motor vehicle manufacturers. There is only one light truck manufacturer of electric vehicles that is a small business. However, there are nine domestically owned small passenger car manufacturers.

Business entities are defined as small business using the North American Industry Classification System (NAICS) code, for the purpose of receiving Small Business Administration assistance. One of the criteria for determining size, as stated in 13 CFR 121.201, is the number of employees in the firm. For establishments primarily engaged in manufacturing or assembling automobiles, light and heavy duty trucks, buses, motor homes, or motor vehicle body manufacturing, the firm must have less than 1,000 employees to be classified as a small business.

We believe that the rulemaking would not have a significant economic impact on the small vehicle manufacturers because under Part 525, passenger car manufacturers making less than 10,000 vehicles per year can petition NHTSA to have alternative standards set for those manufacturers. Those manufacturers that currently don't meet the required levels for their footprint can petition the agency for relief. If the standard is raised, it has no meaningful impact on these manufacturers; they still must go through the same process and petition for relief. Other small manufacturers (e.g. Tesla and Fisker) make electric vehicles or hybrid vehicles that will pass the final rule.

Currently, there are ten small passenger car motor vehicle manufacturers in the United States. Table X1II-1 provides information about the 10 small domestic manufacturers in MY 2010. All are small manufacturers, having much less than 1,000 employees.

Table XIII-1
Small Vehicle Domestic Manufacturers

Manufacturer	Employees	Estimated Sales	Sale Price Range	Est. Revenues*
Carbon Motor[1]	NA	NA	NA	NA
CODA[2]	150	NA	$44,900**	NA
Fisker Automotive Inc.[3]	NA	15,000	$80,000	$1,200,000,000
GGT Electric				
Mosler Automotive	25	20	$189,000	$3,780,000
Panoz Auto Development Company	50	150	$90,000 to $125,000	$16,125,000
Saleen	170	1,000 16***	$39,000 to $59,000 $585,000	$144,355,000
Shelby American, Inc[4]	44	60	$42,000 to $135,000	$5,310,000
Standard Taxi[5]	35	80	$25,000	$2,000,000
Tesla Motors, Inc.	250	2,000	$50,000 to $100,000	$150,000,000

1. Designs, manufactures, and sells law enforcement patrol vehicles
2. Designs, manufactures, and sells electric vehicles.
3. A joint venture of Quantum Fuel Systems Technologies Worldwide, Inc, and Fisker Coachbuild, LLC. The company is just starting. These are planned sales.
4. A division of Carroll Shelby International, Inc.
5. A subsidiary of Vehicle Production Group LLC (VPG). VPG has 35 employees.

* Assuming an average sales price from the sales price range
** Before the $8,000 federal tax credit and state incentives
*** Ford Mustang Conversions

The agency has not analyzed the impact of the final rule on these small manufacturers individually. However, assuming those that do not meet the final rule would petition the agency, rather than meet the final rule, the cost is not expected to be substantial.

4. A description of the projected reporting, record keeping and other compliance requirements of a final rule including an estimate of the classes of small entities which will be subject to the requirement and the type of professional skills necessary for preparation of the report or record.

This final rule includes no new requirements for reporting, record keeping of other compliance requirements.

5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap, or conflict with the final rule

EPA and NHTSA are requiring joint final rules which complement each other. We know of no other Federal rules which duplicate, overlap, or conflict with the final rule.

6. A description of any significant alternatives to the final rule which accomplish the stated objectives of applicable statutes and which minimize any significant economic impact of the final rule on small entities.

The agencies have analyzed 10 different alternative levels of fuel economy and have provided a number of flexibilities. However, there are no other alternatives that can achieve the stated objectives without installing fuel economy technologies into the vehicle that could significantly minimize the impact on small entities.

B. Unfunded Mandates Reform Act

Section 202 of the Unfunded Mandates Reform Act of 1995 (UMRA) requires Federal agencies to prepare a written assessment of the costs, benefits, and other effects of a proposed or final rule that includes a Federal mandate likely to result in the expenditure by State, local, or tribal governments, in the aggregate, or by the private sector, of more than $100 million in any one year (adjusted for inflation with base year of 1995). Adjusting this amount by the gross domestic product price deflator for 2010 results in $136 million (111/81.606 = 1.36). Before promulgating a rule for which a written statement is needed, section 205 of UMRA generally requires NHTSA to identify and consider a reasonable number of regulatory alternatives and to adopt the least costly, most cost-effective, or least burdensome alternative that achieves the objectives of the rule. The provisions of section 205 do not apply when they are inconsistent with applicable law. Moreover, section 205 allows NHTSA to adopt an alternative other than the least costly, most cost-effective, or least burdensome alternative if the agency publishes with the final rule an explanation why that alternative was not adopted.

This final rule will not result in the expenditure by State, local, or tribal governments, in the aggregate, of more than $136 million annually, but it will result in the expenditure of that magnitude by vehicle manufacturers and/or their suppliers. NHTSA considered a variety of alternative average fuel economy standards lower and higher than the final rule, as well as flexibilities for the manufacturers to comply with the final rule. NHTSA is statutorily required to set standards at the maximum feasible level achievable by manufacturers based on its consideration and balancing of relevant factors and has concluded that the fuel economy standards are the maximum feasible standards for the passenger car and light truck fleets for MYs 2017-2025 in light of the statutory considerations.