U.S. Department of Transportation
National Highway Traffic Safety Administration

NHTSA
www.nhtsa.gov

Final Regulatory Impact Analysis

Corporate Average Fuel Economy for MY 2011 Passenger Cars and Light Trucks

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

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EXECUTIVE SUMMARY

This assessment examines the costs and benefits of improving the fuel economy of passenger cars and light trucks for model year (MY) 2011. 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 value to consumers, and other societal benefits such as improved energy security and reduced emissions of pollutants and greenhouse gases[1].

In the previous rulemaking, the agency reformed the corporate average fuel economy (CAFE) standards for light trucks with a size-based standard based on footprint[2]. This rulemaking continues this approach for both passenger cars and light trucks. A continuous mathematical function provides a separate fuel economy target for each footprint. 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 among the footprints of its vehicles. Although the same reformed CAFE scheme is required for both passenger cars and light trucks, they are established with different continuous mathematical functions specific to their design capabilities.

The final rule is the "Optimized (7%)" alternative. In this alternative the agency uses a 7 percent discount rate to value intra-generational future benefits and costs and sets the required mpg levels where marginal costs equal marginal benefits. It is one of eight alternatives examined in the analysis. We also examined an optimized scenario when discounting intra-generational future benefits and costs at 3 percent "Optimized (3%)". In all of the alternatives, inter-generational[3] benefits from future carbon dioxide reductions are discounted at 3 percent. When discussing an alternative we provide the discount rate in parenthesis afterwards to keep track of which alternative we are discussing. In general order of increasing stringency (see Table 1), the seven scenarios examined are:

1: "25% Below Optimized (7%)": This alternative mirrors the absolute difference in mpg derived from the 25% Above Optimized scenario in going the same mpg amount below the Optimized 7% alternative
2: "Optimized (7%)": An increase in the standard based upon availability of technologies and a marginal cost/benefit analysis. The mpg levels are set using a 7 percent discount rate for benefits.
3: "25% Above Optimized (7%)": This alternative looks at the mpg levels of the Optimized (7%) and the Total Cost Equals Total Benefit (7%) alternative and picks mpg levels that are 25 percent of that difference.

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[1] 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.

[2] 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).

[3] 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.

4: “50% Above Optimized (7%)”:   This alternative looks at the mpg levels of the Optimized (7%) and the Total Cost Equals Total Benefit (7%) alternative and picks mpg levels that are 50 percent of that difference.
5: “Optimized (3%)”: An increase in the standard based upon availability of technologies and a marginal cost/benefit analysis, except that the mpg levels are set using a 3 percent discount rate for benefits.
6: “Total Costs Equal Total Benefits (7%)”: An increase in the standard to a point where essentially total costs of the technologies added equals total benefits. In this analysis, for brevity, at times it is labeled “TC = TB (7%)”.
7: “Technology Exhaustion (7%)”: An increase in the standard based upon the maximum usage (based on NHTSA’s perspective) of available technologies, disregarding the cost impacts.

Table 1 shows the agency’s projection of the actual harmonic average that would be achieved by the manufacturers, assuming those manufacturers whose plans were above the requirements would achieve those higher levels. Table 1 also shows the estimated required levels. All of the tables in this analysis compare an adjusted baseline to the projected achieved harmonic average.

Benefits: Benefits are determined mainly from fuel savings over the lifetime of the vehicle, but also include externalities such as reductions in criteria pollutants. Table 3 provides those estimates on an industry-wide basis.

Costs: Costs were estimated based on the specific technologies that were applied to improve each manufacturer’s fuel economy up to the level required under each alternative. Table 2 provides those cost estimates on an average per-vehicle basis, and Table 3 provides those estimates on a fleet-wide basis in millions of dollars. Most costs are not discounted because they occur at the time of purchase.

Net Benefits: Table 3 compares societal costs and societal benefits of each alternative.

Fuel Savings: Table 4 shows the lifetime fuel savings in millions of gallons.

Total Benefits are significantly affected by the decision to discount future fuel savings by a 7 percent or 3 percent discount rate. Based on a marginal cost/marginal benefit analysis, the projected achieved levels in Table 1 are 0.3 mpg higher for the Optimized (3%) scenario than the Optimized (7%) scenario for passenger cars and essentially the same mpg level for light trucks.

Table 1
Alternative CAFE Levels
MY 2011
(in mpg)

	Projected Harmonic Average for the Fleet[4]	Estimated Required Average for the Fleet
Passenger Cars		
25% Below Optimized (7%)	30.7	29.9
Optimized (7%)	30.7	30.2
25% Above Optimized (7%)	30.8	30.5
50% Above Optimized (7%)	31.0	30.9
Optimized (3%)	31.0	31.2
TC = TB (7%)	31.2	31.5
Technology Exhaustion (7%)	32.4	35.5
Light Trucks		
25% Below Optimized (7%)	23.2	24.1
Optimized (7%)	23.2	24.1
25% Above Optimized (7%)	23.2	24.2
50% Above Optimized (7%)	23.2	24.2
Optimized (3%)	23.2	24.1
TC = TB (7%)	23.2	24.3
Technology Exhaustion (7%)	23.7	29.0

[4] The values represent weighted mpg values that we predict will be achieved by the fleet. For most manufacturers, the mpg values represent the higher of the manufacturer's plans and the alternative level of the standard. Some manufacturers are assumed to pay fines in lieu of achieving compliance with their required level.

Table 2
Average Incremental Cost
Per Vehicle
MY 2011
(2007 Dollars)

Passenger Cars	Cost per vehicle
25% Below Optimized (7%)	40
Optimized (7%)	64
25% Above Optimized (7%)	120
50% Above Optimized (7%)	193
Optimized (3%)	220
TC = TB (7%)	310
Technology Exhaustion (7%)	1,445
Light Trucks	
25% Below Optimized (7%)	126
Optimized (7%)	126
25% Above Optimized (7%)	169
50% Above Optimized (7%)	169
Optimized (3%)	126
TC = TB (7%)	242
Technology Exhaustion (7%)	1,177

Table 3
Present Value of Lifetime Societal Benefits[5],
Incremental Total Costs by Societal Perspective, and
Net Total Benefits by Alternative
(Millions of 2007 Dollars)

Passenger Cars	Societal Benefits	Societal Costs	Net Total Benefits
25% Below Optimized (7%)	786	291	496
Optimized (7%)	1,027	496	531
25% Above Optimized (7%)	1,332	1,003	329
50% Above Optimized (7%)	1,773	1,630	143
Optimized (3%)	2,647	1,820	828
TC = TB (7%)	2,487	2,619	(132)
Technology Exhaustion (7%)	6,406	11,907	(5,501)
Light Trucks			
25% Below Optimized (7%)	921	649	272
Optimized (7%)	921	649	272
25% Above Optimized (7%)	989	915	75
50% Above Optimized (7%)	989	915	75
Optimized (3%)	1,176	649	527
TC = TB (7%)	1,189	1,391	(202)
Technology Exhaustion (7%)	2,950	6,214	(3,264)
Passenger Cars and Light Trucks Combined			
25% Below Optimized (7%)	1,707	940	767
Optimized (7%)	1,948	1,145	802
25% Above Optimized (7%)	2,321	1,918	403
50% Above Optimized (7%)	2,763	2,545	218
Optimized (3%)	3,824	2,469	1,355
TC = TB (7%)	3,676	4,009	(334)
Technology Exhaustion (7%)	9,356	18,120	(8,765)

[5] 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, etc.

Table 4
Savings in Millions of Gallons of Fuel
Undiscounted Over the Lifetime of the Model Year
MY 2011

	Passenger Cars	Light Trucks	Passenger Cars and Light Trucks Combined
25% Below Optimized (7%)	352	424	776
Optimized (7%)	463	424	887
25% Above Optimized (7%)	598	456	1,054
50% Above Optimized (7%)	794	456	1,250
Optimized (3%)	946	424	1,371
TC = TB (7%)	1,121	567	1,687
Technology Exhaustion (7%)	2,982	1,420	4,402

I. INTRODUCTION

The purpose of this study is to analyze the effects of changes in the fuel economy standards for passenger cars and for light trucks for MY 2011. It 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.

The agency issued a final rule on April 7, 2003 (68 FR 16868), setting the CAFE standard applicable to light trucks for MY 2005 at 21.0 mpg, for MY 2006 at 21.6 mpg, and for MY 2007 at 22.2 mpg. On April 6, 2006 (71 FR 17566), the agency issued a final rule for MYs 2008 to 2011 under a new "CAFE Reform" structure. Similar to this report, a Final Regulatory Impact Analysis accompanied that final rule.[6] Much of the technical and cost information used in the 2006 analysis was taken from the findings in the National Academy of Sciences study[7] published in January 2002.

The new attribute-based Reformed CAFE system is based on the vehicle footprint (wheel base[8] x average wheel track width[9]). The anticipated advantages of the new reformed CAFE system are:

First, the energy-saving potential of the CAFE program was hampered by the original regulatory structure. Manufacturers who offer predominately small vehicles had little or no regulatory incentive to enhance fuel economy, because their vehicles tend to be more fuel efficient than the CAFE level. Moreover, the difference between the fuel economy standards for passenger cars and light trucks (27.5 mpg and 20.7 mpg, respectively, for MY 2004) encouraged vehicle manufacturers to offer vehicles classified as light trucks for purposes of CAFE, possibly inducing design changes that hurt overall fuel economy. A CAFE system that more closely links fuel economy standards to the various market segments and their fuel economy performance may reduce the incentive to design vehicles which are functionally similar to passenger cars but are classified as light trucks.

Second, we were concerned that the original light truck CAFE standards could create safety risks. Vehicle manufacturers are encouraged to achieve greater fuel economy by downsizing and downweighting. Alternatively, manufacturers may offer small vehicles to offset their offerings of large vehicles. The resulting increase in the disparity between the smallest and largest vehicle sizes and weights in the on-road vehicle fleet is widely believed to have increased the number of fatalities in crashes involving passenger cars and light-duty trucks. The National Academy of Sciences (NAS) report and a NHTSA study[10] have suggested that if downweighting were concentrated on the heaviest vehicles in the fleet, there could be a small fleetwide safety benefit, but downweighting of passenger cars and the lighter light trucks would increase fatalities.

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[6] "Final Regulatory Impact Analysis, Corporate Average Fuel Economy and CAFE Reform for MY 2008-2011 Light Trucks", March 2006, Docket No. 24309-5.

[7] "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards", National Research Council, 2002. The link for the NAS report is http://www.nap.edu/books/0309076013/html/

[8] "Wheel base" is essentially the distance between the centers of the axles.

[9] "Track width" is the lateral distance between the centerline of the tires.

[10] "Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks", Charles J. Kahane, Ph.D., NHTSA, October 2003, DOT HS 809-662.

A third reason for considering CAFE reform relates to the adverse economic impacts that may result from such future increases in the stringency of CAFE standards. Rapid increases in the level of the CAFE standard could have substantial economic consequences on manufacturers, especially those full-line manufacturers with product mixes dominated by large heavier vehicles. For example, full-line manufacturers – especially those with substantial sales in the heavier end of the light truck market – may generate fewer CAFE credits and incur larger compliance costs than vehicle manufacturers who focus their sales in the smaller, lighter end of the light truck market. As CAFE standards become more stringent under the original structure, the full-line manufacturers may experience adverse financial consequences, with resulting disruptions for employees in these firms and their suppliers.

EPCA also gives NHTSA authority to set passenger car CAFE standards for each model year, but sets a default standard of 27.5 mpg. NHTSA has not raised the passenger car CAFE standard from 27.5 mpg since Congress lifted the ban on CAFE rulemakings in 2002 because it did not believe that it had authority to reform passenger car CAFE as it had for light trucks. Reforming the CAFE program achieves larger fuel savings while enhancing safety and preventing adverse economic consequences—objectives which apply equally to passenger cars as to light trucks. NHTSA was unwilling to raise the passenger car CAFE standard without also reforming it, because of the same fuel savings, safety, and economic concerns that led it to reform the light truck CAFE standards.

In December 2007, Congress passed the Energy Independence and Security Act (EISA). 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. That is a 40 percent increase above the average of approximately 25 miles per gallon for the current combined fleet. EISA additionally gives NHTSA authority to reform passenger car CAFE, allowing the agency to set standards for those vehicles according to an attribute-based mathematical function as it currently does for light trucks.

On May 2, 2008, NHTSA published a notice of proposed rulemaking (NPRM) in the Federal Register (73 FR 24352) proposing standards for model years (MY) 2011-2015, the maximum number of model years under EISA for which NHTSA can establish standards in a single rulemaking. A Preliminary Regulatory Impact Analysis (PRIA) accompanied the NPRM.[11] While a large number of alternatives were examined, the proposed required mpg levels (comparable to Table 1) for the proposed alternative (labeled as Optimized 7%) were:

[11] "Preliminary Regulatory Impact Analysis, Corporate Average Fuel Economy for MY 2011-2015 Passenger Cars and Light Trucks" April 2008, NHTSA, (Docket No. 2008-0089-3.1)

Table I-1
Proposed Required Levels

	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
Passenger Cars	31.2	32.8	34	34.8	35.7
Light Trucks	25.0	26.4	27.8	28.2	28.6

These proposed required levels were higher than the agency estimated the harmonic level of the fleet would be in those years, since some manufacturers would not be able to achieve those levels or would choose to not meet those levels and would pay a penalty for not complying. The lower achievable levels served as the basis for many of the analyses in the PRIA. New vehicle price increases included technology costs and penalties for consumers, but benefits only included fuel savings up to the achieved levels.

The dual fuel incentive program, through which manufacturers may improve their calculated fuel economies by producing vehicles capable of operating on alternative fuels, is not considered in this analysis. By law, the agency has always analyzed fuel economy without considering the dual fuel credits, since it is an incentive program designed to increase the availability of alternative fuel vehicles.

Throughout this analysis, unless otherwise noted, the agency has not considered the ability of manufacturers to use credits or credit trading in achieving the alternative fuel economy levels.

Throughout this document, confidential information is presented in brackets [ ].

Additionally, by way of background, the agency notes that in mid-October 2008, the agency completed and released a final environmental impact statement in anticipation of issuing standards for those years. Based on its consideration of the public comments and other available information, including information on the financial condition of the automotive industry, the agency adjusted its analysis and the standards and prepared a final rule and Final Regulatory Impact Analysis (FRIA) for MYs 2011-2015. On November 14, the Office of Information and Regulatory Affairs (OIRA) of the Office of Management and Budget cleared the rule and FRIA as consistent with the Order.[12] However, issuance of the final rule was held in abeyance. On January 7, 2009, the Department of Transportation announced that the final rule would not be issued, saying:

> The Bush Administration will not finalize its rulemaking on Corporate Fuel Economy Standards. The recent financial difficulties of the automobile industry will require the next administration to conduct a thorough review of matters affecting the industry, including how to effectively implement the Energy Independence and Security Act of 2007 (EISA). The National Highway Traffic

[12] Record of OIRA's action can be found at http://www.reginfo.gov/public/do/eoHistReviewSearch (last visited March 8, 2009). To find the report on the clearance of the draft final rule, select "Department of Transportation" under "Economically Significant Reviews Completed" and select "2008" under "Select Calendar Year."

> Safety Administration has done significant work that will position the next Transportation Secretary to finalize a rule before the April 1, 2009 deadline.[13]

In light of the requirement to prescribe standards for MY 2011 by March 30, 2009 and in order to provide additional time to consider issues concerning the analysis used to determine the appropriate level of standards for MYs 2012 and beyond, the President issued a memorandum on January 26, 2009, requesting the Secretary of Transportation and Administrator[14] of the National Highway Traffic Safety Administration NHTSA to divide the rulemaking into two parts: (1) MY 2011 standards, and (2) standards for MY 2012 and beyond.

The request that the final rule establishing CAFE standards for MY 2011 passenger cars and light trucks be prescribed by March 30, 2009 was based on several factors. One was the requirement that the final rule regarding fuel economy standards for a given model year must be adopted at least 18 months before the beginning of that model year (49 U.S.C. 32902(g)(2)). The other was that the beginning of MY 2011 is considered for the purposes of CAFE standard setting to be October 1, 2010. As part of that final rule, the President requested that NHTSA consider whether any provisions regarding preemption are consistent with the EISA, the Supreme Court's decision in Massachusetts v. EPA and other relevant provisions of law and the policies underlying them.

The President requested that, before promulgating a final rule concerning the model years after model year 2011, NHTSA

> [C]onsider the appropriate legal factors under the EISA, the comments filed in response to the Notice of Proposed Rulemaking, the relevant technological and scientific considerations, and to the extent feasible, the forthcoming report by the National Academy of Sciences mandated under section 107 of EISA.

In addition, the President requested that NHTSA further consider whether any provisions regarding preemption are appropriate under applicable law and policy.

In keeping with the President's remarks on January 26 for new national policies to address the closely intertwined issues of energy independence, energy security and climate change, and for the initiation of serious and sustained domestic and international action to address them, NHTSA will develop CAFE standards for MY 2012 and beyond only after collecting new information, conducting a careful review of technical and economic inputs and assumptions, and standard setting methodology, and completing new analyses.

For MY 2011, however, time limitations precluded the adoption of this approach. As noted above, EPCA requires that standards for that model year be established by the end of March of this year. Thus, immediate decisions had to be made about the establishment of the MY 2011 standards. There was insufficient time between the issuance of the President's memorandum in late January and the end of March to revisit and, if and as appropriate, revise the extensive and

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[13] The statement can be found at http://www.dot.gov/affairs/dot0109.htm (last accessed February 11, 2009).

[14] Currently, the National Highway Traffic Safety Administration does not have an Administrator. Ronald L. Medford is the Acting Deputy Administrator.

complex analysis in any substantively significant way. This is particularly so given the requirement under EPCA to consult with the Environmental Protection Agency and the Department of Energy on these complicated and important technical matters. Decisions regarding those matters potentially affect not just NHTSA's CAFE rulemaking, but also programs of other departments and agencies. Accordingly, the methodologies, economic and technological inputs and decision-making criteria used in this rule are necessarily largely those developed by NHTSA in the fall of 2008.

In looking ahead to the next CAFE rulemaking, the agency emphasizes that while the methodologies, economic and technological inputs and decision-making criteria used in this rule were well-supported choices for the purposes of the MY 2011 rulemaking, they were not the only reasonable choices that the agency could have made for that purpose. Many of the key aspects of this rulemaking reflect decisions among several reasonable alternatives. The choices made in the context of last fall may or may not be the choices that will be made in the context of the follow-on rulemaking.

The deferral of action on the CAFE standards for the years after MY 2011 provides the agency with an opportunity to review its approach to CAFE standard setting, including its methodologies, economic and technological inputs, and decision-making criteria. It is reasonable to anticipate that this process may lead to changes, given the further review and analysis that will be conducted pursuant to the President's request, and given the steady and potentially substantial evolution in technical and policy factors relevant to the next CAFE rulemaking. These factors include, but are not limited to, energy and climate change needs and policy choices regarding goals and approaches to achieving them, developments in domestic legislation and international negotiations regarding those goals and approaches, the financial health of the industry, technologies for reducing fuel consumption, fuel prices, and climate change science and damage valuation.

The goal of the review and re-evaluation will be to ensure that the approach used for MY 2012 and thereafter produces standards that contribute, to the maximum extent possible under EPCA/EISA, to meeting the energy and environmental challenges and goals outlined by the President. We will seek to craft our program with the goal of creating the maximum incentives for innovation, providing flexibility to the regulated parties, and meeting the goal of making substantial and continuing reductions in the consumption of fuel. To that end, we are committed to ensuring that the CAFE program for beyond MY 2011 is based on the best scientific, technical, and economic information available, and that such information is developed in close coordination with other federal agencies and our stakeholders, including the states and the vehicle manufacturers.

We will also re-examine EPCA, as amended by EISA, to consider whether additional opportunities exist for achieving the President's goals. For example, EPCA authorizes, within relatively narrow limits and subject to making specified findings, for increasing the amount of civil penalties for violating the CAFE standards.[15] Further, while EPCA prohibits updating the

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[15] Under 49 USC 32904(c), EPA must "use the same procedures for passenger automobiles the Administrator used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle), or procedures that give comparable results."

test procedures used for measuring passenger car fuel economy, it places no such limitation on the test procedures for light trucks.[16] If the test procedures used for light trucks were revised to provide for the operation of air conditioning during fuel economy testing, vehicle manufacturers would have a regulatory incentive to increase the efficiency and reduce the weight of air conditioning systems, thereby reducing fuel consumption and tailpipe emissions of CO_2.

In response to the President's request that NHTSA consider whether any provisions regarding preemption are consistent with EISA, the Supreme Court's decision in Massachusetts v. EPA and other relevant provisions of law and the policies underlying them, NHTSA has decided not to include any provisions addressing preemption in the Code of Federal Regulations at this time. The agency will re-examine the issue of preemption in the content of its forthcoming rulemaking to establish Corporate Average Fuel Economy standards for 2012 and later model years.

[16] 49 USC 32912(c).

Response to Docket Comments
Comments to the NPRM were submitted to www.regulations.gov to NHTSA docket 2008-0089. This section summarizes those comments by issue and provides NHTSA's response to them. The issues are listed in alphabetical order (by our reference method) and the table of contents helps the reader find issues.

Table I-2
Docket Issues and Page Numbers

Docket Issue	Page #	Docket Issue	Page #
Baseline	I-4	Learning Curve	I-32
Congestion, Crashes and Noise Costs	I-6	Marginal Cost/Marginal Benefit	I-32
Consumer Benefits from Additional Driving	I-8	Market Failure	I-33
Cost and Effectiveness of Technologies	I-9	On-road Fuel Economy Adjustment	I-34
Discount Rates	I-10	Payback Period	I-34
Emissions savings per ton – Value of Carbon	I-19	Price of Gasoline	I-36
Emissions Worldwide vs. U.S.	I-21	Product Restrictions	I-44
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Financial Impact	I-27	Safety Standards Impact on Weight	See Chapter IV
Inequality of Impacts on Smaller Manufacturers	I-29	Size/Safety Impacts	See Chapter IV
Leadtime	I-31	Uncertainty Analysis	I-52

Baseline

In the NPRM, the agency used an "adjusted" manufacturer's product plans as a baseline. If a manufacturer's product plans were equal to or above the MY 2010 CAFE requirements, then the manufacturer's product plans were their baseline and costs and benefits were estimated as an increment above that level. However, if the manufacturer's product plans were below the level of the MY 2010 standard, then technologies were added to their plans to bring them up to the level of the MY 2010 standard and this "adjusted" baseline became their baseline for the analysis.

Comment: Alliance, 2008-0089-0179.1, P7

NHTSA should use as a current baseline MY 2006 used by Sierra Research Inc., not a projected baseline. The current baseline has complete data. Manufacturers who planned for new government mandates are penalized and their costs are underestimated. NHTSA has underestimated the increase in vehicle prices by $260 per car and $920 per truck.

Agency response: NHTSA develops an adjusted baseline because the costs and benefits of reaching the MY 2010 standards were already accounted for in prior rulemakings, just as the costs and benefits of reaching the MY 2011 standards are accounted for in the current rulemaking. To avoid double-counting the costs to manufacturers (and the benefits to society) required to meet the MY 2010 standards, NHTSA develops this adjusted baseline, which the agency then uses in analyzing the MY 2011 standards.

Comment: Alliance, 2008-0089-0179.1, Attachment 2 P4-5

NHTSA should consider a constant model mix, rather than the projected changing model mix from the manufacturers. Model mix creates significant uncertainty. Consumer preference ultimately determines model mix, and since forecasts made 8 years before are inherently unreliable, there is significant uncertainty in the use of manufacturers plans and model mix estimates.

Agency response: We agree there is uncertainty in the future model mix, but we are trying to estimate the incremental impact of the fuel economy standards, not the future of the automobile industry sales. The format of the standards, with target goals based on footprint, allows the manufacturer's standard to float with their sales mix and makes model mix less of an issue.

Comment: Union of Concerned Scientists, 2008-0089-0201.13, P3

The Union of Concerned Scientists uses a baseline scenario corresponding to laws on the books at the time.

Agency response: Without the manufacturers' confidential plans, this might be the most reasonable assumption. However, we have the manufacturers' confidential plans and we prefer our approach for purposes of this rulemaking.

Comment: Mercatus Center, George Mason University, 2008-0089-216.1

Raise the baseline forecast of fuel economy of the vehicle fleet to reflect the recent increase in fuel economy in response to higher fuel prices. The Mercatus Center discusses whether the fuel savings calculated in the CAFÉ model correctly reflect the gains that would come from the proposed regulation. Noting current market forces are driving fuel economy higher, the comment argues that NHTSA's analysis underestimates the baseline level of future fuel efficiency, and consequently overestimates the amount of fuel saved by raising CAFE standards.

Agency response: The approach suggested by the Mercatus Center could lead to significant speculation and it would be very hard to justify any particular baseline for the future.

Congestion, Crashes and Noise Costs –

In the NPRM the agency stated that increased vehicle use associated with the fuel economy rebound effect can also contribute to increased traffic congestion, motor vehicle crashes, and highway noise. In the NPRM, NHTSA relied on estimates developed by the Federal Highway Administration (FHWA) of the increased external costs of congestion, accidents (property damage and injuries), and noise costs caused by added driving due to the rebound effect.[17] NHTSA translated these marginal estimates in the tables and then the marginal costs were multiplied by the expected annual increases in automobile and light truck use from the rebound effect to yield the estimated increases in congestion, accident, and noise externality costs during each future year. These estimates are intended to measure the increases in costs due to these externalities caused by automobiles and light trucks that are borne by persons other than their drivers, or "marginal" external costs. The only new comments were on congestion.

Comment: Alliance, 2008-0089-179.1
The Alliance submitted an analysis by NERA Economic Consulting that essentially argued that NHTSA had underestimated the increased costs from congestion, crashes, and noise. The NERA analysis argued that FHWA's estimate was "based on a value of $12.38 per vehicle hour (in 1994 dollars)," while NHTSA used a value of $24 per vehicle hour "to value time savings it estimates would result from fewer fill-ups as a result of higher MPG and increased range for a tank of fuel." Thus, the NERA analysis concluded that NHTSA had overvalued the time savings, which NERA seemed to attribute to its belief that NHTSA does not value time spent in traffic congestion "at least as highly as time spent in service stations while filling up."[18] Thus, the NERA analysis argued that congestion costs per mile would increase by about 68 percent if NHTSA had updated FHWA's estimates in a "consistent" manner with "NHTSA's valuation of time savings for vehicle occupants in another part of its analysis."

Agency response: The agency does not intend to imply that time spent during one activity is more valuable than time spent during another activity. What has occurred is that in 2003 the Department of Transportation updated its estimate of the value of time. The 1997 FHWA report does not include the more recent update. However, the agency cannot go back to every reference it relies on and redo those analyses. This is not the only area that the Department or others have updated their estimates. For example, DOT has updated its estimate of the value of a statistical life, which affects crash costs. The agency does not have the wherewithal to accomplish such a time consuming task. The typical method is to update the dollars estimates to $2007 by using the Gross Domestic Product price index.

Comment: The NERA analysis also argued that the baseline 1997 congestion values "should be adjusted upward even more to reflect increasing levels of congestion between then and now and the further increases likely" within the lifetimes of the vehicles, the basis for NHTSA's cost analysis. The analysis stated that this was because "With higher baseline congestion, the marginal impact of additional VMT will increase because congestion, like other queuing phenomena, increases at an increasing rate as capacity utilization grows."

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[17] These estimates were developed by FHWA for use in its 1997 Federal Highway Cost Allocation Study. *See* http://www.fhwa.dot.gov/policy/hcas/final/index.htm (last accessed April 20, 2008).
[18] NERA appears to suggest that time spent in service stations while filling up includes the fact that "stops at service stations often serve multiple purposes, not just refueling." NERA then appears to suggest that people feel similarly about time spent in traffic congestion.

Comment: The Mercatus Center (2008-0089-216.1) focused only on congestion costs, and commented that NHTSA should consider "The possibility that the cost of increased congestion, a product of the 'rebound effect,' does not take into account likely increasing marginal costs as considered in NHTSA's model." The commenter stated that NHTSA's estimates "implicitly assume a constant marginal cost of congestion across all possible total quantities of vehicle miles driven for each vehicle category." However, it cited the FHWA study as stating that congestion cost impacts are "extremely sensitive" to peak versus off-peak traffic periods. Thus, the commenter argued, if the costs can vary within a day (as during peak and off-peak periods), they must certainly vary across years, if the total amount of traffic varies across years as well. In essence, if VMT increases, total congestion and the marginal cost of congestion must also increase, all other things held constant.
However, if all other things are not held constant, *e.g.* if new roads are built to handle increasing traffic, the commenter argued that "total congestion does not necessarily increase with increases in total vehicle miles driven." The commenter argued that NHTSA should include an estimate of the costs of building additional roads or altering existing ones to mitigate congestion due to the rebound effect. That estimate should include accounting for "the increasing difficulty of building a new road in an urbanized area," which the commenter stated is "probably one of the best examples of an activity that has rapidly increasing marginal costs," as well as the environmental costs of building new roads, *i.e.* costs due to sprawl. The commenter asserted that "It is incumbent upon NHTSA and the Environmental Protection Agency to produce an inclusive estimate of the costs of the rebound effect—one that either includes both increasing marginal cost of congestion and the cost of the new roads that will lead to increased congestion."

Agency response: The agency does not know the relationship between potential increases in VMT and congestion. The FHWA marginal costs were projected for <u>future</u> requirements of highways up through year 2000 using the base period of 1993-1995 and a national value of VMT. There is no other known similar estimate of highway costs beyond 2000. Neither is there an estimate of the relationship between the rebound effect and the amount of congestion for years beyond 2000, i.e. congestion is not assumed to be linear with VMT. Similarly, it is not clear how the additional roads, if built after 2000, would offset congestion and future year costs. Once again, the agency simply does not have the resources or time to redo and update these very complicated analyses that could make very minor differences in the level of the standard.

NHTSA believes it is reasonable to assume that additional vehicle use due to the fuel economy rebound effect will be distributed over the day and among locations in much the same way as current travel is distributed. As a consequence, the FHWA estimates of congestion costs from increased vehicle use are likely to provide more accurate estimates of the increased congestion costs caused by added rebound-effect driving than are the estimates submitted by commenters, which apply to peak travel periods and locations that experience high traffic volumes. Thus, NHTSA has continued to rely upon the FHWA values to estimate the increase in congestion costs likely to result from added rebound-effect driving.

Updated to 2007 dollars, FHWA's "Middle" estimates for marginal congestion, accident, and noise costs caused by automobile use amount to 5.4 cents, 2.3 cents, and 0.1 cents per vehicle-mile (or 7.8 cents per vehicle-mile in total), while costs for light trucks are 4.8 cents, 2.6 cents, and 0.1 cents per vehicle-mile (7.5 cents per vehicle-mile in total).[19] These costs are multiplied by the annual increases in automobile and light truck use from the rebound effect to yield the estimated increases in congestion, accident, and noise externality costs during each future year.

Consumer Benefits from additional driving

In addition to the benefits that drivers receive from increased vehicle use due to the rebound effect, the agency argued in the NPRM that improving the fuel economy of passenger cars and light-duty trucks may also increase their driving range before they require refueling. By reducing the frequency with which drivers typically refuel their vehicles, and by extending the upper limit of the range they can travel before requiring refueling, improving fuel economy thus provides some additional benefits to their owners.

Comment: The Alliance 2008-0089-0179.1, P8, P36, Attachment 2 P5, P103-107**,** stated that "NHTSA incorrectly assumes that its new fuel economy standards will improve vehicle range and thus reduce the number of times a vehicle owner would have to refill the tank (creating consumer benefits)." The Alliance comments focused on two points: one, that analysis by Sierra Research demonstrates "the complete absence of any relationship between fuel economy and range in the light truck fleet," and two, that manufacturers "design fuel-storage capacity to achieve the basic range requirements consumers demand," and will reduce the space necessary for fuel tanks to keep vehicle ranges to 300-400 miles in order to devote it to other uses (such as increasing cargo space) if fuel economy levels rise.

Agency response: As discussed in the PRIA, "…if manufacturers respond to improved fuel economy by reducing the size of fuel tanks to maintain a constant driving range, the resulting cost saving will presumably be reflected in lower vehicle sales prices." Or if a manufacturer decides to increase trunk space, they have implicitly assumed that trunk space is of more value to their consumers than fewer refills. Either way, the benefit or the opportunity for benefit is there. This implies that NHTSA's estimate of the value of increased refueling range will underestimate the true benefits from the resulting changes in vehicle attributes or prices.

Additionally, there is a relationship between typical gasoline engines and hybrids in terms of vehicles with better fuel economy having more range. It was intuitively believed that the market condition was such that drivers would indeed very much like to have a much lower frequency of visits to fuel stations than every 300-400 miles. A review of current hybrid specifications in Table I-3 shows that higher ranges are provided in these vehicles.

Table I-3
Hybrid Vehicle Range Specifications

Vehicle	Specified Range (miles)	Rated Fuel Economy (mpg)
2008 Honda Civic Hybrid	650	47/48
2007 Honda Accord Hybrid	600	29/37

[19] *Id*., at Tables V-22, V-23, and V-24 (last accessed October 5, 2008).

2008 Nissan Altima Hybrid	720	42/36
2008 Toyota Prius	547	46
2008 Toyota Camry Hybrid	585	33/34
2008 Ford Escape Hybrid	510	34/30
2007 Lexus RX Hybrid	530	32/27
2008 Mazda Tribute	544	29/34

Cost and effectiveness of technologies

NHTSA developed detailed estimates for the NPRM of the costs and effectiveness of applying fuel economy-improving technologies to vehicle models for use in analyzing the impacts of the alternative standards considered in this rulemaking. NHTSA explained that the NPRM estimates were based on those reported by the 2002 NAS Report analyzing costs and effectiveness for increasing fuel economy, but NHTSA modified those costs and effectiveness estimates for purposes of the PRIA as a result of extensive consultations among engineers from NHTSA, EPA, and the Volpe Center. As part of this process, NHTSA also developed varying cost and effectiveness estimates for applying certain fuel economy technologies to vehicles of different sizes and body styles. NHTSA stated that it may adjust these estimates based on comments received to the NPRM.

NHTSA explained that the technology cost estimates used in the agency's analysis are intended to represent manufacturers' direct costs for high-volume production of vehicles with these technologies and sufficient experience with their application so that all cost reductions due to "learning curve" effects were fully realized.

Comments: Almost every manufacturer commented that NHTSA had overestimated the benefits of certain technologies or had underestimated the costs of technologies. Several provided confidential information of their estimates. Other commenters indicated that NHTSA had underestimated the benefits of certain technologies. The comments are too numerous to include in this document.
Agency response: The agency hired a contractor (Ricardo) to go through all of the technologies and all of the comments and provide their expert opinion on the appropriate usage of technologies and their costs and benefits. The agency worked in consultation with Ricardo to develop the agency's estimates of technology costs and effectiveness. Costs do change over time and the cost estimates were based on the prices in effect at the time the estimates were made. The agency intends to monitor commodity prices carefully and will adjust affected technology costs as necessary in future rulemakings.
Because costs change over time, the agency re-examines costs for each rulemaking. See Chapter V for more information.

Discount rates

Most of the commenters realized that the discount rate has a significant impact on the level of the standard. The discount rate is used to determine the present value of future benefits (e.g. fuel saved over the lifetime of the vehicle). The agency used a 7 percent discount rate to determine the proposed CAFE levels, and asked for comments about whether a 3 percent discount rate should be used for standard setting purposes. Based on our marginal cost = marginal benefit methodology, discounting by a lower rate results in higher benefits, which allows more countermeasures to be cost effective and the standard to be higher.

Almost every commenter expressed an opinion about the discount rate. Some argued that there is an intergenerational discount rate that should be applied to benefits like carbon emission reductions that occur over long time frames, like 100 to 150 years. The intergenerational discount rate could be different than the conventional discount rate applied to fuel savings (that occur over the next 36 years in the case of light trucks). We will always use the term intergenerational to distinguish this long term discount rate from the conventional discount rate we normally use.

Those favoring a 7 percent discount rate include:
Comment: AIAM, 2008-0089-0205.1, Pg. 6 supports the discount rates used by NHTSA. The NAS report assumed discount rates that bracket those considered by NHTSA.

Comment: National Automobile Dealers Association, 2008-0089-223.1, Pg 6-7 stated that a discount rate of at least seven percent (or higher) should be used to estimate the future costs and benefits of the proposed standards. NHTSA should *not* use the OMB *default* calculation of the economy-wide opportunity cost of capital. As NHTSA correctly notes, financing rates on motor vehicle loans are indicative of appropriate discount rates since they reflect the real-world opportunity costs faced by consumers when buying vehicles having greater fuel economy costs associated with them.

Those favoring a 5 percent discount rate include:
Comment: Consumer Federation of America, 2008-0089-0183, Pg. 52-53 stated that NHTSA should have used 5% (the average of 3% and 7%). The rate NHTSA uses fails to reflect the importance of fuel savings.

Those favoring the 3 percent discount rate, saying that the discount rate should be based on the social rate of time preference, include:
Attorney General of the States, 2008-0089-0199.1, Pg 11
Union of Concerned Scientists, 2008-0089-201.1
Air Resources Board, 2008-0089-0173, Pg. 11
Natural Resources Defense Council, 2008-0089 225.1, Pg. 2 and following

Those discussing a lower rate, but not identifying that rate included:
Comment: Yohe, 2008-0089-139.1 disagrees with NHTSA's rationale for relying primarily on a 7% discount rate. Commenter argues that public investment should be based on a low discount rate if it complements private investment, since by doing so public investment raises the rate of return to private investment, thereby partly offsetting the effect of reduced returns to private investment caused by the corporate profits tax. Commenter contends that mitigating greenhouse gas emissions complements private investment more broadly, while at the same time making adaptation to climate change more productive. Commenter observes that the higher average fuel

economy resulting from applying a lower discount rate indicates that the analysis captures some of the value of this complementarity. Commenter acknowledges that taxes that support public investment generally affect consumption, but argues that this effect is captured in the cost calculation, and states that mitigation offers a co-benefit because it improves the marginal productivity of other private investments. Commenter also believes the definition of the social rate of time preference to be stated incorrectly and believes "utility" should be substituted for "consumption."

Comment: Another discount rate was proposed by Sierra Research, 2008-0089-0046, Page 74, based on an analysis by NERA they use a 12.4% discount rate for future fuel savings.
NERA National Economic Research Association, 2008-0089-050, Page 1-7 uses a 12.4% discount rate based on a range of plausible discount rates to be used in an analysis of the operating cost savings from improvements in automotive fuel economy improvements.
When purchasing a car, a rational consumer will consider future operating costs and will discount them to present value using a discount rate that will reflect the risk or uncertainty in the value or future operating costs. Consumers will perform this discounting using his or her own private discount rate. Consumers will not use a social discount rate that a government agency might use in doing a cost benefit analysis. Nor will consumers use the rate of a new car loan, which is a known certain rate. The operating costs of a vehicle vary with fuel prices and driving patterns, which are much more uncertain. As such, they would consider consumers private discount rate to be higher than the rate of a new car loan. Empirical economic research has consistently demonstrated that consumers use high discount rates when calculating the present value of future cash flows associated with operating costs of durable equipment. One study addressed the discount rate used by consumer with respect to automobile in particular. The appropriate discount rate is the rate that consumers actually use when deciding on vehicle purchases. While the discount rate consumers actually use can not be observed, it can be inferred from consumer behavior. Dreyfus and Viscusi (1995) use a hedonic regression model to estimate consumer value for fuel economy improvements and the associated discount rate. Dreyfus, M. and Viscusi, W., (1995) *Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency*, Journal of Law and Economics. Their estimates of the discount rate range from 10.7 to 17.4 percent, depending upon the specification selected. The study was based on 1988 data when interest rates were higher and should be adjusted to today's economic conditions. The nominal yield on Treasury bonds in 1988 is 8.9 percent. After adjusting for inflation (4.3%) the real rate of growth in treasury bonds was 4.6 percent. Subtracting 4.6 percent from 10.7 – 17.4 percent leaves 6.1 to 12.8%. And after adjusting for interest rates, adding the 10 year Treasury bond yield of 2.9 percent, the rates are 9.0 to 15.7%, the average is 12.4%.

Comment: The Alliance, 2008-0089-0179.1, Pg. 9, 31 supports the 12.4 percent discount rate.

Those discussing the intergenerational discount rate commented:
Comment: Yohe, 2008-0089-139.1 recommends that NHTSA apply a lower discount rate to benefits from future reductions in CO_2.

Comment: Mark Eads, 2008-0089-0165.1

Mr. Eads disagrees with NHTSA choice of 7 percent discount, both in terms of the magnitude of the discount rate and in NHTSA' rationale. He argues that the choices made primarily involve long-term inter-generational environmental benefits and costs rather than intra-generational benefits and costs. He advocates that NHTSA apply a non-constant declining discount rate that begins at 2.6 percent in year one, declining to 0.6 percent in year 300.

Comment: Prof. Michael Hanemann, Dept. of Agricultural and Resource Economics, University of California, Berkeley, 2008-0089-0188, recommends using a discount rate no higher than 4%, and a rate as low as 2% for sensitivity analysis. It is not clear whether these rates are to be applied to benefits from future reductions in CO2 emissions only or to all future benefits from lower fuel consumption (presumably the former). Commenter criticizes 7% and 4% discount rates used by NHTSA and by Nordhaus and Boyer as unjustified for use in assessing benefits from reducing threat or severity of climate change, and briefly cites some research suggesting that discount rates below 3% are appropriate for discounting future climate-related damages.

Comment: Attorney General of the State of California, 2008-0089-0199.4 provides no clear recommendation for action by NHTSA; but provides a detailed presentation from Hanemann to an unidentified audience.

Comment: Center for Biological Diversity, 2008-0089-222.1, Pg. 5, 8 stated that NHTSA's discount rate value is too high, and NHTSA didn't use a reasonable range of values in the sensitivity analysis.
Stern (2007) estimates the discount rate at lower than 1%. Any calculations performed under a selected discount rate for societal benefits must be compared to the same calculations under standard inflationary discount, but without discounting societal benefits to future generations. Stern (2006) notes the discount rate can be negative (in the context of discounting CO2 emissions).

Comment: Environmental Defense Fund, 2008-0089-224.1, Pg. 1 recommends use of a 3 percent discount rate for standard setting, with a sensitivity analysis using a 0.5 and 1 percent rate. Use of a high discount rate does not reflect the intergenerational impacts of CAFE implementation. One of the major benefits of the CAFE standards, in addition to increasing energy security and energy efficiency, is significantly reducing global warming pollution from automobiles. Because the benefits of reducing climate change will occur over multiple generations, we recommend that the Agency use a 3 percent discount rate for standard setting, with a sensitivity analysis using a 0.5 and 1 percent rate. This practice would follow EPA and OMB guidelines for estimating costs or benefits that affect multiple generations.

Comment: Attorneys General, 2008-0089-0495, Pg. 67-89
Provides a paper by Frank Verboven, "Implicit Interest Rates in Consumer Durables Purchasing Decisions – Evidence from Automobiles", March 1999. The paper examines consumer decisions to purchase 41 pairs of identical cars with the exception being whether they are equipped with diesel or gasoline engines in different European countries. Diesel engines have a higher initial purchase price but provide future savings in operating costs. He infers implicit interest rates given the purchases of gasoline and diesel variants, the differences in initial purchase price, price

of gasoline and diesel fuel costs per mile and other characteristics. The implicit interest rate that consumers use in making this decision is estimated to range from 5 to 13 percent.

Agency response: Discounting represents the conversion of the economic values of benefits and costs that are expected to occur in the future to their equivalent values today, or present values. It is intended to account for the fact that most individuals attach lower values to economic outcomes that are not expected to occur until some future date than to equivalent outcomes that are expected to occur sooner. It is particularly important to discount the future values of benefits or costs when they are expected to vary from year to year, or when the time profiles of benefits and costs are not expected to be similar. Discounting enables a consistent comparison of benefits to costs across time periods, and also enables consistent comparison of costs or benefits that are expected to occur in the future to those that occur in the present.

In establishing the proposed CAFE standards for MYs 2011-2015 that were presented in the NPRM, and whose environmental impacts were evaluated in the Draft EIS, NHTSA employed a discount rate of 7% to discount future benefits and costs resulting from increased fuel economy to their present values. Discounting the value of future fuel savings and other benefits that result from higher fuel economy, as well future costs resulting from added driving caused by the fuel economy rebound effect, accounts for the fact that they will occur over the future lifetimes of the MY 2011-15 vehicles. The discount rate expresses the rate at which the value of these future benefits and costs – as viewed from today's perspective – declines for each year they are deferred into the future.

In response to the extensive comments it received to the NPRM and the DEIS on this issue, NHTSA has carefully reviewed published research and OMB guidance on appropriate discount rates, including discount rates that should be applied to benefits that are expected to occur in the distant future and thus be experienced mainly by future generations, and discount rates that buyers of new vehicles apply to savings in fuel costs from higher fuel economy. For purposes of this final rule, the agency has elected to apply separate discount rates to the benefits resulting from reduced CO_2 emissions, which are expected to reduce the rate or intensity of climate change that will occur in the distant future, and the economic value of fuel savings and other benefits resulting from lower fuel consumption, which will be experienced over the limited lifetimes of newly-purchased vehicles. Specifically, NHTSA has decided to discount future benefits from reducing CO_2 emissions using a 3 percent rate, but to discount all other benefits resulting from higher CAFE standards for MY 2011 cars and light trucks at 7 percent.

As some commenters pointed out, OMB guidance on discounting permits the use of lower rates to discount benefits that are expected to occur in the distant future, and will thus be experienced by future generations.[20] The main rationale for doing so is that although most individuals demonstrate a strong preference for current consumption over consumption they expect to occur later within their *own* lifetimes, it may not be appropriate for society to exercise a similarly strong preference for consumption by current generations over consumption opportunities for future generations, particularly when it is contemplating actions that affect the relative income levels of current and future generations. In addition, while market interest rates provide useful guidance about the rates that should be used to discount future benefits that will be experienced

[20] White House Office of Management and Budget, Circular A-4, September 17, 2003, pp. 35-36.

by current generations, no comparable market rates are available to guide the choice of rates for discounting benefits that will be received by future generations.

For this final rule, NHTSA has elected to use a rate of 3 percent to discount the future economic benefits from reduced emissions of CO_2 that are projected to result from decreased fuel production and consumption. These 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 after the impact of this rule on emissions by MY 2011 cars and light trucks occurs, and will thus be experienced primarily by generations that are not now living. As indicated previously, studies of the economic cost of GHG emissions select a rate to discount economic damages from increased emissions. These damages are typically projected to occur over an extended time span beginning many years after the future date when emissions increase, and the chosen rate is used to discount these distant future damages to their present values as of the date when the increased emissions that cause them were assumed to occur.

This procedure yields estimates of the damage costs from increased GHG emissions during specific future years, which NHTSA uses to value the reductions in emissions that would occur each year over the lifetimes of vehicles affected by higher CAFE standards. For example, higher CAFE standards for MY 2011 cars and light trucks would reduce GHG emissions each year from 2011 through approximately 2047, and the estimated value of avoiding each ton of emissions rises each year over that span. In turn, the estimated economic values of the reductions in GHG emissions during each of those future years must be discounted to their present values as of today, so that they can be compared with the present values of other benefits from higher CAFE standards, and with vehicle manufacturers' costs for meeting higher CAFE standards.

The 3 percent rate is consistent with OMB guidance on appropriate discount rates for benefits experienced by future generations, as well as with those used to develop many of the estimates of the economic costs of future climate change that form the basis for NHTSA's estimate of economic value of reducing CO_2 emissions.[21] Of the 125 peer-reviewed estimates of the social cost of carbon included in Tol's 2008 survey, which provides the basis for NHTSA's estimated value of reducing CO_2 emissions, 83 used assumptions that imply discount rates of 3 percent or higher.

Moreover, the 3 percent rate is consistent with widely-used estimates in economic analysis of climate change of the appropriate rate of time preference for current versus distant future consumption, expected future growth in real incomes, and the rate at which the additional utility provided by increased consumption declines as income increases.[22] The Ramsey discounting rule is widely employed in studies of potential economic damages from climate changes in the distant future. The Ramsey rule states that $-r = \delta + \eta g$, where r is the consumption discount rate,

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[21] Richard S.J. Tol, The social cost of carbon: trends, outliers, and catastrophes, *Economics Discussion Papers*, July 23, 2008.

[22] EPA notes that "In this inter-generational context, a three percent discount rate is consistent with observed interest rates from long-term intra-generational investments (net of risk premiums) as well as interest rates relevant for monetary estimates of the impacts of climate change that are primarily consumption effects." See U.S. EPA, Technical Support Document on Benefits of Reducing GHG Emissions, June 12, 2008, p. 9.

δ is the pure rate of time preference (or the marginal rate of substitution between current and future consumption under the assumption that they are initially equal), g is the expected (percentage) rate of growth in future consumption, and η is the elasticity of the marginal utility of consumption with respect to changes in the level of consumption itself. Commonly used values of these parameters in climate studies are δ = -1 percent per year, η= –1, and g = 2 percent per year, which yield a value for r of 3 percent per year.[23]

The remaining future benefits and costs anticipated to result from higher fuel economy are projected to occur within the lifetimes of vehicles affected by the CAFE standards for MY 2011, which extend up to a maximum of 35 years from the dates those vehicles that are produced and sold. Because the vehicles originally produced during this model year will gradually be retired from service as they age, and those that remain in service will be driven progressively less, most of these benefits will occur over the period from 2011 through approximately 2025. Thus, a conventional or "intra-generational" discount rate is appropriate to use in discounting these benefits and costs to their present value when analyzing the economic impacts of establishing higher CAFE standards.[24]

The correct discount rate to apply to these nearer-term benefits and costs depends partly on how costs to vehicle manufacturers for improving fuel economy to comply with higher CAFE standards will ultimately be distributed. If manufacturers are unable to recover their costs for increasing fuel economy in the form of higher selling prices for new vehicles, those outlays will displace or alter other productive investments that manufacturers could make, and the appropriate discount rate is their opportunity cost of capital investment. In contrast, if manufacturers are able to raise selling prices for new vehicles sufficiently to recover all their costs for improving fuel economy, those costs will ultimately affect private consumption decisions rather than capital investment opportunities. Under this second assumption, economic theory and OMB guidance suggest that a consumption discount rate, which reflects the time preferences of consumers rather than those of lenders or investors, is appropriate for discounting future benefits. Since the time preferences of savers and investors are probably similar, financial intermediation would be expected to equalize investment and consumption discount rates. In the presence of corporate income taxation, however, consumption discount rates are generally thought to be lower than the opportunity cost of investment capital. Finally, if competitive conditions in the new vehicle market manufacturers and potential buyers' valuation of higher fuel economy permit manufacturers to recover only part of their costs for meeting higher CAFE standards through higher prices for new vehicles, a rate between an investment discount rate and the lower consumption discount rate may be appropriate, with the exact rate depending on the distribution of compliance costs between vehicle manufacturers and buyers.

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[23] See Tol (2008), p. 3.

[24] NHTSA acknowledges that using different rates to discount the distant and nearer-term future benefits from higher CFAE standards presents a potential problem of time inconsistency, which arises from the much greater uncertainty that surrounds long-term future rates of growth in investment, economic output, and consumption than is associated with near-term estimates of these variables. However, the agency believes that this problem is less serious than those that would result from using a single rate to discount benefits that occur over the next 25-35 year sand those that are likely to occur over a 100-200 year time frame.

OMB estimates that the real before-tax rate of return on private capital investment in the U.S. economy averages approximately 7 percent per year, and generally recommends this figure for use as a real discount rate in cases where the primary effect of a regulation is to displace private capital investment.[25] However, this figure represents an economy-wide average estimate of the return on private investment, which incorporates no risk premium other than that associated with uncertainty about future growth in total economic output. As a consequence, it may understate the opportunity cost of capital for corporations facing firm- or market-specific risks on future investment returns. In addition, domestic motor vehicle manufacturers currently have little or no accumulated earnings available to re-invest, and may be required to enter private capital markets to finance the investments necessary to allow them to comply with higher CAFE standards. In doing so they are likely to face real interest rates well above the 7 percent opportunity cost of capital estimated by OMB, which may provide a more accurate estimate of the appropriate investment rate for discounting future benefits resulting from increased fuel economy.

OMB guidance estimates that an appropriate current value for the consumer rate of time preference – and thus the discount rate that should be used if the costs of complying with a regulation are borne by consumers – is approximately 3 percent. However, this estimate is derived from rates of return demanded by consumers on highly liquid investments, and is intended to apply to situations where there is little or no risk that consumers will actually realize the future benefits resulting from a proposed regulation. In the case of CAFE standards, buyers face considerable uncertainty about future fuel prices, and thus about the value of fuel savings resulting from higher fuel economy. Uncertainty about their future levels of vehicle use and the actual lifetimes of new vehicles also contribute to buyers' uncertainty about the value of future fuel savings that is likely to result from purchasing a vehicle with higher fuel economy. In addition, buyers' initial investments in higher fuel economy are illiquid, and the extent to which they will be able recover the remaining value of an initial investment in a new vehicle that achieves higher fuel economy in the used vehicle market is uncertain. Finally, unlike most of the regulations that OMB Circular A-4 is intended to address, most (75-80 percent) of the benefits from higher CAFE standards accrue directly to the parties they affect – vehicle buyers – rather than to society at large. Taken together, these circumstances may make the use of a riskless consumption discount rate, which is intended for use in discounting the economy-wide effects of a proposed regulation on consumption, inappropriate for discounting the future benefits that result from requiring higher fuel economy.

Empirical studies of the discount rates that new vehicle buyers reveal by trading off the higher purchase prices for more fuel-efficient vehicles against future savings in fuel costs resulting from higher fuel economy, which capture the effects of these uncertainties, conclude that buyers apply real discount rates well above the 3 percent rate recommended by OMB for riskless situations. Dreyfus and Viscusi estimate that, when adjusted to reflect differences between the current interest rate environment and rates at the time the data for their study were drawn, U.S. buyers apply real discount rates in the range of 12 percent when weighing expected future fuel savings against higher purchase prices.[26] Verboven estimates that European buyers' nominal discount

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[25] White House Office of Management and Budget, Circular A-4, September 17, 2003, p. 33.
[26] See Dreyfus, Mark K. and W. Kip Viscusi. 1995. "Rates of Time Preference and Consumer Valuations of Automobile Safety and Fuel Efficiency." Journal of Law and Economics. 38: 79 –

rates for fuel savings resulting from buying more fuel-efficient new vehicle models range from 5 to 13 percent, with an average estimate of slightly above 10 percent. Verboven's estimate corresponds to a real discount rate of approximately 7 percent when adjusted to reflect current and recent U.S. inflation rates.[27] These studies may provide more reliable estimates of the appropriate consumption rate for discounting benefits from higher fuel economy than the 3 percent figure recommended in OMB guidance.

Uncertainty about future developments in the international oil market, the U.S. economy, and the U.S. market for new cars and light trucks make it extremely difficult to anticipate the extent to which vehicle manufacturers will be able to recover costs for complying with higher CAFE standards in the form of higher selling prices for new vehicles. If new vehicle buyers expect fuel prices to remain higher than those used by NHTSA to establish CAFE standards for MY 2011, they may be willing to pay the higher prices necessary for manufacturers to recover their costs for complying with those standards.[28] However, potential buyers who expect future fuel prices to be lower than the forecast NHTSA relies upon are likely to resist manufacturers' efforts to raise new vehicle prices sufficiently to recover all of their CAFE compliance costs, since those buyers' assessment of the value of higher fuel economy will be lower than that reflected in the CAFE standards NHTSA establishes.

From the manufacturer perspective, the current financial condition of some car and light truck producers suggests that they are likely to find it difficult to absorb the full cost of complying with higher CAFE standards. Because CAFE standards apply to all manufacturers, establishing higher standards may provide a ready opportunity for all producers to raise car and light truck prices. However, this opportunity may be restricted if producers that face very low incremental costs for complying with higher CAFE standards because of higher fuel economy levels in their planned model offerings compete aggressively with others that face significant costs for increasing fuel economy levels in their product plans to comply with higher CAFE standards.

After considering the comments received and various arguments about the ultimate incidence of manufacturers' costs for complying with higher CAFE standards, NHTSA has concluded that the costs for complying with higher MY 2011 CAFE standards are likely to be shared by manufacturers and purchasers of new vehicles, but that the exact distribution fraction of these costs between manufacturers and buyers is extremely difficult to anticipate. Generally, NHTSA believes that manufacturers are likely to be able to raise prices only to the extent justified by potential buyers' assessments of the value of future fuel savings that will result from higher fuel economy, but the agency recognizes that buyers' valuations of fuel savings are inherently

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98; and the adjustment of discount rates reported in that source discussed in NERA, "Discount Rates for Private Costs," pp. 4-5, attachment to Alliance of Automobile Manufacturers comment on NPRM, Docket Item NHTSA-2008-0089-50.

[27] See Verboven, Frank, "Implicit Interest Rates in Consumer Durables Purchasing Decisions – Evidence for Automobiles," p. 22, attachment to California Department of Justice, comment on NPRM, Docket Item NHTSA-2008-0089-0495.

[28] Whether they will be willing to do so, however, depends partly on how the combined value of the economic and environmental externalities used to determine CAFE standards compares to current fuel taxes. It also depends on whether new vehicle buyers take account of the value of fuel savings resulting from higher fuel economy over the entire expected lifetimes of the vehicles they purchase, or over only some part of that lifetime (such as the period they expect to own new vehicles).

uncertain, and undoubtedly vary widely among individual buyers. As a consequence, price increases for new cars and light trucks are likely to allow manufacturers to recoup some fraction of their costs for complying with higher CAFE standards, while the remainder of those costs are likely to displace other investment opportunities that would otherwise be available to them.

Regardless of the ultimate incidence of costs for complying with higher CAFE standards, however, both manufacturers' opportunity costs for capital investment and empirical estimates of the discount rates that buyers of new vehicles apply to future fuel savings suggest that a rate in the range of 7 percent is an appropriate rate for discounting the nearer-term benefits from increased fuel economy that will occur over the lifetimes of MY 2011 cars and light trucks. Thus for purposes of establishing the CAFE standards adopted in this final rule and estimating their economic benefits, NHTSA has continued to employ a 7 percent rate to discount future benefits from higher CAFE standards *other than those resulting from reduced CO_2 emissions*. Recognizing the uncertainty surrounding this assumption, NHTSA has also tested the sensitivity of the level of the optimized CAFE standards and their resulting economic benefits to the use of a 3 percent discount rate for all categories of benefits.

NHTSA will consider whether to revise the discount rates used in this analysis when it analyzes the consequences of future CAFE standards. At that time, the agency will consider whether to apply a lower discount rate than 3 percent to the benefits from reducing future emissions of CO_2 and other greenhouse gases, as well as whether to use a rate different from 7 percent to discount the nearer-term benefits from raising CAFE standards. In making these decisions, the agency will consider guidance on discounting future benefits – particularly those from reducing the threat of climate-related economic damages – issued by OMB, EPA, and other government agencies, and will also consider the discount rates used by other federal agencies in similar regulatory proceedings. NHTSA will also consider recent research on appropriate rates for discounting future benefits from reducing the threat of climate-related economic damages, as well as on the discount rates that buyers of new vehicles apply to the fuel savings they obtain from purchasing models with higher fuel economy, since such research is particularly relevant to its choice of discount rates. Finally, the agency will consider the financial situations of vehicle manufacturers and the competitive state of the new vehicle market at the time it considers new CAFE standards, as well as their implications for the choice of an appropriate discount rate for near-term (or "intra-generational") economic benefits that result from higher CAFE standards.

Emissions savings per ton – Value of Carbon

Comment: Air Resources Board, 2008-0089-0173, Pg.3 believes we should use the Phase II European Union Allowances – tradable right to emit one ton of carbon dioxide- market value. They are currently trading at $42 per ton, and the benchmark contracts have fluctuated between $18 and $42 this year, with Germany Deutsche Bank forecasting EUA prices of $60 for 2008 and EUA prices as high as $100 by 2020

Comment: Prof. Michael Hanemann, 2008-0089-0188 recommends that NHTSA use a value of $25 per metric ton of CO2 emissions reduced, growing at 2.4% annually beginning in 2005. Commenter disagrees with NHTSA's rationale for selecting CO2 damage cost, and argues that there is no credible evidence to support a lower bound of zero on range of possible damage costs. Commenter identifies Nordhaus and Boyer's DICE model as a source that NHTSA could instead have relied upon for estimates of climate damages to the U.S. economy, but identifies several key assumptions and parameters that commenter believes cause its estimates of U.S. climate damages to be understated by a factor of two to four. Comment includes a detailed discussion of these key assumptions and parameter values, identifies why the values employed in the DICE model may be incorrect, and recommends values that he views as more defensible on the basis of recent empirical research.

Comment: Union of Concerned Scientists, 2008-0089-201.1 states that NHTSA undervalues the cost of global warming and should employ a value of at least $45 per metric ton CO2, the value at which CO2 emission permits are currently trading on the European Climate Exchange. The recommended value represents a predicted marginal cost of achieving the required level of emissions reduction for the EU, and is likely to be a conservative estimate of mitigation benefits. It is consistent with other recent estimates such as the EPA's assessment of GHG allowance prices under Lieberman-Warner: $22-40 in 2015 and $28-$51 in 2020.

Comment: American Council for an Energy-Efficient Economy (ACEEE), 2008-0089-211.1 argues that the "NHTSA decision to use Tol's estimate of $14 as the upper bound based on the argument that this value includes the worldwide costs CO2 is flawed and the low estimate of the marginal damage cost of carbon emissions also discounts the high risk associated with climate change."
Martin Weitzman says accounting for risk of catastrophe raises marginal damage value further "legislative efforts to implement a carbon regime in which the projected market cost of CO_2 is expected to lie between $20 and $30 – significantly higher than the average damage cost assumed by NHTSA – serves as evidence that the U.S. is now beginning to contemplate the high risk of rising greenhouse gas emissions."

Comment: Center for Biological Diversity, 2008-0089-0222.1, Pg. 6-10 states that NHTSA's value is too low. NHTSA must consider the high premium associated with achieving dramatic reductions in CO2 emissions in the near term. The sensitivity analysis must include the range of values in Stern (2007). (Hansen, 2008) says CO2 will need to be reduced from its current 385 ppm to at most 350 ppm soon to avoid seeding irreversible catastrophic effects. The Volpe model only calculates the marginal costs and benefits provided to consumers and automakers, not society as a whole. NHTSA doesn't take into account the loss of biodiversity and complex and large-scale ecosystem services. The range of estimates of CO2 $/ton extends much higher than $14; there is no justification for a value of $0; and simply splitting the difference between two points is not a defensible methodology. Tol (2005) estimates $95/ton. IPCC estimates at $5-125/ton. The Tol studies date back as much as 18 years, with 25 of them more than 5 years old. IPCC notes that integrated assessment models likely underestimate costs because they do not include significant impacts that have not yet been monetized. IPCC estimates as high as $350/ton. Stern (2002) estimates $25-30/ton or higher. NHTSA's lower value of $0 suggests the US might benefit economically by letting other countries bear the costs of unabated American greenhouse gas emissions. This is unethical and unfounded. NHTSA's paraphrasing of Tol that many studies fail to consider potentially beneficial impact of climate change and don't adequately account for how future development patterns and adaptations could reduce potential impacts isn't cited as a finding by Tol and didn't contribute to the Tol range of estimates.

Comment: National Automobile Dealers Association, 2008-0089-223.1, Pg. 8 states that NHTSA should consider incorporating into its analysis the $2.97 per metric ton recently paid by the U.S. House of Representatives for carbon offsets. See: http://cao.house.gov/press/cao-20080205.shtml.

Comment: Environmental Defense Fund, 2008-0089-0224.1, Pg 1-2 and following
EDF recommends that social cost of carbon (SCC) estimates be based on a rigorous metaanalysis that screens for studies that meet key quality criteria. In particular, included studies should use the same low discount rates (3 percent at maximum) and should come from recent literature. To the extent possible, the studies should account for a broad range of potential climate impacts and risks of catastrophic impacts from climate change. A risk assessment framework may be more appropriate than a benefit cost analysis in light of the inherent uncertainties in SCC estimates.

Comment: Natural Resources Defense Council, 2008-0089 225.1 Pg. 2, 27 states that the social cost of carbon used by NHTSA is based on an arbitrary range of values and incorrectly relies on a central estimate of $7 per metric ton of CO2. Unmitigated, costs of dangerous climate change are very likely much higher than estimates in standard literature, and NHTSA must use a reasonable risk premium in its calculations. They provide a report entitled *The Cost of Climate Change: What We'll Pay if Global Warming Continues Unchecked*. The report was published by NRDC in May 2008. It estimates the potential costs of climate change for the United States and identifies the most vulnerable regions for specific types of climate change effects. The report includes NRDC's policy recommendations to combat climate change, including further increasing fuel economy standards.

Comment: Sierra Club, 2008-0089-0226.1, Pg. 2, 6-8 states that NHTSA's value is too low and was obtained haphazardly. NHTSA needs to consider the costs of adverse impacts of global warming cited by the USDA and NOAA. NHTSA took a low-end carbon study average value and further reduced its validity by cutting it in half. NHTSA's price barely takes a thumb off the scale. NHTSA value is far below current estimates. NHTSA's decision to average $0 and $14 is flawed. The $14 value is itself an average so cannot be used as the max value. Also the Tol $14 value is in 1995 dollars – the 2005 value would be $19. Tol (2005) ways the max value is in the $55-95 range. NHTSA should not rule out the $95 value. Using $0 as the min is wrong because NHTSA has been chastised by the court for doing this in the past and several government reports say the impact of CO2 emissions on the economy is significant. The estimate from (Stern, 2006) is $85. EPA's recent analysis is that it could be as high as $22-40. The futures market value in 2011 under the ETS is already up to $45. The current European Prices for carbon under ETS have been $15-25. The USDA predicts increasing crop failures, decreased livestock productivity, more forest fires, more drought, strains on water resources, etc. NOAA predicts more heat waves, more droughts, more intense hurricanes, more winter storms. Hurricane Katrina demonstrated that the social and economic costs of extreme weather events can be staggering.

Comment: U.S. Senate, 2008-0089-0454, Pg. 1-4 stated that NHTSA's value for SCC is too low. Also NHTSA should throw out the lower bound estimate of $0 in determining the value of SCC. NHTSA's averaging of $0 & $14 is likely to be found arbitrary and capricious. NHTSA should use a number higher than $14 for the upper bound in the averaging because the Tol $14 is itself an average.

Agency response: All of the emissions issues are answered together. See Chapter VIII and the preamble to the final rule for our response.

Emissions worldwide versus only U.S. emissions

Comment: Alliance, 2008-0089-0179.1, P9, P34, Att3, S8, states that NHTSA should only account for U.S. CO2 benefits, not globally. NERA uses a 20 percent factor for U.S. versus global. EPCA says when considering maximum feasible, the Secretary of Transportation should consider the need of the United States to conserve energy. They argue that phrase is an extraterritoriality canon and by law NHTSA must limit consideration of social costs of carbon to domestic impacts.

Comment: Center for Biological Diversity, 2008-0089-0222.1, Pg. 7, 11 stated that NHTSA must take into account the costs of climate change outside the US. NHTSA fails to understand the tremendous threats and challenges posed by global climate change. The air basin for GHG is the global atmosphere. Benefits should be estimated wherever they are experienced. Not doing so vastly underestimates the true costs of climate change. Restricting to the US carries the terrible and arrogant implication that the people of the US believe that people in other countries should bear the environmental and economic burdens caused by American consumer preferences. Nothing in EPCA, NEPA, or other applicable law allows NHTSA to restrict to the US. The impact on the developing world is disproportionate.

Comment: National Automobile Dealers Association, 2008-0089-223.1, Pg 8 stated that NHTSA should only count domestic impacts of reducing the social costs of motor vehicle CO_2. Air "Pollutants" Criteria pollutant reduction benefits associated with the proposed CAFE standards are overstated as the negative impact of inhibited fleet turnover was not accounted for. With respect to greenhouse gases, NHTSA should account only for any *domestic* impacts of reducing the social costs of motor vehicle CO_2, given that EPCA focuses on U.S. energy security and all other costs and benefits evaluated with respect to the proposed CAFE standards are domestic only.

Comment: U.S. Senate, 2008-0089-0454, p. 3 stated that NHTSA shouldn't ignore the international benefits from GHG reduction. NHTSA's argument that it should exclude non-domestic benefits for consistency with prior CAFÉ rulemakings is irrelevant because NHTSA has not previously valued SCC. OMB specifically allows for the consideration of non-domestic benefits. The U.S. is obligated under the 1992 U.N. Framework Convention on Climate Change to consider global impacts. If every nation ignored non-domestic benefits, each would set emissions standards that are far short of socially optimal. NHTSA's treatment of SCC would put the rule at substantial litigation risk.

Emissions Growth rate in the value of carbon emissions over time

Comment: Center for Biological Diversity, 2008-0089-0222.1, Pg. 8, states that the growth rate over time is 2-4% per year and cites the IPCC.

Agency response: See Chapter VIII and the preamble to the final rule for our response.

Emission reductions values for Criteria pollutants

(CO, VOC, NOx, fine particulate matter (PM), and sulfur dioxide (SO2)

Comment: Mark A. Delucchi, 2008-0089-0025, NHTSA needs to include more externalities. It is not clear what kinds of damages are included in your $/ton estimates (e.g., page 24403). You should include health damages, visibility, crop damages, materials damages, and natural-ecosystem damages. I am fairly sure that the EPA damage estimates do not include all of these. You can find peer-reviewed estimates of damages in most of these categories on my faculty web page.

Comment: Alliance, 2008-0089-0179.1, Pg. 9 P37, Att 2 P107-108, stated that NHTSA should use published EPA estimates on conventional pollutants, not ad/hoc EPA/NHTSA estimates. Upstream emissions will not be reduced. NHTSA did not take into account the new source review standards, and otherwise assumed away federal and state laws that would have the effect of requiring offsets from the upstream refineries that NHTSA attempts to claim credit for. The upstream emission factors aren't realistic. NHTSA needs to consider the fleet-turnover effect. Most criteria pollutants will worsen for decades. NHTSA did not consider that consumers will delay purchasing new more fuel efficient vehicles in the current marketplace prior to an expensive new government mandate.

Comment: Ford, 2008-0089-0202.1, Pg. 10 recommended that NHTSA consider using CO2 mitigation cost in their analysis in lieu of emission damage cost. Although vehicles are often perceived to be the major source of CO2 emissions, in fact, 70 percent of man-made emissions in the United States come from sources other than transportation. Power generation, home energy use and other industries are just a few. It should also be noted that it would be more cost effective to remove CO2 from the utility sector than the vehicle sector presently. As shown in Chart 4, when it comes to the auto industry, light duty cars and trucks contribute only about 20 percent of CO2 emissions in the U.S. And on a global scale, that figure is about 11 percent. No single sector can provide the total solution. All sectors must contribute.

Comment: Center for Biological Diversity, 2008-0089- 0222.1, Pg. 11, stated that NHTSA must include in its benefits analysis emissions of methane, nitrous oxide, and hydroflourocarbons. They represent large amounts of GHGs. Nitrous oxide emissions are equivalent to 29 million metric tons of CO2. NHTSA must analyze the impacts of the standard in relation to the emissions scenarios and impacts identified in Bernstein (2007).

Agency response: In response to Mr. Delucchi's comment, NHTSA is confident that the damage cost estimates it used in the NPRM to value reductions in criteria air pollutants and their chemical precursors include the full ranges of human health impacts known to be associated with exposure to each of these pollutants. Differences between these damage costs and the estimates by OMB cited by commenters reflect the fact that the estimates provided to NHTSA by EPA apply specifically to emissions by motor vehicles, and include separate costs for emissions from stationary sources such as petroleum refineries where such differences are appropriate. The estimates provided by EPA also reflect more up-to-date knowledge about the human health impacts of exposure to criteria air pollutants and the economic costs associated with those impacts than do the estimates reported by OMB. Thus in the analysis it conducted for this Final Rule, NHTSA has continued to use the damage cost estimates supplied by EPA to determine the economic costs or benefits from changes in emissions of criteria air pollutants that result from higher CAFE standards.

In response to comments provided by NERA on behalf of the Alliance, NHTSA acknowledges that it may have overestimated reductions in upstream emissions of some criteria air pollutants (particularly PM and NOx) resulting from fuel savings in the analysis it conducted for the NPRM. NHTSA has taken two steps to remedy this possible overestimation. First, the agency used updated emission factors for vehicles used to transport crude petroleum and refined fuel, including ocean tankers, railroad locomotives, barges, and heavy-duty trucks supplied by EPA to recalculate the emissions factors for each stage of fuel production and distribution in Argonne's GREET model. These updated emission factors reflect the effects of recent and pending EPA regulations on vehicle emissions and fuel composition, and result in significant reductions in the upstream emission rates for fuel production and distribution estimated using GREET. These lower upstream emission rates reduce NHTSA's estimates of emissions during fuel production and distribution under both Baseline and alternative CAFE standards, and by doing so also lower the reductions in upstream emissions projected to result from any increase in CAFE standards from their Baseline levels.

In addition, NHTSA notes that the estimates of reductions in upstream emissions it reported in the NPRM incorrectly included reductions in ocean tanker emissions for transportation of crude petroleum from overseas to ports or offshore oil terminals in the U.S. Since most of these emissions probably occur outside of the U.S., they should not be included in NHTSA's estimates of upstream emissions reductions, since those are intended to represent changes in *domestic* emissions of criteria air pollutants.[29] NHTSA has revised its analysis for this Final Rule to exclude reductions in ocean tanker emissions.

In response to comments by Sierra Research and NERA submitted by the Alliance, NHTSA notes that there are currently two cap-and-trade programs governing emissions of criteria pollutants by large stationary sources. The Acid Rain Program seeks to limit NOx and SO_2 emissions, but applies only to electric generating facilities.[30] The NOx Budget Trading Program is also primarily intended to reduce electric utility emissions, but does include some other large industrial sources such as refineries; however, as of 2003, refineries participating in the program accounted for less than 5% of total NOx emissions by U.S. refineries.[31] In addition, some

[29] Emissions from ocean tankers while in port areas, as well as pipeline or truck emissions occurring during transportation of crude petroleum from import terminals to U.S. refineries, do occur within the U.S., and reductions in these emissions should be included when estimating changes in domestic emissions. However, it is not possible to separate these emissions from those that occur in foreign ports or on the open oceans, so NHTSA's analysis does not include reductions in them. As a consequence, the analysis may underestimate reductions in upstream emissions occurring within the U.S.

[30] For a detailed description of the Acid Rain program . see http://www.epa.gov/airmarkt/progsregs/arp/basic.html#princips (last accessed October 6, 2008).

[31] Estimated from EPA, NOx Budget Trading Program (SIP Call) 2003 Progress Report, Appendix A,

refineries could be included among the sources of NOx emissions that will be controlled under EPA's Clean Air Interstate Rule, which is scheduled to take effect beginning in 2009. However, refinery NOx emissions could only be affected in states that specifically elect to include sources other than electric generating facilities in their plans to comply with the rule, and EPA has indicated that it expects states to achieve the emissions reductions required by the Clean Air Interstate Rule primarily from the electric power industry.[32] Thus the agency continues to assume that the reduction in domestic gasoline refining estimated to result from the adopted CAFE standard will be reflected in reduced refinery emissions of criteria pollutants.

NHTSA also notes in response to comments by Sierra Research and NERA submitted by the Alliance that emissions occurring during refueling at retail stations are included in the emissions factors estimated using EPA's MOBILE emission factor model, which also accounts for expected future reductions in these emissions. Thus NHTSA believes that reductions in refueling emissions were correctly estimated in its NPRM analysis, and has not revised its procedures for doing so.

Finally, in response to comments by the Alliance and NERA, NHTSA acknowledges that the effect of higher prices for new vehicles on the retention and use of older vehicles is potentially significant, depending on the magnitude of expected price increases. Based on detailed econometric analysis of the effects of new vehicle prices and other variables on retirement rates for used vehicles very similar to the analysis conducted by NERA for the Alliance, NHTSA concludes that price increases for 2011 cars and light trucks likely to result from higher CAFE standards are unlikely to cause significant or lasting changes in retirement rates for older vehicles. NHTSA also notes that the vehicles whose retirement rates would be most affected by increases in prices for model year 2011 passenger cars and light trucks are those that will be 10-15 years of age at the time when 2011 vehicles are offered for sale.[33] These include cars and light trucks produced during model years 1996 through 2005, and NHTSA's analysis of their emission rates at those ages predicted using EPA's MOBILE6.2 motor vehicle emission factor model suggests that they will not be dramatically higher than emission rates for comparable new 2011 models. Thus the effect on total motor vehicle emissions of criteria air pollutants resulting from any reduction in new vehicle sales and accompanying increase in use of older vehicles caused by increased prices for new 2011 cars and light trucks is likely to be modest.

Externalities - Monopsony effect

Comment: Mark A. Delucchi, 2008-0089-0025, recommends use global warming damages in the U.S. only. Your discussion on p. 24414 is correct: if you include Paul Leiby's estimate of the

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http://www.epa.gov/airmarkets/cmprpt/nox03/NBP2003AppendixA.xls, and National Air Quality and Emissions Trends Report 2003, Table A-4, http://www.epa.gov/air/airtrends/aqtrnd03/pdfs/a4.pdf

[32] The Clean Air Interstate Rule also requires reductions in SO2 emissions and establishes an emissions trading program to achieve them, but only electric generating facilities are included in the rule's SO2 emissions trading program; see EPA, Clean Air Interstate Rule: Basic Information, http://www.epa.gov/cair/basic.html#timeline (last accessed October 6, 2008) and http://www.epa.gov/cair/pdfs/cair_final_fact.pdf (last accessed October 6, 2008).

[33] This conclusion is based on detailed econometric analysis of the effects of new vehicle prices and other variables on retirement rates for used vehicles conducted by the Volpe Center. This analysis concluded that retirement rates for 10-15 year old vehicles are most sensitive to changes in new vehicle prices.

monopsony cost (e.g., p. 24411) -- which in a global accounting is a transfer and not a resource cost -- on the grounds that your counting costs and benefits to the U. S. only, then consistency requires that you count global warming damages in the U. S. only. It is possible to estimate U. S. damages only: I have done it in the following report, available on my faculty web page: Summary of the Nonmonetary Externalities of Motor-Vehicle Use. Delucchi, Mark A. ITS-Davis. Report #9 in the series: The Annualized Social Cost of Motor-Vehicle Use in the United States, Based on 1990-1991 Data. October 2004. Publication No. UCD-ITS-RR-96-3 (9) rev. 1. Revision of report originally published in September 1998.

Agency response: We concur with this comment and include monopsony when counting global warming damages in the U.S. only. See Chapter VIII for more discussion on monopsony.

Externalities - Supply disruption costs

Comment: Union of Concerned Scientists, 2008-0089-0201.13, Pg. 24, 31 stated that NHTSA's value is too low. ORNL assesses the benefits of reduced oil consumption for reducing supply disruption and market price spikes at $14.51 per barrel. This is a conservative assessment as it excludes all military costs and the foreign policy impact of oil import reliance.

Agency response: We use the same data source, ORNL, but find a much smaller value. See Chapter VIII for more discussion on supply disruption costs.

Externalities - Military costs

Comment: Air Resources Board, 2008-0089-0173.14, appears to recommend that reductions in military outlays equivalent to $0.03-0.15 per gallon of fuel saved be included as benefit from fuel savings attributable to higher CAFE standards. Comment consists of recent article authored by Mark Delucchi and James Murphy, published in journal *Energy Policy* (citation: *Energy Policy* 36 (2008) 2253– 2264). Article attempts to estimate total U.S. military outlays that are directly attributable to securing flow of oil imports to the U.S. from the Persian Gulf region, and the fraction of these that are attributable to meeting U.S. demand for motor vehicle fuel. Authors conclude that these amount to $15 billion annually, or $0.03-0.15 per gallon of fuel consumed by U.S. motor vehicles.

Comment: Mark A. Delucchi, 2008-0089-0025 stated that military costs should not be zero (p. 24411). I have just published a peer-reviewed article in Energy Policy that can serve as one basis for making a non-zero estimate of the cost.

Comment: Public Citizen, 2008-0089-0187, Pg. 4 objects to the zero valuation of military security costs associated with oil consumption. NHTSA states "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 passenger cars and light trucks."[23] NHTSA justifies this claim by stating that there are other national security and foreign policy objectives served by military actions in the Middle East. NHTSA used similar logic to justify assigning zero value to reducing CO2 emissions in the light truck rule. The Ninth Circuit Court of

Appeals rejected this justification in *Centerfor Biological Diversity v. NHTSA*, finding that uncertainty about how to assign a value was not a justification for setting the value at zero.[24]

Comment: Attorney General of the States, 2008-0089-0199.1, Pg. 11. It is true that an increase in CAFE standards will not, in and of itself, eliminate these energy security costs. The same could be said as to global warming costs. It is also the case, however, that the impact of higher CAFE standards on energy security is not zero. Energy security costs are a necessary piece of the puzzle in assessing all of the costs and benefits of a CAFE standard. In fact, a recent peer-reviewed economic analysis did assign values to the military savings attributable to decreased oil imports. *See* Mark A. DeLucchi & James J. Murphy, US Miliary Expenditures to Protect the Use of Persian Gulf Oil Imports, 36 *Energy Policy* 2253 (2008) (assigning a cost of between $0.03 and $0.15 per gallon, and referencing earlier work on this issue).

Comment: Consumer Federation of America, 2008-0089-0183, Pg, 47-48, 61-62 stated that a zero value is simply wrong. NHTSA should use 30 cents/gallon. The fact that the statute had energy independence and security in its title should have alerted NHTSA to the likelihood that Congress considers the military and strategic value of oil important.

Comment: Natural Resources Defense Council, 2008-0089 225.1, Pg. 2 and following, the economic value of military security to protect oil supplies should be non-zero and positive. When NHTSA used zero it ignored the U.S. military security-related benefits of reduced oil consumption, such as enhanced flexibility to respond to supply threats and move the country in the direction of oil being a nonstrategic resource. The report also suggests that NHTSA should include the benefits from lower oil use that would result from the subsequent marginal decline in the need for military resources protecting a strategic commodity (oil).

Comment: Sierra Club, 2008-0089-0226.1, Pg. 2, 7 stated that NHTSA must recognize the national security costs of oil. The military-related expenses are tremendous. See the 2005 report of the International Center for Technology Assessment. NHTSA's decision to ignore military costs is arbitrary and capricious.

Agency response: The Deluchi estimates are clearly identified as savings that would result if demand for petroleum-based fuels by U.S. motor vehicles were completely eliminated. The article includes little or no discussion of the extent to which military outlays would vary in response to marginal reductions in U.S. fuel consumption of the scale likely to result from higher AFE standards or other fuel conservation measures, indicating only that any reduction in U.S. military outlays would result from policy decisions to be made by Congress. The agency believes at this time that military outlays would not vary depending upon the fuel economy standards and uses $0.00 in the main analysis, with a sensitivity analysis examining the impact of $0.05 per gallon for military outlays.

While NHTSA believes that military expenditures appropriated by the U.S. Congress are not directly related to changes in domestic petroleum consumption, the agency recognizes that reductions in petroleum consumption may provide other benefits that are more difficult to quantify, by reducing some constraints on U.S. diplomatic and military action. U.S. foreign policy decisions consider a wide range of U.S. interests, including the maintenance of secure petroleum supplies. Reduced consumption of petroleum might allow the U.S. to more vigorously pursue other foreign policy interests, by reducing concerns about the implications of pursuing these other interests for the availability and continuity of petroleum imports.

The agency recognizes, however, that both the effect of reducing U.S. petroleum imports on the flexibility of its foreign policy initiatives and the economic value of such additional flexibility are highly uncertain. Reducing petroleum consumption is likely to have unpredictable effects on both military actions and diplomatic initiatives, and even if the U.S. government planned and signaled its foreign policy intentions under various levels of petroleum consumption in advance, NHTSA is unaware of any accepted methods for establishing the economic value of increased freedom in designing military or diplomatic actions. And because the nation's foreign policy intentions are not communicated in advance, the agency would need to develop a procedure for anticipating how military and diplomatic actions would respond to future changes in petroleum consumption. Nevertheless, in its future rulemaking activities, NHTSA will investigate whether practical methods for predicting and valuing in economic terms any increased flexibility in U.S. foreign policy that is likely to result from reduced petroleum imports exist or can be developed.

Financial Impacts of Raising CAFE Standards and ability of manufacturers to finance fuel economy improvements

In the PRIA, the agency admitted that the agency does not have 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. We asked several questions regarding the manufacturers' financial capabilities in meeting the proposal and the alternatives examined. Specifically we asked:

> For each of the model years 2011-2015, please provide the best possible estimate of the incremental capital investments required for your company to comply with the alternatives discussed in this analysis
>
> Please discuss whether you anticipate that your firm will to be able to raise the incremental capital investments necessary to meet the levels predicted in answer to the questions above. If the answer is no, what level appears likely to be achievable. What alternatives are available to raise the incremental capital investments necessary?

Essentially, the agency received no comments about the companies' abilities to raise capital or finance the capital investments necessary to meet alternative levels of the standard. Instead, it received comments that the proposal wasn't feasible or that the standard are inconsistent with those in the European Union or Japan, or that they are currently losing money.

Comment: General Motors, 2008-0089-0162, Pg. 9, stated that NHTSA assumes that manufacturers either have the capital or the ability to borrow funds to meet the proposed standards. That assumption ignores the reality facing GM. None of the supporting studies, nor NHTSA's modeling process, quantitatively address the real world constraints that exist in terms of technical and financial resources. The roll-out rate may substantially exceed the capability of GM to actually implement. If the future standards cannot be achieved by technology, then compliance can only be achieved by product eliminations, plant closings and job losses. They provide in Attachment 6 a section from GM's 10-K statement, that is a general statement indicating that sales levels in the industry are projected to decline in 2008. They have relatively high fixed costs and high unit contribution margins, such that small changes in the number of vehicles sold can materially adversely affect their operation and financial conditions.

Agency response: GM does not specifically address their potential to finance technology improvements and NHTSA does not have the wherewithal to know how to determine what level of capital financing will be available to GM in the future.

Comment: The Alliance, 2008-0089-0179.1, Pg. 8, 20, 21, state that NHTSA should account for the industry's capital constraints. NHTSA recognized capital constraints in the 2008-2011 light truck rulemaking. Why has NHTSA changed course on that issue?

Rod Lache of Deutsche Bank stated "we do not expect automakers to be able to pass all of these costs along to consumers". Quote "an agency is arbitrary and capricious if the agency … entirely failed to consider an important aspect of the problem, offered an explanation for its decision that runs counter to the evidence before the agency … entirely failed to consider an important aspect of the problem, offered an explanation for its decision that runs counter to the evidence before the agency, or is so implausible that it could not be ascribed to a difference in view of the product of agency expertise."

Agency response: The agency did not take into account capital constraints in the 2008-2011 light truck rulemaking. The agency recognizes that vehicle manufacturers must have sufficient lead time to incorporate changes and new features into their vehicles. In making its lead time determinations, the agency considered the fact that vehicle manufacturers follow design cycles when introducing or significantly modifying a product. We have applied the same rationale here. If the market (or regulation) drives manufacturers to make changes, they must do so to sell their vehicles. The Alliance provides no estimate of their own on how to account for capital constraints.

Comment: Mitsubishi, 2008-0089-0197.1, Pg. 1, 5-6 stated that the NPRM requires extremely expensive and complex adjustments to product plans to meet very strict standards for cars and trucks in MY 2011. MMC would likely suffer severe financial difficulties. The NPRM has not considered capital constraints. MMC requests NHTSA consider capital constraints in the final rule. The product development cycle is already underway for MY 2011. Retail prices for MMC's compact vehicles, which comprise the majority of our overall sales in the US market, are expected to double as a result of the standard. In FY 2007, MMC had an operating income deficit of $178M. In 2008, MMC forecasts net sales in North America will drop by 25.5% and that ordinary income in the US will further decline by an additional $92M. We are still in the process of recovery after our alliance with DAG dissolved in 2004. MMC has limited access to additional capital for investments in new technologies.

Agency response: Mitsubishi provides no estimate of their own on how to account for capital constraints.

See Chapter VII for our general discussion of financial impacts.

Inequality of impacts on smaller manufacturers

Comment: BMW, 2008-0089-0146.2, Pg. 2 and 0146.3 Pg. 1 stated that the standard is costly to small manufacturers. Niche manufacturers (such as BMW whose vehicles offer extraordinary safety, comfort, and convenience features, and so have a high mass per footprint density) have to fulfill more ambitious requirements. BMW requests an option of not using the footprint, but a standard increase per year.

Comment: Fuji (Subaru), 2008-0089-0157, Pg. 2-4, 6-8 stated that the standards aren't fair to small manufacturers. The passenger car standard requires virtually nothing of the high volume manufacturers but requires large fuel economy increases among small manufacturers. Small manufacturers don't have the same capability to offset targets for smaller footprint vehicles with larger vehicles. Subaru proposes small manufacturers be provided an option to pay civil penalties based on their target fuel economy, instead of meeting the target.

Comment: Ferrari, 2008-0089-0168, Pg. 3-5 stated that NHTSA's assertion that its proposal will not have a significant economic impact on small businesses is wrong. NHTSA does not always grant petitions from small manufacturers for alternative standards. Ferrari's fines will increase significantly. Also the standards aren't fair to niche manufacturers, specializing in higher performance sport vehicles. The same set of gas guzzler vehicles can be penalized or not under the standard, depending on whether they are made by a small manufacturer or a large one (who can offset these with other vehicles exceeding the standard). This is discrimination.

Comment: Porsche, 2008-0089-0174.1, Pg. 12-13 stated that the standards result in inequities for smaller limited line manufacturers. The footprint-only attribute assigns to smaller limited line manufacturers targets that are beyond the reach of their vehicle fleets. The only choices for these manufacturers are to leave the market, restrict product or pay exorbitant civil penalties. The car standard requires virtually no improvement by the larger full line manufacturers during the early years. The standards were set using only the 7 largest manufacturers. From MY 2007 to MY 2011 Porsche is required to increase its passenger car fleet an average of nearly 10% per year, over twice the predicted annual industry average.

Comment: Volkswagen, 2008-0089-0181, Pg. 3 commented that an alternative attribute in addition to footprint should be used to equalize cost burden on all manufacturers. Volkswagen argued that the footprint attribute alone when applied to the passenger car fleet creates challenges for some automakers with limited product range and/or limited market segments. For some automakers it appears that their products or fleet mix demonstrate unfavorable correlation to the footprint curves as generated by NHTSA and result in additional burden for those automakers. NHTSA should consider alternative compliance approaches to alleviate the stringency applied to limited product line producers. An example of this is the uniform increase concept.

Comment: Mercedes, 2008-0089-0190, Pg. 3-4 stated that the requirements on manufacturers excluded when setting the standard are disproportionate to those imposed on larger full line manufacturers. The standard requires virtually no improvement by the 7 largest manufacturers.

The targets require colossal investment by the excluded manufacturers to modify their fleets. Even then, these companies many still be subject to severe civil penalties. Mercedes would need to improve its fleet in MY 2011 by 28% over MY 2007.

Comment: Mitsubishi, 2008-008900197.1, Pg. 2, 5 stated that the standard puts manufacturers with smaller average footprints at a competitive disadvantage. The targets were set using manufacturers that have larger average footprints. These manufacturers face disproportionately burdensome requirement in the early years. It is more difficult for these manufacturers to negotiate supplier contracts to purchase new components. Large suppliers can negotiate more cost effective supplier contracts and in some instances co-develop or internally develop new components before the market creates an economy of scale. Small and midsize companies are also at a disadvantage in terms of when new components are received from suppliers. The supply of new components is limited due to supplier capacity and output. The sizable demand for new components from larger manufactures is fulfilled first by suppliers.

Comment: Ford, 2008-0089-0202.1, Pg. 3 stated the agency should revise the proposal to ensure that all manufacturers have a comparable burden, or at least ensure that whatever differences may exist will not hinder any manufacturer's ability to compete in the marketplace. Given the manner which NHTSA has chosen to draw the car and truck curves, some manufacturers have tasks to improve their fuel economy every model year, while others do not. In particular, the proposal gives domestic full-line manufacturers significant tasks relative to their competitors. This is not inevitable; it is a reflection of the particular shapes that NHTSA has chosen for the curves.

Comment: Association of International Automobile Manufacturers (AIAM), 2008-0089-205.1, Pg. 3 stated that the abrupt increase in fuel economy required in the early years is particularly severe for smaller companies. Smaller companies face required increases in fuel economy of 17-88% from 2007 to 2011. Smaller companies tend to have fewer resources to implement major changes on an expedited basis. These companies tend to produce vehicles that fall in the steep central portion of the car curve. They have a limited range of product offerings, so have fewer options for achieving required fuel economy increases. Redesign cycles may not coincide with the 2011 start date.

Agency response: For the final rule the agency is including all manufacturers (not just the largest seven producers) in determining the CAFE requirements. We will have one standard that is applicable to all medium to large size passenger car manufacturers (very small companies – less than 10,000 sales worldwide - can petition for alternative standards). While the current form of the standard may cause difficulty for some manufacturers, the standard is designed more to deal with the overall industry than with particular, niche vehicle makers.

For purposes of this rulemaking, the agency is not interested in providing an alternative flat standard that includes a set year-by-year increase in the CAFE levels. The current CAFE structure is designed to be attribute-based per legislative mandate. We also have the simultaneous objectives of improving industry-wide fuel savings, GHG emissions, and preserving safety. NHTSA has an attribute-based approach which provides no incentive to build smaller cars just to meet a fleet-wide average, because smaller vehicles will be subject to more stringent fuel economy standards. The approach is to determine what level of fuel economy can be achieved primarily by new technology.

Leadtime issues

Comments: With the exception of Borg Warner, 2008-0089-0142 Page 1, that stated that leadtime and levels are very aggressive but possible, the remainder of the commenters on leadtime stated that the proposed requirements in the early years were too aggressive or beyond the maximum feasible level for their company. Included in this group were:
Fuji (Subaru), 2008-0089-0157, Pg. 2, 5, 7-8
General Motors, 2008-0089-0162, Pg. 2,
The Alliance, 2008-0089-0179.1, Pg. 23
Mercedes Benz, 2008-0089-0190.1, Pg. 3
Mitsubishi, 2008-0089-0197.1, Pg. 1-2
AIAM, 2008-0089-0205.1,Pg. 3-5
Toyota, 2008-0089-212, Pg. 2 wants a 3.3% improvement per year, not 4.5%.
Mercatus Center, 2008-0089-216.1
National Automobile Dealers Association (NADA), 2008-0089-223.1, Pg. 2
Washington Legal Foundation, 2008-0089 228, Pg. 3,5

Agency response: The costs for technologies and effectiveness and the leadtime issues were all addressed in consultation with our contractor. The model year 2011 requirements are not as aggressive in the final rule as proposed in the NPRM.

Learning curve
In the PRIA for some of the technologies, we included a learning factor. The "learning curve" describes the reduction in unit production costs as a function of accumulated production volume and small redesigns that reduce costs.

Comment: Borg Warner, 2008-0089-0142, Pg. 1, stated that the learning curve assumptions aren't correct. Learning curve do not apply to many of their products. The technologies are well developed and in high volumes in other parts of the world, so our price/cost estimates already represent higher volumes. In fact, increasing global volumes could lead to higher prices if demand for certain raw materials exceeds supply.

Comment: The Alliance, 2008-0089-0179.1, Pg. 6-7 believes the learning curve assumptions are not supported. Martec's updated 2008 analysis explains that its corrected and original study both fully accounted for learning effects.

Comment: AIAM, 2008-0089-0205.1-Pg. 5 stated that some of NHTSA's cost estimates may reflect double counting of the cost learning curve effect. The learning curve estimates in the 2002 NAS study and the EEA and Martec reports already reflect to some degree learning curve considerations.

Comment: Public Citizen, 2008-0089-0187,Pg. 7 The agency has included "learning curves" to attempt to model the reductions in cost of compliance due to economy of scale effects. Public Citizen observes that economy of scale effects should be accounted for; however, we wish to point out that again these effects are often estimated incorrectly. In a survey of emission reduction regulations, the author finds: "In all cases except one, the early estimates [of cost of compliance] were at least double the later ones, and often much greater." Inaction based on inflated estimates of cost of compliance cannot be tolerated in the face of an energy crisis and environmental catastrophe.

Comment: Honda, 2008-0089-0191, Pg 6 stated that learning curve costs should be raised in early years and decreased in later years. The cost estimates provided to NHTSA through NAS, Energy and Environmental Analysis Inc (EEA), and the Martec Group all assume high volume production and thorough product development. Thus, these costs already include substantial amounts of learning. Proper application of learning factors would increase costs for early, low volume production of these technologies, to reflect that they have not yet achieved the learning and cost reductions assumed by NAS, EEA, and Martec. Once sales exceed about 300,000 per year per manufacturer, the learning factors could begin to decrease the cost estimates from NAS, EEA, and NHTSA. But the learning factors must be applied consistently to both raise costs in the early years and decrease them in later years, not just reduce costs.

Agency response: For the final rule, **t**he learning curve assumptions were all reviewed in consultation with our contractor (Ricardo). The learning curve assumptions have been changed and are addressed in Chapter V.

Marginal cost = Marginal benefit (MC=MB) versus total cost = total benefit (TC=TB) approach in setting final rule

In the NPRM, the agency provided alternatives which included both MC=MB and TC=TB. However, the proposal was based on MC=MB.

Comment: The Alliance 2008-0089-0179.1, Att3, P-7 commended NHTSA for using MC=MB, rather than TC=TB stating that TC=TB costs $12.5 billion more, but only yields $7 billion in benefits.

Comment: Attorney General of the States, 2008-0089-0199.1, Pg. 9 stated that the standard should maximize energy conservation instead of net economic benefits. Congress has already made the judgment that energy conservation is the highest priority among the factors for NHTSA to balance. *Center for Biological Diversity*, 508 F.3d at 527-28 (discussing *Center for Auto Safety v. NHTSA*, 793 F.2d 1322 (D.C. Cir. 1986)). To achieve this goal, NHTSA should set the standards at a level where the total costs equal total benefits.[2] From a societal point of view, there cannot be substantial adverse consequences if the costs do not outweigh the benefits. We urge NHTSA to set the standard at a level where total costs equal total benefits.

Comment: Union of Concerned Scientists, 2008-0089-201.1 and 2008-0089-0201.13 Pg. 3-4, 25-30 recommends against the use of a marginal cost-marginal benefit analysis, and believes NHTSA should instead use a total cost-total benefit analysis to determine maximum feasible fuel economy standards. The use of a TC=TB analysis would maximize the need to conserve energy while ensuring consumers are as "well off" as they are today. An analysis of the recommended form would reduce the impact of any inaccurate monetizing of the benefits of reduced fuel consumption, and would increase the economically practicable fleet average between 2.8 and 5.7

miles per gallon. MC=MB is very sensitive to different valuations of benefits, making it more error prone. An MC=MB analysis that excludes or undervalues even some of the benefits is fundamentally flawed.

Agency response: For purposes of this rulemaking, NHTSA has concluded that the maximum feasible standards are represented by the level at which net benefits are maximized. NHTSA recognizes that the overarching purpose of EPCA is energy conservation, and considers the need to conserve energy as part of its balancing of the four statutory factors. However, NHTSA disagrees with the Attorneys General that there would be no substantial adverse consequences for purposes of this rulemaking from setting the standards at the level represented by TC = TB. Based on NHTSA's analysis and given the unique circumstances surrounding this rulemaking, including the economic crisis and the concurrent burden on manufacturers, NHTSA has concluded that TC = TB would be beyond the maximum feasible level at which the MY 2011 standards could be set. However, the agency will reconsider in future rulemakings whether to set standards at the level of TC = TB.

Market Failure

Executive Order 12866 requires that all new federal regulations specify the market failure that will be addressed by the rulemaking. The agency state that the Energy Policy and Conservation Act (EPCA) directs the Department to balance the technological and economic challenges related to fuel economy with the nation's need to conserve energy. Congress decided that the market would not balance these challenges in the best interest of the nation, and that the Department should regulate fuel economy.

Comment: The Consumer Federation of America, 2008-0089-0183 -pp. 37-40 stated that NHTSA's view of market failure is very narrow, generally admitting only a problem of externalities that are not internalized. We suspect there are other sources of market failure, like information problems, agency problems, perverse incentives, etc. Moreover the problem is not limited to the demand side of the market. There are imperfections in the supply side. NHTSA discovers that there are fuel savings technologies that pay for themselves, but have not been moved into the vehicle fleet. Since this cannot be explained by externalities market failure, there must be other market failures operating.

NHTSA's pro industry view of the world blames the market failure on the consumer, when in fact the problem is the automakers.

Agency response: NHTSA didn't present a view of the world, just a statement that Congress requires it to set fuel economy standards.

Comment: The Mercatus Center, 2008-0089-216.1 questions whether there is failure in the "market" for fuel economy that needs to be regulated. To support this assertion they present evidence of recent market forces (e.g. rising fuel costs) driving fuel economy standards above current CAFE standards. They also suggest that drivers are becoming more willing to demand and pay for fuel economy due to heightened awareness of environmental externalities (CO_2 emissions).

Agency response: We see no need to debate the needs for regulation, since Congress requires us to set fuel economy standards.

On-road fuel economy adjustment – 20 percent

In the NPRM, the agency reduced the EPA test data by 20 percent to account for on-road fuel economy in determining the benefits of the proposal.

Comment: There were two comments on this issue (Sierra Research 2008-0089-0046, Page 76, and Air Resource Board 2008-0089-0173.11, p10). Sierra Research employed a different adjustment factor, adjusting the EPA dynamometer test results downward by 10% for the city cycle and 22% for the highway cycle to better reflect real world driving (18% reduction used for a hybrid). The Air Resource Board presented a study “Analysis of In-Use Fuel Economy Shortfall Based on Voluntarily Reported MPG Estimates”, by Greene et al., Nov. 2005.

Agency response: The agency will rely on the published EPA final rule guidelines and continue using 20 percent. The report by Greene *et al*. was completed prior to EPA’s changes to its labeling regulations. Neither commenter suggested that NHTSA use these numbers instead of EPA’s for analyzing fuel savings.

Payback Period

In the PRIA, we assume in the sales impact analysis section that consumers will only value fuel savings over a 5 year time horizon.

Comment: Mark A. Delucchi, 2008-0089-0025, states that you should not do a "payback" analysis with a zero discount rate and a 5-year payback period, because there is no economic theory or consumer behavioral evidence to support this.

Agency response: Commenter provides no alternative, other than using a full lifetime payback period. NHTSA disagrees that consumers think in that long term.

Comment: Sierra Research, 2008-0089-0046, Pg. 77, considers 5 years and 20 years, but say that average consumers are more likely to consider the time they own the car to be 5 years.

Comment: Consumer Federation of America, 2008-0089-0183, Pg. 53-59 state that a simple payback is one of the weaker economic concepts for evaluating investment. It is not clear that one must assume a payback for any component of a vehicle purchase, but if one does, the logical connection is between the period of ownership and the payback, not the loan period.

Most alternative investment opportunities available to consumers do not yield a 5 year payback period. Hybrids, many of which have payback periods of ten year or more, are flying off auto dealer lots. There is a logical inconsistency in saying that consumer decisions to buy vehicles reflects undiscounted treatment of fuel savings, but auto industry sales reflect discounted fuel savings.

Agency response: We don't have an inconsistency in our analysis, the consumer decision is in the same section where we estimate the impact on auto industry sales. When we do our MC=MB analysis it is from a societal perspective and full lifetime benefits are calculated.

Comment: Union of Concerned Scientists (UCS), 2008-0089-201.1 states that NHTSA should modify its resale value estimate. UCS asserts that the agency's cost-benefit analysis ignores the fact that fuel efficient vehicles have higher resale values than inefficient vehicles. UCS asserts that NHTSA's assumed 5-year resale evaluation timeline is unfounded. Also, citing a CBO study, commenter asserts that the assumption of a fixed resale value rate ignores the fact that fuel efficient vehicles are valued more highly on the used vehicle market

Agency response: Assuming that more fuel efficient vehicles have a higher resale value would be inconsistent with our assumption that consumers only think 5 years into the future for a payback period. Essentially we would be assuming that if a vehicle is sold in 5 years, consumers think about the fuel that would be saved in years 6 to 10, and how the next purchasers would value that and how that would affect the resale value. But if consumers keep their vehicle, and don't sell it, they don't think about the fuel savings in years 6 to 10.

Comment: National Automobile Dealers Association (NADA), 2008-0089-223.1, Pg. 7

The proposal reasonably assumes that buyers value any fuel savings associated with the purchase of a new motor vehicle over a five-year period, rather than over a vehicle's full useful life. Even at high fuel prices, consumers who view fuel economy as an important purchase criteria are hard pressed to make the case for buying a more fuel efficient new vehicle if the up-front capital costs associated with doing so cannot be recouped in short order. Thus, NHTSA should assume that most prospective purchasers will not invest in fuel economy improvements that do not exhibit a payback of five years or sooner. Of course, for purposes of calculating payback, real-world purchaser finance costs, opportunity costs, and additional maintenance costs all should be accounted for.

Agency response: NADA essentially agrees with out methodology.

Price of Gasoline

Projected future fuel prices are a critical input into the regulatory impact analysis of alternative CAFE standards, because they determine the value of fuel savings both to new vehicle buyers and to society. In the PRIA we relied on the most recent fuel price projections from the U.S. Energy Information Administration's (EIA) *Annual Energy Outlook* (AEO) in analyzing the proposed standards. Specifically, the agency used the AEO 2008 Early Release forecasts of the Reference Case inflation-adjusted (constant-dollar) retail gasoline and diesel fuel prices, which NHTSA stated represent the most up-to-date estimate of the most likely course of future prices for petroleum products.[34] In Jun 2008, EIA released the full AEO 2008 with an updated

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[34] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2008*, *Early Release*, Reference Case Table 12. *Available at* http://www.eia.doe.gov/oiaf/aeo/pdf/aeotab_12.pdf (last accessed August 29, 2008). EIA released the full AEO 2008 in June 2008, which NHTSA stated in the NPRM it would use in the final rule. EIA explained upon releasing the full AEO 2008 that it had been updated from the Early Release to reflect

Reference Case, a Low Case, and a High Case. Federal government agencies generally use EIA's projections in their assessments of future energy-related policies. We received a large number of comments indicating that we should rely on the High Case for the final rule. There were a few comments favoring the reference case or other prices of gasoline. A summary of their comments are:

Comment: Sierra Research, 2008-0089-0046, Pg. 77,

Do sensitivity analysis on fuel price using $2.50, $3.00, and $3.50

Comment: Consumer Federation of America, 2008-0089-0183 -pp. 45-46, 49-51

NHTSA's price is not consistent with the real world. EIA's high price seems much more appropriate. EIA's projections have been consistently low. They have been off by 35% but their projection for 2015 does not reflect this adjustment.

Comment: Environment America, National Wildlife Federation, National Resources Defense Council, Pew Environment Group, Sierra Club, Union of Concerned Scientists, 2008-089-0119

NHTSA should use a higher price of gas

Comment: Members of Congress (21), 2008-0089-0145.1

NHTSA used EIA's forecast of fuel prices that range from $2.42 per gallon in 2016 to $2.51 in 2030. When compared to the prices at the pumps, these numbers are nothing short of absurd. For modeling purposes, NHTSA uses EIA's higher gasoline price scenario, which ranges from $3.14 in 2016 to $3.74 in 2030 demonstrates that technology is available to cost-effectively achieve 35 mpg by 2015. On June 11, 2008, Guy Caruso testified before the House Select Committee on Energy Independence and Global Warming that NHTSA should use EIA's higher gasoline price scenario in setting fuel economy standards. They urge us to promulgate final fuel economy standards based on the EIA's high gasoline price scenario (which they understand will soon be revised) to comply with the EISA directive that maximum feasible standards be required.

Comment: Air Resources Board, 2008-0089-0173, Pg 2.

Want NHTSA to use a higher price of fuel, at least the EIA high price case scenario.

NHTSA dramatically underestimated the future price of fuel. They provide several sources indicating higher fuel prices. EIA's recent propensity to hurriedly revise its estimates upward, and EIA's own recent forecast puts fuel at $3.92/gallon in 2009, resulting in a significant divergence from their short term and long term forecast.

Comment: Air Resource Board, 2008-0089-0173.6, Pg. 8

EIA's expectations of the effect of EISA, which was enacted after the Early Release was made public. The full AEO 2008 is a*vailable at* http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf (last accessed August 29, 2008).

Absent supply disruptions, it will be difficult to sustain oil prices above $100/barrel (2008 dollars) over the next 10 years. This is based on an analysis by the Federal Reserve Bank of Dallas that examined the impacts of expected future demand, geopolitical factors, exchange rate movements, the ability of suppliers to meet demand, and non-conventional oil sources.

Comment: The City of Key West, 2008-0089-0182

Urges NHTSA to use $3.40 per gallon in setting standards.

Comment: Public Citizen, 2008-0089-0187

NHTSA's sensitivity analysis shows that the level of fuel economy standards is highly sensitive to the price of gasoline. The agency's estimate for the high price scenario would set the car standard at 37.4 mpg in 2011, almost 20 percent higher than the agency's "optimized" scenario.

Comment: Attorney General of the States, 2008-0089-0199.1, Pg. 11

NHTSA acknowledges that a significant factor in the agency's analysis of maximum fuel economy is the price of gasoline. 73 Fed. Reg. at 24,476-1; *see also* PRIA at IX-1 2 (table IX- 5a). As such, it is important that future gasoline price estimates be the best available estimates. NHTSA used gasoline prices of between $2.25 and $2.51 per gallon, depending on the future year. PRIA at VIII-20 (table VIII-3). This is startling, given that in June 2008 the national average price for gasoline reached $4.13 per gallon. *See* Energy Information Administration, Weekly Retail Gasoline and Diesel Prices (downloaded June 25, 2008 and enclosed). Unless NHTSA can provide publicly-available, mainstream documentation supporting an almost fifty percent drop from current prices, it must substantially re-calibrate those estimates.

Comment: Union of Concerned Scientists, 2008-0089-0201.13, Pg. 24-25

NHTSA's value for price of gasoline is too low. A more plausible, yet still conservative, estimate would be to average the past few year's prices. The EIA estimates are too low given current oil prices, the increased global demand for energy from countries such as China and India, and the increased use of market mechanisms (such as emissions trading) to limit carbon emissions.

Comment: Northeast States for Coordinated Air Use Management (NESCAUM), 2008-0089-204.1, Pg. 2, Currently, the average price of a gallon of gasoline exceeds $4.00 and the principal reason given is high global demand in a supply constricted market. There is little expectation that the gap between supply and demand will be narrowed in the foreseeable future. Therefore, assuming this reasoning is correct, the price of gasoline should remain high; certainly well above the mid-$2.00 range. We urge NHTSA to reevaluate the effect of a wider range of gasoline prices to the $4.00 per gallon level and above. We would expect the results to show that there are more fuel savings technologies capable of cost-effectively achieving greater overall average fuel economy, even according to NHTSA's conservative "net societal benefit" cost-analysis approach.

Comment: American Council for an Energy-Efficient Economy (ACEEE), 2008-0089-211.1

Work with EIA to produce an up-to-date fuel price projection for purposes of the final rule or, failing that, use the High Price projection from AEO 2008. EIA Administrator's comments before the House Select Committee on Energy Independence and Global Warming

"EIA's High Price forecast [does not] necessarily capture fully current understanding of how high fuel prices are likely to be in the coming decades."

Comment: State of Wisconsin Department of Natural Resources, 2008-0089-219.1

NHTSA should use the high price fuel scenario from DOE.

Comment: Center for Biological Diversity, 2008-0089-0222.1, Pg. 9-10

NHTSA's price is too low and impossible to justify. NHTSA needs to run the model with today's average gas price of $4.09/gallon. There is no indication that oil prices will subside in the long term. NHTSA needs to use reality-based inputs. Today's gas price must be the starting point for the analysis.

Comment: National Automobile Dealers Association, 2008-0089-223.1, Pg. 7

Fuel Prices Projected future fuel prices are critical to determining the value of fuel savings and the cost beneficial fuel economy standards for passenger cars and light trucks. To this end, NHTSA should continue to rely on the most recent reference case fuel price projections of the U.S. Energy Information Administration's (EIA). As demonstrated by the many years where EIA's projections fell above or below reality, forecasting future fuel prices is by no means an exact science. Despite the inherent volatility or uncertainty of fuel prices, EIA and NHTSA would be remiss if they were to arbitrarily abandon the best models and data available or to use "high" or "low" price case projections that are inherently not probabilistic. For example, the use of a high price case to justify unduly costly CAFE standards could lead to decreased new motor vehicle sales and a commensurate lower than projected rate of fuel energy savings and greenhouse gas reduction benefits.

Comment: Natural Resources Defense Council, 2008-0089 225.1, Pg. 2 – pp 2 following

NHTSA should use the higher fuel price estimate. NHTSA relies on the Energy Information Administration's Reference Case forecast for fuel prices. However, both the Reference and High Case forecasts have consistently underestimated fuel prices and NHTSA must choose a reasonable forecast consistent with likely price trajectories.

Comment: Sierra Club, 2008-0089-0226.1, Pg. 2, 4-5

NHTSA's price is too low. At a minimum NHTSA should use the high EIA forecast. NHTSA should examine other fuel price estimates, such as the oil futures market price predictions.

NHTSA's prices are not consistent with today's gas prices, futures market projections or the assessment of the EIA Administrator that higher prices are more appropriate to setting the standards. EIA has vastly underestimated the price in recent years. Secretary Peters commented on the oil price problem. The oil futures market price predictions run consistently above $130 per barrel.

Comment: U.S. Senate, 2008-0089-0454, Pg. 1, 4

NHTSA's gas prices are far below what consumers are paying today, and we do not believe it's reasonable to assume that the price of gas will drop precipitously, as NHTSA has done. Guy Caruso told Congress that NHTSA should use the EIA high price. NHTSA's treatment of gas prices would put the rule at substantial litigation risk.

Agency response:
NHTSA has carefully considered available evidence, recent trends in petroleum and fuel prices, and the comments it received on the NPRM analysis. After doing so, NHTSA has decided to use EIA's High Price Case forecast in its final rule analysis and to determine the MY 2011 CAFE standards. As NHTSA recognized in the NPRM, commenters are correct that projected future fuel prices have the largest effect of all the economic assumptions that NHTSA employs in determining benefits both to new vehicle buyers and to society, and thus on CAFE stringency. This is why it is vital that NHTSA base its fuel price assumptions on what it believes to be the most accurate forecast available that covers the expected lifetimes of MY 2011 passenger cars and light trucks, which can extend up to 25-35 years from the date they are produced. The long time horizon of NHTSA's analysis also makes it critical that the agency not rely excessively on current price levels as an indicator of the prices that are likely to prevail over an extended future period. Instead, NHTSA relies largely on EIA's professional expertise and extensive experience in developing forecasts of future trends in energy prices, as do most other federal agencies.

In addition, NHTSA notes that several manufacturers employed fuel prices consistent with or exceeding the AEO 2008 High Price Case for the time period covered by the rulemaking in their revised product plan estimates of fuel economy and sales for individual models. If the agency employs fuel price forecasts that differ from those used by manufacturers, it may incorrectly attribute the fuel savings resulting from increased market demand for fuel economy to higher CAFE standards, or conversely, underestimate the fuel savings resulting from increased standards by attributing too much of the increase in fuel economy to higher market demand. Given manufacturers' assumptions about fuel prices, the agency's estimates of fuel savings and economic benefits resulting from the standards adopted in this final rule are conservative, because they are likely to underestimate fuel savings attributable to the increase in fuel economy above its market-determined level that CAFE standards will require.

Although some commenters suggested that NHTSA develop its own fuel price forecasts based on then-current pump prices, NHTSA does not believe that it has the independent capability to provide a more reliable prediction of future fuel prices, or that it would have the credibility of EIA's forecasts. If NHTSA had assumed that that fuel prices would remain at their mid-2008 peak levels throughout the lifetimes of MY 2011 cars and light trucks, the agency would have overvalued the benefits attributed to fuel savings, and thus likely have established excessively stringent standards. While petroleum prices were rising at the time the NPRM was published, eventually reaching nearly $140 per barrel, since then global average prices for crude oil have declined to levels as low as $35 per barrel.[35] The recent extreme volatility in petroleum and fuel prices illustrates the danger in relying on current prices as an indicator of their likely future levels, and gives NHTSA greater confidence in relying on EIA's forecasts of future movements in fuel prices in response to changes in demand and supply conditions in the marketplace. While NHTSA also agrees with the commenters that the sensitivity analysis demonstrates that higher CAFE standards could be established if higher fuel price assumptions were employed, the agency cannot simply choose to employ higher fuel price assumptions because it wishes to raise CAFE levels. Doing so would be inconsistent with the agency's approach of using what it concludes is the most reliable estimate of the benefits from conserving fuel when establishing fuel economy standards. NHTSA recognizes that predicting future oil prices is difficult, particularly during periods when world economic conditions are as volatile as they are today. Nevertheless, NHTSA continues to believe that EIA's fuel price forecasts as reported in its AEO represent the most reliable estimates of future fuel prices, and thus of the benefits from reducing fuel consumption through higher CAFE standards. While NHTSA recognizes that other forecasts exist, the agency believes the EIA forecasts are preferable for its purposes, since they are the product of an impartial government agency with considerable and long-standing expertise in this field. Any simple extrapolation of current or recent retail fuel prices, which commenters recognize have shown extreme volatility in recent months, is likely to provide a considerably less reliable forecast of future prices than the current AEO. Each time EIA issues a new AEO, it considers recent and likely future developments in the world oil market, the effect of the current geopolitical situation on oil supply and prices, and conditions in the domestic fuel supply industry that affect pump prices.[36]

For example, the Overview section to AEO 2008 states that because EISA was passed between the Early Release and the time of publication for AEO 2008, EIA updated the Reference Case to reflect the impact it expected EISA to have on fuel prices. EIA also updated its projections for the AEO 2008 Reference Case "to better reflect trends that are expected to persist in the economy and in energy markets," including a lower projection for U.S. economic growth (a key determinant of U.S. energy demand), higher price projections for crude oil and refined petroleum products, slower projected growth in energy demand, higher forecasts of domestic oil production (particularly in the near term), and slower projected growth in U.S. oil imports.[37] Thus NHTSA is confident that EIA is aware of and has accounted reasonably for current political and economic conditions that are likely to affect future trends in fuel supply, demand, and retail prices.

Although a majority of commenters asserted that EIA's Reference Case forecast is likely to underestimate future fuel prices significantly, and that NHTSA's reliance on the Reference Case resulted in insufficiently stringent proposed CAFE standards, they did so in an environment

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[35] Energy Information Administration, World Crude Oil Prices, data for week ended 1/2/2009, available at http://tonto.eia.doe.gov/dnav/pet/pet_pri_wco_k_w.htm (last accessed February 12, 2009).

[36] AEO 2008 states as follows with regard to factors which EIA accounts for in developing the Reference Case:

> As noted in AEO2007, energy markets are changing in response to readily observable factors, which include, among others: higher energy prices; the growing influence of developing countries on worldwide energy requirements; recently enacted legislation and regulations in the United States; changing public perceptions on issues related to emissions of air pollutants and greenhouse gases and the use of alternative fuels and; and the economic viability of various energy technologies.

[37] AEO 2008 Overview, *at* http://www.eia.doe.gov/oiaf/aeo/overview.html (last accessed October 10, 2008).

when retail fuel prices were at or above $4.00 per gallon. Many commenters stated that at a minimum, NHTSA should use EIA's High Price Case as the source for its fuel price forecasts, primarily because those appeared to be more consistent with then-current fuel prices. As one illustration, NRDC cited EIA's own International Energy Outlook 2008, published the same month as the AEO 2008, which stated that given "…current market conditions, it appears that world oil prices are on a path that more closely resembles the projection in the high price case than in the reference case."[38] Commenters also cited EIA Administrator Caruso's June 2008 statement that "We're on the higher price path right now. If you were to ask me today what I would use, I would use the higher price." NHTSA also notes that several manufacturers in their confidential product plan submissions indicated that they had based their product plans on gas price estimates that were either between EIA's Reference and High Price Cases, or above even the High Price Case.

The AEO High Price Case is best understood in the context of its relationship to the Reference Case. EIA described the Reference Case as follows in AEO 2008:

> The reference case represents EIA's current judgment regarding exploration and development costs and accessibility of oil resources in non-OPEC countries. It also assumes that OPEC producers will choose to maintain their share of the market and will schedule investments in incremental production capacity so that OPEC's conventional oil production will represent about 40 percent of the world's total liquids production.[39]

In contrast, EIA describes its Low Price case in the following terms:

> The low price case assumes that OPEC countries will increase their conventional oil production to obtain approximately a 44-percent share of total world liquids production, and that conventional oil resources in non-OPEC countries will be more accessible and/or less costly to produce (as a result of technology advances, more attractive fiscal regimes, or both) than in the reference case. With these assumptions, non-OPEC conventional oil production is higher in the low price case than in the reference case.[40]

Finally, EIA describes its High Price case as follows:

> The high price case assumes that OPEC countries will continue to hold their production at approximately the current rate, sacrificing market share as global liquids production increases. It also assumes that oil resources in non-OPEC countries will be less accessible and/or more costly to produce than assumed in the reference case.[41]

As these descriptions emphasize, EIA's Low and High Price Cases are based on specific assumptions about the possible behavior of oil-producing countries and future developments affecting global demand for petroleum energy, and how these might differ from the behavior

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[38] Energy Information Administration (2008) International Energy Outlook 2008: Complete Highlights. June 25.
[39] AEO 2008, at 199. *Available at* http://www.eia.doe.gov/oiaf/aeo/pdf/0383(2008).pdf (last accessed October 10, 2008).
[40] *Id.*
[41] *Id.*

assumed in constructing its Reference Case. However, this distinction does not necessarily imply that EIA expects either its Low Price or High Price Case forecast to be more accurate than its Reference Case forecast, since EIA offers no assessment of which set of assumptions underlying its Low Price, Reference, and High Price cases it believes is most reliable.

EIA did recognize that world oil prices at the time the final version of AEO 2008 were above even those forecast in its High Price Case. However, it attributed this situation to short-term developments, most or all of which were likely to prove transitory, as evidenced by its statement in the Overview to AEO 2008:

> As a result of recent strong economic growth worldwide, transitory shortages of experienced personnel, equipment, and construction materials in the oil industry, and political instability in some major producing regions, oil prices currently are above EIA's estimate of the long-run equilibrium price.[42]

This observation is consistent with EIA's statement in IEO 2008 that current market conditions appeared to place world oil prices on a path closer to the High Price Case than the Reference Case. While EIA clearly expects prices to remain high in the near term, this does not necessarily imply that it expects its High Price Case forecast to be more reliable over the extended time horizon spanned by AEO 2008.

NHTSA has seriously considered the comments it received on the fuel price forecasts used in the NPRM analysis, and paid close attention to recent developments in the world oil market and in U.S. retail fuel prices. The agency has also reviewed forecasts of world oil prices and U.S. fuel prices available from sources other than EIA, as well as the views expressed by petroleum market experts, professional publications, and press reports.[43] The agency notes that although both the views of experts and projections of petroleum prices differ widely, the emerging consensus appears to be that world petroleum and U.S. retail fuel prices are likely to remain at levels that are more consistent with those forecast in the AEO 2008 High Price Case than with the Reference Case forecasts over the foreseeable future.[44]

Over the period from 2011, when the standards adopted in this final rule would take effect, and 2030, the outer time horizon of the AEO 2008 forecasts, retail gasoline prices in the

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[42] *Id*., at 5.

[43] These include EIA, Short-Term Energy Outlook, various issues, *available at* http://www.eia.doe.gov/emeu/steo/pub/contents.html (last accessed November 13, 2008); International Energy Agency, *World Energy Outlook 2008*, summary *available at* http://www.iea.org/Textbase/npsum/WEO2008SUM.pdf (last accessed November 13, 2008); AJM Petroleum Consultants, The AJM Price Forecast, *available at* http://www.ajmpetroleumconsultants.com/index.php?page=price-forecast (last accessed Novemebr 13, 2008); PetroStrategies, Inc, Survey of Oil Price Forecasts, *available at* http://www.petrostrategies.org/Graphs/Oil_Price_Forecasts.htm (last accessed November 13, 2008); International Monetary Fund, World Economic Outlook, October 2008, Chapter 3: Is Inflation Back? Commodity Prices and Inflation, *available at* http://www.imf.org/external/pubs/ft/weo/2008/02/pdf/c3.pdf (last accessed November 13, 2008); and Federal Reserve Bank of Dallas Economic Letter, Volume 3, No. 5, May 2008, *available at* http://www.dallasfed.org/research/eclett/2008/el0805.html (last accessed November 13, 2008).

[44] In the AEO High Price Case, prices for imported petroleum are projected to average about $75 per barrel over the next 10 years, while U.S. retail gasoline prices are forecast to average $2.90 per gallon over that same period; see AEO 2008, High Price Case Table 12, available at http://www.eia.doe.gov/oiaf/aeo/excel/aeohptab_12.xls (last accessed October 19, 2008).

AEO 2008 High Price case are projected to rise steadily from $2.95 to $3.62 per gallon, averaging $3.28 per gallon (all prices expressed in 2007 dollars). For the years 2031 and beyond, the agency's analysis assumes that retail fuel prices will remain at their forecast values for the year 2030, or $3.62 per gallon. These prices are significantly higher than the AEO 2008 Revised Early Release Reference Case forecast used in the agency's NPRM analysis, which averaged $2.34 per gallon (in 2006 dollars) over that same period.[45] After deducting state and federal fuel taxes, this revised forecast results in an average value of $3.08 per gallon of fuel saved over the lifetimes of 2011 passenger cars and light trucks. Because of the uncertainty surrounding future gasoline prices, the agency also conducted sensitivity analyses using EIA's Reference and Low Price case forecasts of retail fuel prices.

NHTSA is aware that EIA recently released a preliminary version of its Annual Energy Outlook 2009, which appears to confirm then-EIA Administrator Caruso's testimony before the House Select Committee in June 2008 that the future path of gasoline prices likely more closely resembles the AEO 2008 High Price Case than the 2008 Reference Case. However, the agency has elected not to use this newly-available forecast of fuel prices, in part because it did not have adequate time to replicate the entire analysis reported in this rule using revised forecasts of fuel prices.[46] Moreover, the forecast of gasoline prices from AEO 2009 Early Release averages $3.45 over the period from 2009-30, only slightly higher than the comparable figure for the AEO 2008 High Price forecast the agency relied upon in preparing this analysis. Thus incorporating EIA's newest forecast would be unlikely to have an effect on the fuel economy standards adopted in this rule.

In its future CAFE rulemaking activities, the agency will continue to rely on EIA's Annual Energy Outlook as its primary source for fuel price forecasts. As indicated previously, NHTSA continues to believe that the forecasts reported in EIA's Annual Energy Outlook represent the most suitable estimates of future fuel prices for the purpose of assessing the economic benefits from reducing fuel consumption through higher CAFE standards. Under normal conditions, the agency is likely to view EIA's Reference Case forecast as the most reliable basis for estimating benefits from reducing future fuel consumption, although the agency will retain the option of drawing its forecasts from other scenarios presented in AEO if, as here, it deems that circumstances warrant. The agency will also continue to monitor fuel price forecasts available form other forecasts, and to consider their implications for its choice among alternative price scenarios developed by EIA.

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[45] The fuel price forecasts reported in EIA's AEO 2008 Revised Early Release and Final Release reflect the estimates effects of various provisions of EISA – including the requirement to achieve a combined CAFE level of 35 mpg by model year 2020 – on the demand for and supply of gasoline and other transportation fuels. Thus the fuel price forecasts reported in these versions of AEO 2008 may already account for the reduction in fuel demand expected to result form the CAFE standards adopted in this Final Rule, whereas the agency's analysis of their effects would ideally use fuel price forecasts that do not assume the adoption of higher CAFE standards for model years 2011-20. However, the agency notes that the difference between the Reference Case forecasts of retail gasoline prices for 2011-30 between EIA's Early Release of AEO 2008, which did not incorporate the effects of EISA, and its subsequent Revised Early Release, which did reflect EISA, averaged only $0.0004 (*i.e.*, less than one-half cent) per gallon over the period 2011-30, This suggests that accounting for the effect of EISA would have had only a minimal effect on the fuel price forecasts used in this analysis.

[46] U.S. Energy Information Administration, Annual Energy Outlook 2009 Early Release, available at http://www.eia.doe.gov/oiaf/aeo/index.html (last accessed February 12, 2009).

Product restrictions

Comment: Recreation Vehicle Industry Association (RVIA), 2008-0090 229, Pg. 3-5 wants a 3.2% adjustment in the curve for "heavy tow capable" vehicles if its Trailer Weight Rating is equal to or greater than 7,700 lbs. per the SAE J2897 recommended practice. 75% of RVIA product in any year are towable products, travel trailers, pop-up campers, truck campers, or fifth-wheel trailers. In order to safety tow and stop these vehicles they need a truck that is properly equipped. An aggressive CAFE standard will force manufacturers to scale back vehicle power or make weight based changes to SUVs and light trucks. If there is a serious sales impact, there is a serious possibility that towable RV industry sales will be impacted. Given that towable RV shipments were 261,000 units and thousands of American workers produce those units, NHTSA cannot overlook the impact of its proposal no RV industry jobs and sales.

Trailers owners will have four choices, retail older tow vehicles, use light weight under powered vehicles, purchase larger trucks (over 8,500 lbs. GVWR), or abandon their vehicles.

Agency response: The agency's methodology for setting the standards gives appropriate weight to and already accounts for towing needs.

Rebound Effect

Comment: Mark A. Delucchi, 2008-0089-0025 Pg. 1. Without giving a specific figure this commenter stated that the rebound effect coefficient should be lower than the value used by NHTSA because more weight should be given to the Small and Van Dender study. He also noted that Hughes et al. recently found a very low short-run price elasticity of demand for gasoline [The Energy Journal, 29(1), January 2008].[47]

Comment: Sierra Research, 2008-0089-0046-1, Pg. 74. Based on a 1999 paper by Greene of Oak Ridge National Laboratory[48], the rebound effect is 20%, they use a "conservative" 17%. As Greene explains, it is well documented that increased fuel economy produces a long term rebound effect of 20%. In other words, a 100% improvement in fuel economy induces a 20% increase in vehicle travel.

Comment: Air Resources Board, 2008-0089-0173-1, Pg. 10. The California Air Resources Board states that NHTSA "declines to adopt two critical findings from previous analysis: 1) the future decline in value of rebound effect as household real income increases, and 2) as fuel prices

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[47] 2008 Volume 29 Number 1 Evidence of a Shift in the Short-Run Price Elasticity of Gasoline Demand Jonathan E. Hughes*, Christopher R. Knittel** and Daniel Sperling***
Understanding the sensitivity of gasoline demand to changes in prices and income has important implications for policies related to climate change, optimal taxation and national security. The short-run price and income elasticities of gasoline demand in the United States during the 1970s and 1980s have been studied extensively. However, transportation analysts have hypothesized that behavioral and structural factors over the past several decades have changed the responsiveness of U.S. consumers to changes in gasoline prices. We compare the price and income elasticities of gasoline demand in two periods of similarly high prices from 1975 to 1980 and 2001 to 2006. The short-run price elasticities differ considerably: and range from -0.034 to -0.077 during 2001 to 2006, versus -0.21 to -0.34 for 1975 to 1980. The estimated short-run income elasticities range from 0.21 to 0.75 and when estimated with the same models are not significantly different between the two periods.

[48] David L. Greene, et al, "Fuel Economy Rebound Effect for U.S. Household Vehicles", The Energy Journal, Vol. 20, No. 3, 1999.

increase, people are forced to spend a larger share of their income on fuel, thus becoming more sensitive to fuel prices. The Air Resources Board recommends a rebound effect in the range of a maximum of 10 per cent.

Comment: Air Resources Board, 2008-0089-0173.15. In an additional comment by the Air Resources Board, testimony by Small is cited to show a marked decline in rebound effect for California to 1% for a single year vs. 4.9% in the years 1975-2001. A number of variables and additional effects to rebound were modeled and given in Small's testimony. While no clear recommendation is given for a change in NHTSA's value for rebound effect, the clear implication is that the value should probably be lower.

Comment: Alliance, 2008-0089-0179.1, P9, Att3 S-8. In this attachment to other comments by the Alliance a supporting study by NERA is summarized. NERA cites four economic effects which increase external costs and one effect which reduces external costs as being directly impacted by a higher rebound effect. The primary discussion is on net benefits with respect to the Volpe model; and NERA provides data which increases overall costs due to an assumption of a higher rebound effect of 20%.

Comment: Public Citizen, 2008-0089-0187, Pg. 4. This commenter states that NHTSA has "assumed a very high rebound effect – 15 percent." Furthermore, it is stated that NHTSA looked at 29 estimates and attempts to reflect the current conditions; however according to the Small and Van Dender study, "most empirical measurements of the rebound effect rely heavily on variations in the fuel price," which raises again the question of whether NHTSA's assumptions about the rebound effect are colored by the estimates of future fuel price.

Comment: Union of Concerned Scientists 2008-0089-0201.7, Pg. 1 etc. and Union of Concerned Scientists, 2008-0089-0201.11. These comments focus on a paper authored by Kenneth Small and Kurt Van Dender, prepared for the State of California Air Resources Board, the California Environment Protection Agency, and the California Energy Commission. The article attempts to estimate the magnitude of rebound effect in the short-run and long-run rebound effect using cross-sectional time series U.S. data from 1966-2001. For the U.S. as a whole authors estimate a rebound effect of 5.3 % in the short run, and 26% for the long run, with the latter estimate very similar to the consensus from the authors' literature review. The authors also conclude that the rebound effect declines with increases in income. The estimates of the rebound effect during future years presented in this study are specific to California, in that they reflect California household incomes, fuel prices, and fuel economy, and in any case have been superseded by several updates to the original study published by Small and Van Dender, CARB, and EPA.

Comment: Environmental Defense Fund, 2008-0089-0224.1, Pg. 3. NHTSA selected the rebound effect of 15 per cent based on the review of studies conducted from 1983 through 2005. However, a recent literature review suggests that many previous studies overestimated the rebound effect because of problems with model specification. Also, latest research work suggests that the rebound effect decreases over time with rising income.

Agency response: The rebound effect is generally considered to be that effect where an improvement in fuel economy induces a percentage increase in demand for vehicle travel. Considering the empirical evidence on the rebound effect as a whole, but according greater importance to the updated estimates from studies allowing the rebound effect to vary – particularly the Small and Van Dender study – NHTSA originally proposed a final rebound value of 15 percent to evaluate the fuel savings and other effects of alternative standards for the time period covered by this rulemaking.

Of the 7 organizations commenting on the subject of rebound effect, 2 recommended a higher value and 5 recommended a lower value than the 15 per cent used by NHTSA. NHTSA had previously evaluated 22 studies containing 66 estimates covering the period 1983 to 2005 to determine the basis for selecting a single value for rebound effect. NHTSA tentatively attached greater significance to studies that allow the rebound effect to vary in response to changes in the various factors that have been found to affect its magnitude. Recently, a review of this by NHTSA with other agencies and consultants has determined that in light of previous studies and the fact that net benefits will be determined on the basis of rebound effect, the value of 15 per cent will be used for the final rule. (See Chapter VIII for more discussion about the rebound effect.)

Regulatory Flexibility Analysis

Comment: National Automobile Dealers Association, 2008-0089-223.1, Pg. 9 stated that a full regulatory flexibility analysis must be undertaken. Many of the nation's dealerships are directly impacted by the proposal and are small businesses as defined by the SBA. Moreover, the overwhelming majority of these dealerships have 200 employees or less, that standard established by DOT in a recently published rule that examined that issue (72 Federal Register 15614-7 (April 2, 2007). Therefore, a full regulatory flexibility analysis must be undertaken to examine what modifications may be necessary to lessen the regulation's potential impact on motor vehicle dealerships.

Agency response: Dealers are not directly impacted by the CAFE rules, they are indirectly impacted. Dealers are not a regulated entity under CAFE.

Retail Price Equivalent Multiplier

Typically cost estimates for technologies, for example when the agency has a cost tear down study for a safety countermeasure, are provided on a variable cost basis. NHTSA applied an indirect cost multiplier in the NPRM of 1.5 to the estimate of the vehicle manufacturers' direct costs for producing or acquiring each fuel economy-improving/CO_2 emission-reducing technology. Historically for safety and fuel economy purposes, NHTSA used an almost identical multiplier, 1.51, for the markup from variable costs or direct manufacturing costs to consumer costs. The markup takes into account fixed costs, burden, manufacturer's profit, and dealers' profit. NHTSA's methodology for determining this markup was peer-reviewed. This value is based on an examination of auto industry financial reports[49].

Comment: The Alliance 2008-0089-0169.1 cited the Martec Cost study and stated that the agency should use a 2.0 Retail Price Equivalent (RPE) markup factor. In order for a company to

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[49] Spinney, Bruce C., CPA, NHTSA "Advanced Air Bag System Cost Weight and Leadtime Analysis Summary Report" Docket No. 2007-27453-10.

remain financially viable, that Retail Price Equivalent (RPE) markup factor must be at least 2.0. This estimate of RPE was documented by Dr. Winn V. Bussmann in a submission that provided a correction to the earlier Jack Faucett study. In addition as part of that submission, Dr. Bussmann also showed with more recent financial data that an estimate of 2.0 for RPE is still valid. Commodity prices for many of the materials necessary for these technologies have increased dramatically in the last two years and are at record highs. These prices are significant factors in determining manufacturing variable costs.

The Alliance 2008-0089-0179.1, P6, P17, Attachment 2 P1,

The Alliance believes the retail price equivalent markup should be 2.0, not 1.5, based on

Wynn V. Bussman, "Study of Industry-Average Mark-up Factors to Estimate Retail Price Equivalents", Jan. 24, 2008, and Attachment 4. Also, Argonne National Laboratory report recommended 2.0. NHTSA misused the Argonne report by citing 1.5 RPE for outsourced components. See Sierra Report Attachment at 61.

Agency Response: The agency disagrees with a 2.0 RPE. Commodity prices do not affect the RPE. NHTSA has its own report on mark-up factors justifying 1.51 that we rely upon. This report implicitly includes historical levels of outsourced components.

Comment: Alliance, 2008-0089-0195.1, Attachment 4, P1-3

The Jack Faucett Associates (JFA), used by a draft EPA staff report in 2005 (EPA420-R-05-012) analysis that estimates a markup factor of 1.26 does not accurately account for full costs. The work done by Sierra Research indicates a mark-up factor of at least 2.0 would be necessary. JFA failed to recognize that research and development and other indirect costs were combined with direct manufacturing costs. JFA also assumed that emission control equipment does not change dealer overhead expenses. The author of the study has agreed that the study underestimates the markup factor. Correcting the problems would result in a markup factor of at least 1.7.

The CARB justification for its markup of 1.4 is that it fell between the 1.26 factor and 1.5 suggested in a paper published by Argonne National Laboratory. CARB apparently misinterpreted Argonne's reference to a 1.5 markup factor, which would be appropriate for certain categories of components, such as batteries that are developed entirely by vendors. The same paper makes it clear that the markup for engines and transmissions primarily developed by OEMs would be 2.0 to 2.05.

The NRC and NESCCAF markup factors of 1.4, are contributed to a consultant Mr. Duleep, who has since testified that "1.4 might represent the low end of the scale of markups" and that markup factors as high as 2.0 would be appropriate for certain items.

Pg. 11, Dr. Bussmann estimates inbound and outbound transportation costs at 6% of direct manufacturing costs.

Agency response: NHTSA has used a RPE of 1.51 for years and agreed with EPA to use 1.5 for this rulemaking. The commenter does not analyze NHTSA's methodology.

Comment: The Air Resources Board, 2008-0089-0173, p 8, stated that

NHTSA's RPE methodology is unsound. The cost to incorporate a technology is the same regardless of vehicle production. NHTSA's approach implies an engineering cost of $35.2 million for a vehicle model with 50,000 unit production, but $352 million for a vehicle model with 500,000 production.

Agency response: The markup is for many other factors than just engineering costs. It includes all fixed costs, manufacturer profit and dealer profit.

Comment: Air Resources Board, 2008-0089-0173.4, P4

ARB objects to Sierra's RPE of 2.0, and suggests adjustment to 1.4. They argue that many components are sourced to suppliers. Since the manufacturer doesn't bear the burden of R&D and investment and some level of warranty, a 2.0 markup is not appropriate and should be adjusted to 1.4.

Agency response: NHTSA's 1.5 RPE includes the historical levels of outsourcing.

Comment: Northeast States for Coordinated Air Use Management (NESCAUM), 2008-0089-204.1, Page 4, All reported costs and benefits, attributed to NESCCAF by NHTSA, should be reviewed carefully for errors and amended accordingly, using a 1.4 RPE not 1.5. Information from a 2004 NESCCAF5 study entitled "Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles" is cited in the NHTSA proposal. Some of this information is reported in a way that is either confusing or incorrect. For example, NHTSA applies a 1.5 retail price equivalent (RPE) factor to the manufacturer costs presented in Appendix C of the NESCCAF report, and at other times uses a 1.4 RPE – and presents both costs as NESCCAF costs. In the report, NESCCAF only used a 1.4 RPE. The reporting of costs using the 1.5 multiplier as NESCCAF costs is incorrect and leads to uncertainty as to how the costs were developed. A specific case is the cost of a turbocharger. NHTSA states the NESCCAF turbocharger cost is $600. In this case, NHTSA applied a 1.5 RPE factor to manufacturer costs presented in Appendix C of the NESCCAF report to arrive at the $600 cost. This is different from the cost that NESCCAF developed. Conversely, on page 24369 of the Federal Register notice, NHTSA accurately states the NESCCAF cylinder deactivation costs ranged from $161 to $210. This cost accurately reflects manufacturer costs presented in Appendix C of the NESCCAF report, multiplied by the 1.4 retail price equivalent used by NESCCAF.

Agency response: NHTSA notes that the analysis for this final rule relies on entirely new cost estimates for fuel economy technologies developed by the agency in response to comments and in coordination with an international engineering consulting firm, Ricardo, Inc., based on a bill of materials approach and not based on the 2004 NESCCAF study, so the issue of apparent inconsistency in the RPE factor applied to those estimates noted by NESCAUM and CARB is no longer relevant. The agency also notes that both the production and application of fuel economy-improving technologies include separate engineering cost components. Developing these technologies and readying them for high-volume production entails significant initial investments in product design and engineering, while as the NPRM pointed out, applying individual technologies to specific vehicle models can entail significant additional costs for accompanying engineering changes to its existing drive train, development and testing of prototype versions, recalibrating engine operating parameters, and integrating the technology with other attributes of the vehicle. While design and engineering costs for developing fuel economy-improving technologies are included in the production cost estimates for individual technologies, additional engineering costs incurred by manufacturers in applying them to specific vehicle models are included in NHTSA's estimate of the RPE factor. Finally, the agency notes that its estimate of the RPE factor includes is consistent with high-volume production and application of fuel economy technologies, because it assumes that initial design and engineering costs to develop and begin production of these technologies will be recovered over large production volumes. Thus, NHTSA believes that CARB's concerns about potential double-counting of engineering costs for developing and applying fuel economy technologies reflect a failure to recognize that engineering costs arise in both their development and application. The agency also believes that CARB's concern about whether NHTSA's RPE factor assumes the spreading of initial design and engineering costs for developing these technologies over insufficiently high production volumes is unfounded.

In response to the concerns expressed by the Alliance and others that NHTSA's RPE factor is too low, the agency notes that the RPE factor of 2.0 reported in the Argonne and Sierra Research studies includes various categories of production overhead costs (for product development and engineering, depreciation and amortization of production facilities, and warranty) that are included in NHTSA's estimates of production costs for fuel economy technologies. When applied to technology production costs defined to include these components, the agency's RPE factor of 1.5 is thus consistent with full recovery of these cost components. This conclusion is independent of whether overhead costs for developing and producing fuel economy technologies are initially borne by equipment suppliers or by vehicle manufacturers themselves. Consequently, NHTSA has continued to employ an RPE factor of 1.5 in its analysis for this final rule.

Comment: National Automobile Dealers Association, 2008-0089-223.1, P **7**

When calculating fuel economy technology costs, NHTSA uses a 1.5 multiplier to account for related additional costs, including "dealer profit." NHTSA should review whether its estimates include *all* dealer costs-of–sales when calculating "dealer profit" and the extent to which it has properly accounted for the finance costs consumers typically pay when purchasing new automobiles. NADA would be happy to meet with NHTSA staff to discuss these issues further.

Agency response: The dealer markup does not include finance costs. Those are not a societal cost but a transfer payment from the purchaser to the lender.

Sales Impacts and Related Employment Impacts

In the NPRM the agency presented an analysis of how sales and employment might be affected by higher fuel economy standards. The standards are expected to increase the price of passenger cars and light trucks, while reducing fuel expenditures in the future. Because the proposed alternative is based on a marginal cost/marginal benefit analysis, sales were estimated to slightly increase under this scenario. In other words, consumers would believe they would save more in fuel economy expenditures in the future than the initial price increase of the vehicle.

Comment: The Alliance 2008-0089-0179.1, P5, P44 (gives table), Att3, S6-7, Att3 S5, 17, A-1-9 presents the results of an analysis by NERA which finds that NHTSA's proposed standards would reduce the sales of new vehicles by 856,000 and create associated job losses of 82,000. NERA finds that NHTSA's sales increase makes no economic sense. Where is the market failure? NERA has a new vehicle market model. If improving fuel economy would increase sales, why haven't manufacturers included these measures in their plans? NHTSA has either overestimated benefits or underestimated costs, or both.

Agency response: NHTSA consulted with a contractor to examine benefit and cost estimates. The commenter offers no advice on how to change the NHTSA analysis.

Comment: Ford, 2008-0089-0202.1, pp 5-6 believes that the combination of benefit overestimation, misunderstanding of our current technology deployment, and specific technology incompatibilities has led to an over-estimation of the potential fuel economy improvements on Ford's products. Ford believes there will be a loss of sales due to overestimation of technology application for benefits.

It is a common practice to use hedonic pricing technique ..[which] determines the price of a vehicle by the characteristics of the car such as towing, cargo volume, performance etc. We recommend that NHTSA modify its analysis to incorporate this technique into its analysis. NHTSA treated the difference between the technology costs (of increasing the fuel economy of each vehicle model) and value of fuel savings as the "effective price" to vehicle buyers. The "effective price" calculated was then assumed to represent consumer valuation of fuel economy. This is conceptually inaccurate. First, it was implicitly assumed that the technology costs incurred by the manufacturers can be fully passed on to buyers. In the competitive environment of the U.S. automotive market, this is not true. Second, using alternative gasoline price assumptions will change the estimates of "effective price". A higher gasoline price assumption will lower the effective price estimates, holding everything else constant. The Sierra Research Inc. (Sierra) analysis, dated June 26, 2008, estimates that a consumer would not breakeven over a 20 year period unless gas prices are sustained at $4.47 a gallon. Sierra also concluded that by using a more conservative payback period of 5 years the estimated breakeven gas price would have to be $6.59.

Agency response: The agency does not believe it needs a hedonic pricing technique. We are estimating the incremental costs and benefits to the same make/model by adding fuel economy technologies only. All other parts of the vehicle are not impacted and we hold the performance of the vehicle at an equivalent level. Inputs to the model (e.g. the price of technology, the price of gasoline, etc.) do change the results. So, when Sierra Research assumes higher prices and lower effectiveness for various technologies, it is easy to see how their results would be very different. Assuming that manufacturers cannot pass on price increases to consumers has important implications for the automobile manufacturers, but in this analysis it makes it a better deal for consumers and sales should increase.

Comment: The Consumer Federation of America, 2008-0089-0183-pp. 22, 43 states that NHTSA ignores that pushing the industry to produce more fuel efficient cars might improve employment opportunities by better aligning supply and demand. NHTSA has it backwards. It is more likely that the absence of significantly increasing fuel economy standards in the past half decade has led to significant sales losses, than vice versa.

Agency response: From an industry perspective, sales have been at an all-time high in recent years. Only in the last two years when the price of gasoline went up greatly would a better alignment of supply and demand for more fuel efficient vehicles have improved sales.

Comment: The United Auto Workers (UAW) 2008-0089-0226.3, pp 2, is concerned the NPRM could lead to more job loss and threaten health care coverage for retirees of the Detroit-based mfrs. The CAFÉ increase would impose enormous, separate retooling costs on these companies. In light of the serious economic difficulties already facing these firms, this could lead to even more job loss and potentially threaten health care coverage for over half a million retirees and their families.

Agency response: As discussed by the larger companies, the footprint attribute-based system is an advantage over the flat rate standards. If the American companies do not improve fuel economy and lose market share, the job losses may be even more.

Safety standards impact on vehicle weight, or fuel economy

All of the vehicle weight comments were confidential. See Chapter IV.

Size/safety Impacts

See Chapter IV

Uncertainty Analysis

Comment: Alliance, 2008-0089-0179.1, Pg. 40-41 stated that NHTSA should reevaluate its statistical model on uncertainty. Technology changes are more uncertain the farther the attempts to peer into the future, yet the uncertainty analysis shows 100 percent certainty that the changes will be cost beneficial for MY 2014 and 2015.

Agency response: Let us consider the effectiveness of a technology as an example. It is true that if you consider each individual technology, that the farther you peer into the future, the more uncertain the results. However, we are looking at a group of technologies, some of which could be more effective than we currently predict and some of which could be less effective than we currently predict. While this final rule is limited to one model year, theoretically, one could assume effectiveness is plus or minus ten percent in the first year, 15 percent in the second year, 20 percent in third year, etc. That would unnecessarily complicate the model since we believe that the combined range in the later years will be close to the combined range in the earlier years of the standard.

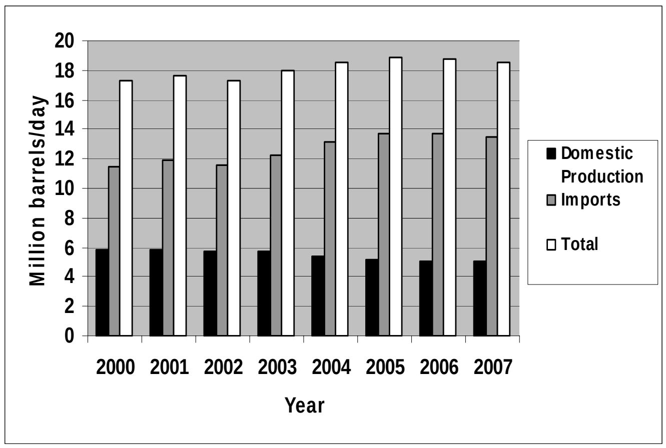
We could simply increase the range symmetrically by some arbitrary factor, but, assuming the same normal distribution that is employed for most of the variables in our uncertainty analysis, increasing the range of both costs and benefits proportionally would be unlikely to significantly impact the conclusions of the uncertainty analysis. Thus, the agency would not increase this range of uncertainty by progressively more for successive model years, were this a multi-year rulemaking. As it is not, the issue of changing levels of uncertainty over time is largely academic for purposes of this rulemaking.

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."[50]

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 and is now declining slowly averaging approximately 18.5 million barrels per day in 2007[51]. World demand, however, is expected to continue to rise until 2030[52].



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

- Crude oil prices are over $100 per barrel in August 2008 and in June 2008 reached at over $140 per barrel. As recently as 1998, crude prices averaged about $13 per barrel ($15.85 in 2006 dollars).[53] Gasoline prices have more than doubled during this ten year period.[54]
- U.S. domestic oil production peaked in 1970 at 9.7 million barrels per day. Between 1970 and 2006, U.S. domestic production declined by 47 percent, while U.S. petroleum consumption increased by 20 percent. Net petroleum imports now account for 73 percent of U.S. domestic petroleum consumption[55].
- Worldwide oil demand is fairly inelastic: declining prices do not induce large increases in consumption, while higher prices do not significantly restrain consumption. For

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[50] 49 USC 32902(f)

[51] Energy Information Administration, *Petroleum Basic Statistics, August, 2008.* See http://www.eia.doe.gov/basics/quickoil.html

[52] Energy Information Administration, *International Petroleum (Oil) Consumption, August, 2008.* See http://www.eia.doe.gov/emeu/international/oilconsumption.html

[53] Energy Information Administration, *Annual Energy Review 2006*, Table 5.21, p. 171. See: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec5_51.pdf

[54] Energy Information Administration, *Annual Energy Review 2006*, Table 5.24, p. 177. See: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec5_57.pdf

[55] Energy Information Administration, *Annual Energy Review 2006*, Table 5.1, p. 125. See: http://www.eia.doe.gov/emeu/aer/pdf/pages/sec5_5.pdf

example, the price of unleaded regular gasoline rose from an average of $2.59 in 2006 to $2.80 in 2007 (an 8.1 percent increase) and vehicle miles traveled decreased by 0.6 percent. Within the United States, demand for gasoline, diesel, and jet fuel within the transportation sector is particularly inelastic.

- Demand for oil may increase significantly in Asia and worldwide in the future resulting in upward oil cost pressure.
- 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 in particular have not thus far been subject to national regulation. Studies by multiple sources suggest that rising atmospheric concentrations of greenhouse gases will damage human health and welfare.[56] 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, U.S. energy consumption has increasingly been outstripping U.S. energy production.

Table II-1 presents trend data on the production and consumption of petroleum for transportation. Domestic petroleum production has been decreasing over time, while imports of petroleum have been increasing to meet the rising U.S. demand for petroleum.

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.

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[56] 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/*, .

This reformed CAFE final rule encourages 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

Petroleum Production and Supply

(millions of barrels per day)[57]

	Domestic Petroleum Production	Net Petroleum Imports	U.S. Petroleum Supply	World Petroleum Consumption	Import Share of U.S. Supply
1975	**8.4**	**6.1**	**14.4**	**52.8**	**42%**
1985	**9.0**	**5.1**	**14.0**	**54.0**	**36%**
1995	**6.6**	**8.8**	**15.4**	**62.4**	**57%**
2005	**5.2**	**13.7**	**18.9**	**84.3**	**73%**
DOE Predictions					
2015	**6.2**	**9.9**	**16.0**	**95.7**	**62%**
2025	**6.0**	**10.1**	**16.1**	**106.5**	**63%**
2030	**5.6**	**11.0**	**16.6**	**112.5**	**66%**

Table II-2

Transportation Consumption by Mode
(thousands of barrels per day)[58]

	Passenger Cars	Light Trucks	Total Light Vehicles	Total Transportation	Light Vehicles as % of Trans.
1975	**4,842**	**1,087**	**6,081**	**8,474**	**72%**
1985	**4,665**	**1,785**	**6,450**	**9,552**	**68%**
1995	**4,440**	**2,975**	**7,415**	**11,347**	**65%**
2005	**5,050**	**3,840**	**8,890**	**13,537**	**66%**

[57] "Petroleum Production and Consumption and Some Important Percent Shares, 1950-2006", Transportation Energy Data Book: Edition 26 (2007), Table 1.12. http://cta.ornl.gov/data/Index.shtml
"Comparison of petroleum projections, 2015, 2025, and 2030", Department of Energy, Energy Information Administration, Annual Energy Outlook 2007, Table 23. http://www.eia.doe.gov/emeu/aer/contents.html
[58] Transportation Energy Data Book, Table 1.14. http://cta.ornl.gov/data/chapter1.shtml .

III. ALTERNATIVES

In developing the proposed alternatives for the NPRM, the agency considered the four statutory factors underlying maximum feasibility as defined in EPCA (technological feasibility, economic practicability, the effect of other standards of the Government on fuel economy, and the need of the nation to conserve energy) as well as other relevant considerations such as safety. NHTSA assessed what fuel saving technologies would be available, how effective they are, and how quickly they could be introduced. This assessment considered technological feasibility, economic practicability and associated energy conservation. We also considered other standards to the extent captured by EPCA[59] and environmental and safety concerns. This information was factored into the computer model used by NHTSA for applying technologies to particular vehicle models.

In developing its proposed standards, the agency used a net benefit-maximizing analysis that placed monetary values on relevant externalities (both energy security and environmental externalities, including the benefits of reductions in CO_2 emissions) and produced what is called the "optimized scenario." The optimized standards reflect levels such that total benefits minus total costs are higher than at every other examined level of stringency. The agency also reviewed the results of the model's estimates of stringencies maximizing net benefits to assure that the results made sense in terms of balancing EPCA's statutory factors and in meeting EISA's requirements for improved fuel economy.

The agency proposed the "Optimized (7%)" alternative. In this alternative the agency used a 7 percent discount rate to value benefits and set the proposed mpg levels where marginal costs equal marginal benefits. It is one of six alternatives examined in the analysis using a 7 percent discount rate. We also examined a second optimized scenario when discounting benefits at 3 percent "Optimized (3%). In general order of increasing severity (see Table 1), the seven scenarios examined are:

1: "25% Below Optimized": This alternative mirrors the absolute difference in mpg derived from the 25% Above Optimized scenario in going the same mpg amount below the Optimized 7% alternative
2: "Optimized (7%) An increase in the standard based upon availability of technologies and a marginal cost/benefit analysis, as was used in setting the MY 2008-2011 light truck standard. The mpg levels are set using a 7 percent discount rate for benefits.
3: "25% Above Optimized": This alternative looks at the mpg levels of the Optimized (7%) and the Total Cost Equals Total Benefit alternative and picks mpg levels that are 25 percent of that difference.
4: "50% Above Optimized": This alternative looks at the mpg levels of the Optimized (7%) and the Total Cost Equals Total Benefit alternative and picks mpg levels that are 50 percent of that difference.
5: "Optimized (3%) An increase in the standard based upon availability of technologies and a marginal cost/benefit analysis, as was used in setting the MY 2008-2011 light truck standard, except that the mpg levels are set using a 3 percent discount rate for benefits.

[59] 71 Fed. Reg. 17566, 17669-70; April 6, 2006.

6: "Total Costs Equal Total Benefits": An increase in the standard to a point where essentially total costs of the technologies added equals total benefits. In this analysis, for brevity, at times it is labeled "TC = TB". [60]
7: "Technology Exhaustion": An increase in the standard based upon the maximum usage (based on NHTSA's perspective) of available technologies, disregarding the cost impacts. [61]

Table III-1
NPRM Alternative CAFE Levels
Projected Harmonic Average for the Fleet[62]
(in mpg)

Passenger Cars	MY 2011	MY 2012	MY 2013	MY 2014	MY 2015
25% Below Optimized	30.5	31.2	31.9	32.8	33.5
Optimized (7%)	31.0	32.3	33.1	33.9	34.7
25% Above Optimized	31.5	33.3	34.2	35.3	36.1
50% Above Optimized	31.7	34.0	35.1	36.4	37.6
Optimized (3%)	32.2	34.5	35.5	37.0	38.2
TC = TB	32.3	35.0	36.1	37.6	38.8
Technology Exhaustion	32.3	35.2	36.6	38.5	39.9
Light Trucks					
25% Below Optimized	24.3	25.5	27.3	27.3	27.4
Optimized (7%)	24.4	25.8	27.5	28.0	28.4
25% Above Optimized	24.4	26.1	27.8	28.5	29.5
50% Above Optimized	24.6	26.3	28.0	28.9	30.0
Optimized (3%)	24.4	25.8	27.7	28.2	28.8
TC = TB	24.7	26.5	28.5	29.5	30.5
Technology Exhaustion	24.7	26.6	29.4	30.3	31.3

For the final rule, the agency considered the same seven alternatives:
When discussing an alternative we provide the discount rate in parenthesis afterwards to keep track of which alternative we are discussing. There is one notable difference between the NPRM

[60] The agency considered the "TC=TB" alternative because one or more commenters in the rulemaking on standards for MY 2008-2011 light trucks urged NHTSA to consider setting the standards on this basis rather than on the basis of maximizing net benefits. In addition, while the Ninth Circuit Court of Appeals concluded that EPCA neither requires nor prohibits the setting of standards at the level at which net benefits are maximized, the Court raised concerns about tilting the balance more toward reducing energy consumption and CO_2.
[61] This was accomplished by determining the stringency at which a reformed standard would require every manufacturer to apply every technology estimated to be potentially available. At such stringencies, all but one manufacturer would be expected to fail to comply with the standard, and many manufacturers would owe large civil penalties as a result. The agency considered this alternative because the agency wished to explore the stringency and consequences of standards based solely on the potential availability of technologies at the individual manufacturer level.

[62] The values represent the higher of the manufacturer's plans and the alternative level of the standard.

and final rule in terms of discount rate. For all of the alternatives below, a 3 percent discount rate is used for the social cost of carbon and the intergenerational benefits. In general order of increasing severity, the seven scenarios examined are:

1: "25% Below Optimized (7%)": This alternative mirrors the absolute difference in mpg derived from the 25% Above Optimized scenario in going the same mpg amount below the Optimized 7% alternative
2: "Optimized (7%)": An increase in the standard based upon availability of technologies and a marginal cost/benefit analysis. The mpg levels are set using a 7 percent discount rate for benefits.
3: "25% Above Optimized (7%)": This alternative looks at the mpg levels of the Optimized (7%) and the Total Cost Equals Total Benefit (7%) alternative and picks mpg levels that are 25 percent of that difference.
4: "50% Above Optimized (7%)": This alternative looks at the mpg levels of the Optimized (7%) and the Total Cost Equals Total Benefit (7%) alternative and picks mpg levels that are 50 percent of that difference.
5: "Optimized (3%)": An increase in the standard based upon availability of technologies and a marginal cost/benefit analysis, except that the mpg levels are set using a 3 percent discount rate for benefits.
6: "Total Costs Equal Total Benefits (7%)": An increase in the standard to a point where essentially total costs of the technologies added equals total benefits. In this analysis, for brevity, at times it is labeled "TC = TB (7%)".
7: "Technology Exhaustion (7%)": An increase in the standard based upon the maximum usage (based on NHTSA's perspective) of available technologies, disregarding the cost impacts.

IV. IMPACT OF OTHER FEDERAL MOTOR VEHICLE STANDARDS ON FUEL ECONOMY

Introduction

The Energy Policy and Conservation (EPCA or the Act) requires that fuel economy standards be set at the maximum feasible level after taking into account 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. Using MY 2010 as a baseline, or the manufacturers' plans already provided to NHTSA on specific rulemakings, this section discusses the effects of other government regulations on model year (MY) 2011 passenger car and light truck fuel economy.

The Impact on Weight of Safety Standards and Voluntary Safety Improvements

The fuel economy impact of safety improvements will typically take the form of increased vehicle weight, which reduces the fuel economy of the vehicle. The manufacturer's estimates of weight and fuel economy impact have already been included in their baseline fuel economy projections. In some instances the manufacturers' weight estimates are similar to NHTSA's, in some instances they are less than NHTSA's, but often they are more than NHTSA's. The agency's estimates are based on cost and weight tear-down studies of a few vehicles and cannot possibly cover all the variations in the manufacturers' fleets. NHTSA requested and various manufacturers provided estimates of increases in weight resulting from safety improvements.

We have broken down our analysis of the impact of safety standards that might affect the MY 2011 fleets into three parts: 1) those NHTSA final rules with known effective dates, 2) proposed rules or soon to be proposed rules by NHTSA, without final effective dates, and 3) currently voluntary safety improvements planned by the manufacturers.

Weight Impacts of Required Safety Standards (Final Rules)

The National Highway Traffic Safety Administration (NHTSA) has issued two final rules on safety standards that become effective for passenger cars and light trucks for MY 2011. These have been analyzed for their potential impact on passenger car and light truck weights, using manufacturers' voluntary plans as a baseline.

1. FMVSS 126, Electronic Stability Control
2. FMVSS 214, Side Impact Oblique Pole Test

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

Table IV-1

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 75 percent of all light vehicles to meet the ESC requirement for MY 2010, 95 percent of all light vehicles to meet the ESC requirements by MY 2011, and all light vehicles must meet the requirements by MY 2012.

The agency's analysis of weight impacts found that ABS adds 10.7 lbs. and ESC adds 1.8 lbs. per vehicle for a total of 12.5 lbs. Based on manufacturers' plans for voluntary installation of ESC, 85 percent of passenger cars in MY 2010 would have ABS and 52 percent would have ESC. Thus, the total incremental added weight over manufacturers' plans in MY 2011 for passenger cars would be about 1.8 lbs. (0.10*10.7 + 0.43*1.8). Light trucks manufacturers' plans show that 99 percent of all light trucks would have ABS and that 74 percent would have ESC by MY 2010. Thus, for light trucks the incremental weight impacts of adding ESC would be 0.4 lbs. (0.21*1.8) in MY 2011.

<u>FMVSS 214, Oblique Pole Side Impact Test</u>
The phase-in requirements for the side impact test are as shown below in Table IV-2:

Table IV-2
FMVSS 214 Final Rule Phase-In Schedule

Phase-in Date	Percent of each manufacturer's light vehicles that must comply during the production period
September 1, 2010 to August 31, 2011	20 percent (excluding vehicles GVWR > 8,500 lbs.)
September 1, 2011 to August 31, 2012	40 percent vehicles (excluding vehicles GVWR > 8,500 lbs.)
September 1, 2012 to August 31, 2013	60 percent vehicles (excluding vehicles GVWR > 8,500 lbs.)
September 1, 2013 to August 31, 2014	80 percent vehicles (excluding vehicles GVWR > 8,500 lbs.)
On or after September 1, 2014	All vehicles including limited line vehicles, except vehicles with GVWR > 8,500 lbs., alterers, and multi-stage manufacturers
On or after September 1, 2015	All vehicles, including vehicles with GVWR > 8,500 lbs., excluding alterers and multi-stage manufacturers
On or after September 1, 2016	All vehicles, including vehicles with GVWR > 8,500 lbs., alterers and multi-stage manufacturers

A teardown study of 5 thorax air bags resulted in an average weight increase per vehicle of 4.77 pounds (2.17 kg).[63] A second study[64] 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 is assumed to be average for all vehicles in the future.

Based on manufacturers' plans to voluntarily provide window curtains and torso bags, we estimate that 90 percent of passenger cars and light trucks would have window curtains for MY 2010 and 72 percent would have torso bags. A very similar percentage is estimated for MY 2011. Thus, the final rule requiring 20 percent compliance is not likely to impact manufacturers' weights in MY 2011.

Weight Impacts of Proposed/Planned Safety Standards

Proposed FMVSS 216, Roof Crush

On August 23, 2005, NHTSA proposed amending the roof crush standard to increase the roof crush standard from 1.5 times the vehicle weight to 2.5 times the vehicle weight[65]. The NPRM proposed to extend the standard to vehicles with a GVWR of 10,000 pounds or less, thus including many light trucks that had not been required to meet the standard in the past. The proposed effective date was the first September 1 occurring three years after publication of the final rule. A Supplemental NPRM was published by the agency in January 2008, asking for public comment on a number of issues that may affect the content of the final rule, including possible variations in the proposed requirements. In the PRIA, the average passenger car weight was estimated to increase by 4.0 pounds and the average light truck weight was estimated to increase by 6.1 pounds for a 2.5 strength to weight ratio. Based on comments to the NPRM, the agency believes that this weight estimate is likely to increase. However, the agency does not yet have an estimate for the final rule. Regardless, the final rule will not be effective for MY 2011 vehicles.

Planned NHTSA initiative on Ejection Mitigation

The agency is planning on issuing a proposal on ejection mitigation. The likely result of the planned proposal is for window curtain side air bags (likely to be used to meet the FMVSS 214 oblique pole test in all vehicles) to be larger and for a rollover sensor to be installed. Preliminary agency estimates are that current curtain bags need be widened by 28% to fully cover the window opening area. According to a cost & weight analysis (DOT HS 809 842), head air bags (loomed cloth) installed in a vehicle weigh 2.59 lbs and the inflators weigh 4.73 lbs. Thus, the incremental weight would be about 2 lbs. (2.59 lbs + 4.73 lbs) x 0.28 = 2 lbs. However, this analysis is not complete at this time and will not be effective for MY 2011 vehicles.

Summary – Overview of Anticipated Weight Increases

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[63] 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.

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

[65] See 70 FR 53753, the PRIA is in Docket No. 22143, entry #2 "Preliminary Regulatory Impact Analysis, FMVSS 216, Roof Crush Resistance," August 2005.

Table IV-3 summarizes estimates made by NHTSA regarding the weight added by the above discussed standards or likely rulemakings. NHTSA estimates that weight additions required by final rules and likely NHTSA regulations effective in MY 2011, compared to the MY 2010 fleet and manufacturers' plans, will increase passenger car weight by at least 10.4 lbs. and light truck weight by at least 10.6 lbs.

Table IV-3

NHTSA Estimates of Weight Additions Due to Final Rules or Likely NHTSA Regulations for MY 2011 Compared to Manufacturers' Plans

Standard	**Added Weight in pounds** Passenger Car	**Added Weight in kilograms** Passenger Car	**Added Weight in pounds** Light Trucks	**Added Weight in kilograms** Light Trucks
126 – ESC	1.8	0.8	0.4	0.2

Based on NHTSA's weight-versus-fuel-economy algorithms, a 3-4 pound increase in weight equates to a loss of 0.01 mpg in fuel economy. Thus, the agency's estimate of the safety/weight effects for cars is 0.006 mpg or less and for light trucks is 0.001 mpg or less for already issued or likely future safety standards.

CONFIDENTIAL SUBMISSIONS
Weight Impacts of Potential Future Voluntary Safety Improvements

At the time the agency requested information about fuel economy plans and capabilities for the future, the agency also requested information on weight increases that could occur due to safety improvements. Several manufacturers provided confidential information about plans they had to meet final rules, proposed safety standards, or to voluntarily increase safety for the years 2011-2015. Several of these plans were to meet IIHS offset frontal and side impact testing. Most of these improvements will be installed on vehicles by MY 2011. [ ] The areas covered above and the regulatory areas described as final, proposed, and voluntary safety initiatives from manufacturers that have confidential increases for the period after MY 2010 are shown in the following tables.

[Table IV-4
Confidential Submissions of Weight Impacts After MY 2010

		Ford											
		Car MY						**Light Truck MY**					
Final Rules		**2011**	**2012**	**2013**	**2014**	**2015**	**Total**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
126	**ESC**												
214	**Side Impact**												
Total Final Rule Increments													
Proposed Rules													
216	**Roof Crush**												
226	**Ejection Mitigation**												
Total Proposed Rule Increments													
Voluntary and Other Rules													
202a	**Head Restraints**												
TBD	**Ped. Protection**												
TBD	**Public Domain ratings (TBD for finer details)**												
	EDR part 563												
N/A	**Voluntary**												
N/A	**Other**												
Total Voluntary and Other Rule Increments													
Total by Year													

		Chrysler											
		Car MY						Light Truck MY					
Final Rules		**2011**	**2012**	**2013**	**2014**	**2015**	**Total**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
126	**ESC**												
214	**Side Impact**												
Total Final Rule Increments													
Proposed Rules													
216	**Roof Crush**												
226	**Ejection Mitigation**												
Total Proposed Rule Increments													
Voluntary and Other Rules													
202a	**Head Restraints**												
TBD	**Ped. Protection**												
TBD	**Public Domain ratings (TBD for finer details)**												
	EDR part 563												
N/A	**Voluntary**												
N/A	**Other**												
Total Voluntary and Other Rule Increments													
Total by Year													

		GM											
		Car MY						Light Truck MY					
Final Rules		**2011**	**2012**	**2013**	**2014**	**2015**	**Total**	**2011**	**2012**	**2013**	**2014**	**2015**	**Total**
126	**ESC**												
214	**Side Impact**												
Total Final Rule Increments													
Proposed Rules													
216	**Roof Crush**												
226	**Ejection Mitigation**												
Total Proposed Rule Increments													
Voluntary and Other Rules													
202a	**Head Restraints**												
TBD	**Ped. Protection**												
TBD	**Public Domain ratings (TBD for finer details)**												
	EDR part 563												
N/A	**Voluntary**												
N/A	**Other**												
Total Voluntary and Other Rule Increments													
Total by Year													

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Vehicle Weight, Size and Safety

For many years there has been a controversy over the effect of vehicle size and weight on vehicle safety. With each fuel economy rulemaking, the debate continues. The following discussion provides NHTSA's point of view, the most serious comments on the issue, and NHTSA's response to those comments.

NHTSA believes that an attribute based Reformed CAFE system removes the incentive to downsize that is inherent in the traditional fleet-wide CAFE flat standard requirement. The agency believes that the attribute based standard is likely to have beneficial impacts on safety compared to the flat standard. Other things being equal, smaller vehicles provide less protection to their occupants in the event of a crash because there is less vehicle mass to absorb the crash energy and less interior space to buffer occupants from sheet metal intrusion. In addition, smaller vehicles are generally more likely to roll over. In single vehicle crashes, smaller vehicles are less safe than larger vehicles. When you hit a tree, more weight helps you knock that tree down and reduce your delta V, and more interior space allows you to ride down the crash safer. In multi-vehicle crashes, both individual vehicle size and the relative size of the involved vehicles play a role in determining the injury outcome of occupants of both vehicles. Generally, larger vehicles will provide better protection, but often at the expense of occupants of smaller vehicles. If larger vehicles were to be reduced in size, it would likely decrease the chance of injury in crashes with smaller vehicles, but it would also likely increase the chance of injury for the occupants of the larger vehicles. The makeup of any future mix-shifts in vehicle sales is purely speculative and the overall impact on injuries in multi-vehicle crashes of any future mix-shifts in vehicle size is unknown. However, downsizing is likely to increase the crash risk for vehicle occupants in single vehicle crashes, which make up 30% of all crashes and 57% of all fatalities. An attribute based system will require improvements in fuel economy for all vehicle sizes, and will thus minimize incentives to downsize vehicles. There may be other incentives for consumers to demand smaller vehicles (for example, an increase in the price of gasoline), but those external factors would not be influenced by the final rule structure.

We would like to clarify that our analysis does not mandate weight reduction, or any specific technology application for that matter. Our analysis relied exclusively on other fuel-saving technologies for passenger cars and only applied weight reduction to light trucks that have a curb weight greater than 5,000 lbs. to demonstrate that manufacturers can comply with the fuel economy levels without the need for what NHTSA believes are potentially unsafe compliance measures.

We first present a recent historical perspective of the debate:

The NAS study (2002)

The 2002 National Academy of Sciences (NAS)[66] report made explicit links between weight and vehicle safety. The NAS study conclusions were divided, with 11 of 13 committee members

[66] "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards", National Research Council, 2002. The link for the NAS report is http://www.nap.edu/books/0309076013/html/

representing the majority view and 2 of 13 the minority view. The findings of the majority presented on page 77 were:
"In summary, the majority of the committee finds that the downsizing and weight reduction that occurred in the late 1970s and early 1980s most likely produced between 1,300 and 2,600 crash fatalities and between 13,000 and 26,000 serious injuries in 1993. The proportion of these casualties attributable to CAFE standards is uncertain. It is not clear that significant weight reduction can be achieved in the future without some downsizing, and similar downsizing would be expected to produce similar results. Even if weight reduction occurred without any downsizing, casualties would be expected to increase. Thus, any increase in CAFE as currently structured could produce additional road casualties, unless it is specifically targeted at the largest, heaviest light trucks." …
"Some might argue that this improving safety picture means that there is room to improve fuel economy without adverse safety consequences. However, such a measure would not achieve the goal of avoiding the adverse safety consequences of fuel economy increases. Rather, the safety penalty imposed by increased fuel economy (if weight reduction is one of the measures) will be more difficult to identify in the light of the continuing improvement in traffic safety. Just because these anticipated safety innovations will improve the safety of vehicles of all sizes does not mean that downsizing to achieve fuel economy improvements will have no safety costs.

If an increase in fuel economy is effected by a system that encourages either downweighting or the production and sale of more small cars, some additional traffic fatalities would be expected. Without a thoughtful restructuring of the program, that would be the trade-off that must be made if CAFE standards are increased by any significant amount."

The minority view summarized on page 123 was:

"The relationship between vehicle weight and safety are complex and not measurable with any reasonable degree of certainty at present. The relationship of fuel economy to safety is even more tenuous. But this does not mean that there is no reason for concern. Significant fuel economy improvements will require major changes in vehicle design. Safety is always an issue whenever vehicles must be redesigned.

In addition, the distribution of vehicle weights is an important safety issue. Safety benefits should be possible if the weight distribution of light-duty vehicles could be made more uniform, and economic gains might result from even partly correcting the negative externality that encourages individuals to transfer safety risks to others by buying ever larger and heavier vehicles.

Finally, it appears that in certain kinds of accidents, reducing weight will increase safety risk, while in others it may reduce it. Reducing the weights of light-duty vehicles will neither benefit nor harm all highway users, there will be winners and losers…."

The Kahane Study (NHTSA - 2003)

The Kahane study[67] estimates the effect of 100-pound reductions in heavy light trucks and vans (LTVs), light LTVs, heavy passenger cars, and light passenger cars. It compares the fatality rates of LTVs and cars to quantify differences between vehicle types, given drivers of the same

[67] "Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks", Charles J. Kahane, Ph. D., NHTSA, October 2003, DOT HS 809-662.

age/gender, etc. In this analysis, the effect of "weight reduction" is not limited to the effect of mass *per se* but includes all the factors that were naturally or historically confounded with mass in 1991-1999 cars, such as length, width, structural strength and size of the occupant compartment. The rationale here is that when you add length, width or strength to a car, you will also make it heavier. The one exception could be a sweeping replacement of existing materials with light, high-strength components. But when you are looking at historical data – at cars of a certain era (namely, 1991-1999), they tend to be built in similar ways, and there is essentially a continuum from lighter and smaller cars to heavier, bigger and stronger cars.

Some of its findings are:

"Heavy vehicles had lower fatality rates per billion miles of travel than lighter vehicles of the same general type. When two vehicles collide, the laws of physics favor the occupants on the heavier vehicle (momentum conservation). Furthermore, heavy vehicles were in most cases, longer, wider and less fragile than light vehicles. In part because of this, they usually had greater crashworthiness, structural integrity and directional stability. They were less rollover-prone and easier for the average driver to control in a panic situation. In other words, heavier vehicles tended to be more crashworthy and less crash-prone. Some of the advantages for heavier vehicles are not preordained by the laws of physics, but were nevertheless characteristic of the MY 1991-99 fleet. Offsetting those advantages, heavier vehicles tended to be more aggressive in crashes, increasing risk to occupants of the vehicles they collide with."

Six different crash modes were analyzed (principal rollover, fixed object, pedestrian/bicycle/motorcyclist, and multi-vehicle crashes with heavy truck, light trucks, and passenger cars). Summing all these crash modes together, the net annual effects per 100-pound weight reduction were:
For passenger cars weighing less than 2,950 pounds – fatalities increased by 597
For passenger cars weighing 2,950 pounds or more – fatalities increased by 216
For light trucks weighing less than 3,870 pounds – fatalities increased by 234
For light trucks weighing 3,870 pounds or more – fatalities increased by 71

In all cases, annual fatalities increased with a reduction in weight. However, further analysis of the Kahane study found that the net safety effect of removing 100 pounds from a light truck is zero for the group of all light trucks with a curb weight greater than 3,900 lbs. [68] Given the significant statistical uncertainty around that figure, we determined that there is a crossover weight, which occurs somewhere between 4,264 and 6,121 pounds, with a point estimate at 5,085 pounds, above which there is no safety penalty for reducing vehicle weight. This is because the added harm for other road users from the additional weight exceeds any benefits for the occupants of the vehicles. NHTSA embodied this finding in its CAFE rulemaking by restricting materials substitution in its development of stringency levels to vehicles over 5,000 pounds and used 5,000 lbs. as the threshold for considering weight reduction of specific models. In the MY 2008-2011 light truck final rule, NHTSA included weight reduction as a fuel improving technology for light trucks over 5,000 lbs. curb weight where we determined that

[68] Kahane, Charles J., PhD, Vehicle Weight, Fatality Risk and Crash Compatibility of Model Year 1991-99 Passenger Cars and Light Trucks, October 2003. DOT HS 809 662. Page 161. Docket No. NHTSA-2003-16318 (http://www.nhtsa.dot.gov/cars/rules/regrev/evaluate/pdf/809662.pdf)

weight reduction would not reduce overall safety and would be a cost-effective choice. We are applying the same methodology in this final rule, weight reduction is considered a technology that can be applied to light trucks over 5,000 lbs. curb weight.

The agency believes a number of conclusions can be drawn from these studies:

- Heavier vehicles are more crashworthy and less crash prone.[69]
- The net impacts on safety, considering the six different crash modes, of reducing weight are negative for all but the larger light trucks. However, this type of analysis can not examine extreme cases. For example, if there were a large mix shift from 50 percent passenger car and 50 percent light truck sales, to 80 percent compact or smaller passenger cars and 20 percent pickup truck sales, this analysis cannot determine the net impacts on safety. Nothing in the manufacturer's plans suggests a drastic change in the mix of vehicles, nor is there any incentive, in our opinion, for such a change based on NHTSA's attribute based final rule on fuel economy.
- Lighter vehicles fare worse in single vehicle collisions. In 2006, 57 percent of all passenger car and light truck fatalities were in single vehicle crashes and 43 percent were in multi-vehicle crashes. Fatalities are almost split between rollovers (29 percent) and fixed or non-fixed objects (28 percent).
- Reducing weight increases the likelihood of rolling over. When you are sliding sideways and digging into mud or grass or hit a curb, all things being equal, the lighter vehicle is more prone to rolling over. Increasing track width (part of the footprint calculation) reduces the likelihood of rolling over. Track width is more important than weight for rollovers. Rollover is the only area in which track width is the most important factor. Weight is more important than track width or wheelbase in the other five crash modes investigated.[70]
- Reducing weight increases the likelihood of being killed in a fixed or non-fixed object crash. If you run into a tree, you are safer if you knock that tree down than if the tree stops your vehicle. A heavier vehicle has a better chance of knocking the tree down.

The Kahane report also examined the total fatality crash rates in all crash modes; including fatalities to occupants of the case vehicle (i.e. in rollovers, single vehicle and multi-vehicle crashes), occupants of the other vehicle it collided with (to account for aggressive vehicles) and pedestrians. Kahane used VMT data based on CDS odometer readings and controlled for age and gender based on State data on nonculpable crash involvements (induced exposure). With these controls, the societal fatality rates per billion miles were:

[69] See Kahane study, page xiv Table 3 for prorated fatal crash involvements per billion miles.
[70] See Kahane (Docket No. 2003-16318-16)

TABLE IV-5

ADJUSTED FATAL-CRASH INVOLVEMENT RATES
PER BILLION CASE VEHICLE MILES, BY VEHICLE TYPE

(Case vehicles are MY 1996-99 light trucks and 4-door cars with air bags in CY 1996-2000, adjusted for age/gender, rural/urban, day/night, speed limit, and other factors)

Vehicle Type and Size	Average Curb Weight	Fatal Crash Involvements Per Billion Miles
Very small 4-door cars	2,105	15.73
Small 4-door cars	2,469	11.37
Mid-size 4-door cars	3,061	9.46
Large 4-door cars	3,596	7.12
Compact pickup trucks	3,339	11.74
Large (100-series) pickup trucks	4,458	9.56
Small 4-door SUVs	3,147	10.47
Mid-size 4-door SUVs	4,022	13.68
Large 4-door SUVs	5,141	10.03
Minivans	3,942	7.97

In other words, mid-size cars had somewhat lower societal fatal crash rates than SUVs that weighed considerably more. Large cars and minivans had the lowest rates.

The DRI Studies (2003, 2004, 2005)

Honda sponsored DRI to complete several reports, which it asserted demonstrated that limited weight reductions would not reduce safety and could possibly decrease overall fatalities. Honda stated that the 2003 study by DRI found that reducing weight without reducing size slightly decreased fatalities, and that this was confirmed in a 2004 study by DRI[71] that assessed new data and methodology changes in the 2003 Kahane Study. Honda asserted that the DRI results tend to confirm “that curb weight reduction would be expected to decrease the overall number of fatalities.”

DRI submitted an additional study, Supplemental Results on the Independent Effects of Curb Weight, Wheelbase, and Track Width on Fatality Risk in 1985-1998 Model Year Passenger Cars and 1985-1997 Model Year LTVs, Van Auken, R.M. and J. W. Zellner, May 20, 2005 (Docket No. 2003-16128-1456). This DRI study concluded that reductions in footprint are harmful to safety, whereas reductions in mass while holding footprint constant would benefit safety. The DRI study disagreed with NHTSA’s finding that mass had greater influence than track width or wheelbase on the fatality risk of passenger cars in non-rollover crashes.

[71] See Docket Nos. 2003-16318-2, 2003-16318-3, 2003-16318-7, and 2003-16318-17.

NHTSA disagrees with the numerical findings of the DRI reports on the safety effects of mass, track width and wheelbase. As a consequence, we also cannot endorse the inferences by Honda and others, based on those reports, that mass reductions in small cars are harmless as long as we maintain wheelbase and track width or even as long as we limit the reductions to material substitution (although we agree those seem to be the least harmful ways to lose mass).

DRI has over the years issued various analyses of historic fatal crash rates with three measures of cars size – curb weight, track width and wheelbase – treated as if they were three independent variables.[72] In general, the results are that reductions in track width and wheelbase are associated with substantial increases in fatal crash risk, whereas reduction in mass *per se*, if track width and wheelbase are held constant, is associated with reductions in risk. Based in part on these analyses, Honda and various others have inferred that future mass reductions, while track width and wheelbase remained unchanged – by substituting lighter materials of equal strength or by other means – would apparently benefit safety.[73]

NHTSA is generally skeptical of analyses that include mass, track width and wheelbase as separate independent variables. Although it is true that, for any given curb weight, there may be some variations in the track widths and wheelbases of make-models at that curb weight, these variations are not, as it were, random but are usually confounded with other factors such as the vehicle's design or market class. Specifically, sporty 2-door coupes such as Ford Mustang and Chevrolet Camaro have exceptionally short wheelbase for their mass. They also have exceptionally high fatal crash rates. Inclusion of sporty 2-door coupes in the analysis produces a finding that higher wheelbase increases safety but higher mass decreases safety. These findings are spurious unless you sincerely believe either: (a) the high fatality rates of Mustang and Camaro are due to their short wheelbases and have nothing to do with their drivers' speeding, drinking and risk-taking – or (b) it is the short wheelbases of Mustangs and Camaros that impels their drivers to drink, speed and take risks, and if you transplanted these drivers to Grand Marquis and LeSabres they would become safe, prudent, and sober.

Therefore, NHTSA restated in its response to public comments[74] on its 2003 weight-safety report that it is imperative that analyses be limited to a set of make-models that do not vary greatly in style and market class, but rather represent a gradually varying continuum of lighter to heavier cars used for similar purposes – namely, 4-door sedans or station wagons excluding police cars.

In their most recent, 2005 analysis, DRI agreed, at least for comparison purposes, to limit some of their analyses to 4-door cars excluding police cars.[75] DRI further claimed that they could now mimic NHTSA's logistic regression approach for an analysis of MY 1991-1998 4-door cars in CY 1995-1999 crashes. DRI claimed this new analysis still showed results directionally similar to their earlier work – increased risk for lower track width and wheelbase, reduced risk for lower mass – although the wheelbase and mass effects were no longer statistically significant after removing the 2-door cars from the analysis.

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[72] Docket No. NHTSA-2003-16318-7, Docket No. NHTSA-2003-16318-17.
[73] http://www.arb.ca.gov/cc/ccms/meetings/042108/4_21_current_techn_4_german.pdf
[74] Docket No. NHTSA-2003-16318-16.
[75] Docket No. NHTSA-2003-16318-17.

The actual numbers – DRI vs. NHTSA

In MY 1991-1998, the average car weighing N+100 pounds had .34 inches larger track width and 1.01 inches longer wheelbase than the average car weighing N pounds. Thus, you might say the "typical" or "historical" 100-pound weight reduction would have been accompanied by a .34 inch track-width reduction and a 1.01 inch wheelbase reduction. But if you disassociate these three measures and treat them as independent parameters, DRI's logistic regression of MY 1991-1998 4-door cars excluding police cars attributes the following effects:

DRI

Reduce mass by 100 pounds	379	*fewer* fatalities
Reduce track width by .34 inches	1000	more fatalities
Reduce wheelbase by 1.01 inches	207	more fatalities
Reduce mass by 100 lb., track by .34" and WB by 1.01"	828	more fatalities

Now, DRI may claim to have mimicked our database and analysis method, but clearly their data are not the same as NHTSA's or their analysis is not the same. Because if you apply NHTSA's logisitic regression analyses to NHTSA's database, exactly as described in the agency's response to comments on its 2003 report,[76] except for limiting the data to MY 1991-1998 (instead of 1991-1999), just as DRI did, the effects are not at all like DRI's:

NHTSA

Reduce mass by 100 pounds	485	more fatalities
Reduce track width by .34 inches	334	more fatalities
Reduce wheelbase by 1.01 inches	9	more fatalities
Reduce mass by 100 lb., track by .34" and WB by 1.01"	828	more fatalities

That is the principal reason we cannot accept DRI's results or the inferences that Honda or anybody else makes from DRI's results: we get quite different results when we apply our analysis to our database, even when we make the analysis as similar to DRI's as possible. DRI may have tried to mimic our results, but they're obviously doing something differently.

Intuitively, weight reductions that (1) hold track width and wheelbase constant and (2) are the result of materials substitution are likely to be less harmful to safety than other types of weight reductions. But because we disagree with DRI's numerical results, we cannot conclude at this point that such weight reductions would be intrinsically harmless, let alone beneficial, if applied to small cars.

> Even though our analyses continue to attribute a much larger effect for mass than for track width or wheelbase in small cars, we still do not claim that mass *per se* is the "magic bullet" that increases or decreases fatality risk in non-rollover crashes. There might not be any single magic bullet, but rather mass and a variety of other factors historically correlated with mass. The importance of our analyses is that they do not corroborate the "easy way out" offered by DRI: that track width and wheelbase explain the entire size-safety effect and then some, and that mass can be reduced without any harm and maybe even with a benefit. Our

[76] Docket No. NHTSA-2003-16318-16.

> results show, until we have a better understanding of all the size-related factors that affect safety, we cannot assume that mass reductions in small cars are harmless as long as we maintain wheelbase and track width or even as long as we limit the reductions to material substitution (although we agree those seem to be the least harmful ways to lose mass).

While NHTSA agrees that limited weight reduction to heavier vehicles will not reduce safety, we disagree with DRI's overall conclusion, cited by Honda, that weight reductions while holding footprint constant would significantly benefit safety in lighter vehicles. NHTSA's analyses of the relationships between fatality risk, mass, track width and wheelbase in 4-door 1991-1999 passenger cars (Docket No. 2003-16318-16) found a strong relationship between track width and the rollover fatality rate, but only a modest (although significant) relationship between track width and fatality rate in non-rollover crashes. Even controlling for track width and wheelbase – e.g., by holding footprint constant – weight reduction in the lighter cars is strongly, significantly associated with higher non-rollover fatality rates in the NHTSA analysis. By contrast, the DRI study of May 20, 2005 analyzed 4-door cars and found a strong relationship between track width and fatality risk, and non-significant associations of mass and wheelbase with fatality risk (Docket No. 2005-22223-78, p. 31). In other words, when DRI analyzed the same group of vehicles as NHTSA, they did not get the same results.

The agency continues to believe that weight reduction in lighter vehicles would reduce safety. However, we also believe that weight reductions in the heavier light trucks, while holding footprint constant, will not likely result in a net reduction in safety. In our opinion, it is impossible to reduce weight and maintain footprint unless you (a) substitute light for heavy materials in a big way or (b) remove features that customers want and are willing to pay for. In that sense, DRI's contention that weight is unimportant could only be true for material substitution, because under present circumstance weight reduction usually also means size reduction, and DRI agrees with NHTSA that a reduction in footprint is harmful to safety.

Important Comments to Previous Dockets

General Motors (Docket No. 2005-22223-1493) and the Alliance (Docket No. 2005-22223-1642) were more explicit in their concerns over the safety impact associated with weight reduction. The Alliance stated that the fundamental laws of physics dictate that smaller and/or lighter vehicles are less safe than larger/heavier counterparts with equivalent safety designs and equipment. General Motors agreed that improvements in material strength, flexibility, and vehicle design have helped improve overall vehicle and highway safety. But, General Motors added, for a given vehicle, reducing mass generally reduces net safety. Further, General Motors stated that it does not intentionally reduce mass by replacing it with advanced materials, presuming that such action alone will result in improved protection for the occupants in a lighter vehicle; instead GM continues to believe that vehicles with larger mass will provide better protection to occupants involved in a crash than a vehicle of the same design with less mass, given equivalent crashes.

General Motors also questioned the agency's reliance on a 5,000 lbs. minimum vehicle weight for considering weight reduction, which was based on the finding of the 2003 Kahane report. General Motors stated that the agency's conclusion is inconsistent with the sensitivity analysis performed by William E. Wecker Associates, Inc.[77] and submitted to the ANPRM docket. General Motors stated that the inflection point on the Wecker report's graph for General Motors light trucks in both the periods of MYs 1991-1995 and MYs 1996-1999 is higher than 5,000 pounds.

Additionally, General Motors stated that the NPRM did not acknowledge or respond to the main point of the Wecker report, which was that Dr. Kahane's "analysis alone does not support the proposition that a crossover weight at or near 5,085 pounds is a robust, accurate description of the field performance of the fleet."

We believe that General Motors was confusing the 5,085 lbs. crossover weight (where the safety effect of mass reduction in a vehicle weighing exactly 5,085 lbs., is zero) with the breakeven point, which is the point where the total effect of reducing all vehicles heavier than the breakeven weight by an equal amount is zero. NHTSA estimated that the breakeven point as described in the NPRM is 3,900 lbs., if footprint is held constant.

If the 3,900 lbs. estimate were perfectly accurate, we would be confident that weight reductions in vehicles down to 3,900 pounds would not result in net harm to safety. However, there is considerable uncertainty about the crossover weight and also the breakeven point. Therefore, in our analysis, we limited weight reduction to vehicles with a curb weight greater than 5,000 pounds. We believe that the 5,000 lbs. limit is sufficient so that we can be confident that such weight reductions will not have net harm on safety.

Advocates for Highway and Auto Safety commented that Kahane's (NHTSA's) 2003 analysis may not apply if the effects of size and weight reductions are disaggregated, "weight reductions without corresponding reductions in vehicle wheelbase length and track width could be expected to produce net benefits in reducing occupant crash risks." This is essentially the DRI argument.

NHTSA's response is that Footprint (especially track width) is an important variable in terms of a vehicle's propensity for rollovers, a type of crash that accounts for 29 percent of all light vehicle occupant traffic fatalities. Track width is one of the two vehicle properties that define Static Stability Factor (SSF). SSF was used as a single predominant factor to predict rollover rate in the agency's original rollover NCAP, and it is still the most powerful element in the agency's current rollover NCAP risk model that also factors in a road maneuver test. Wheelbase does not have a direct effect on rollover resistance. However, there are hypotheses that an increase in wheelbase could reduce loss-of-control crashes by making the vehicle react slower in yaw and thereby reduce the number of single-vehicle pavement departure crashes that produce most rollovers. Currently, the agency does not have any data to substantiate this theory.[78]

Environmental Defense (Docket No. 2005-22223-1805) commented that by limiting the use of weight reduction to heavier vehicles, the agency disregarded the likelihood that manufacturers would rely on weight reduction in smaller, lighter vehicles. Environmental Defense suggested that the improved baselines should reflect this weight reduction strategy.

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[77] Docket No. 2003-16128-1112

[78] See Kahane (Docket No. 2003-16318-16)

Environmental Defense asserted that weight reduction is among the most common and cost-effective options available to manufacturers for improving vehicle fuel economy across the light truck fleet. Environmental Defense referenced estimates presented in DeCicco (2005) that suggest that the cost per pound of weight reduced through use of high-strength steel and advanced engineering techniques has been as low as, or lower than, 31 cents per pound reduced.

Moreover, Environmental Defense stated, the exclusion of mass reduction in NHTSA's analysis bears no relation to what will actually happen in the marketplace when standards are implemented. Environmental Defense argued that absent safety regulations prohibiting the use of mass reductions, manufacturers are likely to choose this compliance alternative in vehicles of all weights as a cost-effective way to comply with CAFE. Environmental Defense stated that NHTSA should consider the potential for mass reduction among its compliance alternatives for *all* light trucks.

As stated above, the agency does not dictate which fuel-savings technologies must be applied to vehicles. Mass reduction is a compliance alternative for all light vehicles. However, one of NHTSA's considerations in setting fuel economy standards is to set standards that will not force the manufacturers to reduce safety. The standards set by the agency are those capable of being achieved by the manufacturers without the need to reduce safety. If the agency were to consider weight reduction as a compliance option, we are concerned that the resulting increased stringency would force unsafe downweighting.

A group of experts at a workshop sponsored by the International Council on Clean Transportation (ICCT) examined many of the size/safety reports and wrote a June 2007 report "Sipping Fuel and Saving Lives: Increasing Fuel Economy Without Sacrificing Safety."[79] NHTSA agrees with two of the three ICCT report findings. We agree that fuel economy technologies exist that don't affect safety. We agree that reducing weight (on vehicles over 5, 000 lbs) can make certain vehicles less aggressive and reduce their weight and probably improve safety. Many, but not all of the experts at the workshop, agreed with the last conclusion: "Advanced technologies can decouple size from mass, creating important new possibilities for increasing fuel economy and safety without compromising functionality". We continue to believe, until someone demonstrates to the contrary with some kind of rigorous, scientific analysis, that reducing weight on smaller lighter vehicles will only make them more dangerous in single-vehicle crashes, because of fundamental physics.

A study examined similar safety issues - "The "Arms Race" on American Roads: The Effect of Sport Utility Vehicles and Pickup Trucks of Traffic Safety", Michelle J. White, University of California San Diego, Journal of Law and Economics, Volume XLVII, October 2004. The White paper finds that "When drivers shift from cars to light trucks or SUVS, each crash that involves fatalities from light truck or SUV occupants that is prevented comes at a cost of at least 4.3 additional crashes that involve deaths of car occupants, pedestrians, bicyclists, or motorcyclists."

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[79] See www.theicct.org/documents/ICCT_SippingFuelFull_2007.pdf

The White study is an analysis of NHTSA's National Automotive Sampling System, General Estimates System and, as such, looks at the fatality risk given that a crash occurred. However, it does not control for VMT (likelihood of a crash given a mile of driving). Furthermore, the study does not address the safety of big cars vs. small cars or big LTVs versus small LTVs. Whether overall safety would be improved by shifting sales from SUV and pickups to passenger cars depends on what size of passenger cars you shifted to (see the table above), if you shifted to small or very small passenger cars, overall safety would decrease.

Another study examined the size/safety issues – "The Fatality Risks of Sports Utility Vehicles, Vans, and Pickups Relative to Cars", Ted Gayer, Georgetown University, The Journal of Risk and Uncertainty, 28-2, 103-133, 2004. This study finds that "Using a cross-sectional variation in snow depth as an instrument to determine VMT, the results suggest that light trucks are 2.63 to 4.00 times more likely to crash than cars." "…once one adjusts for the greater frequency of crashes by light trucks, the aggregate risk they pose substantially dominates the risk from cars. Indeed a world of light trucks would lead to three to ten times more fatalities than a world of cars."

This study does not address the safety of big cars vs. small cars or big LTVs versus small LTVs. This analysis using snow depth exaggerates the difference in crash frequency and fatality rates between passenger cars and light trucks. Kahane's study also adjusted the raw data for VMT, but we have used odometer readings by age of vehicle to control for VMT and found no such discrepancy in crash rates. The table above from the Kahane study does not show light trucks having substantially higher fatality rates than passenger cars.

A 2001 study by Dr. Leonard Evans,[80] modeled the risk of driver fatality in car 1 in a head-on collision with car 2. The equations in the report indicate that reducing the curb weight of car 1 would increase the risk to the driver of car 1, while reducing the curb weight of car 2 would decrease the risk to the driver of car 1. However, the equations also indicate that reducing the wheelbase of either car increases the total risk to both drivers.

In a 2004 SAE paper, Dr. Evans claimed that increasing the amount of lightweight materials in vehicle design can provide reduced occupant risk both in two-vehicle and single-vehicle crashes, and also reduce risk for occupants in other vehicles[81]. However, he produced no analysis using real world data of vehicles with lightweight material to substantiate that claim[82].

In an amicus brief, the Insurance Institute for Highway Safety[83]stated "Crash safety should be a consideration in how the balance is struck between programs to improve air quality and our efforts to protect people in crashes. Physics dictates that vehicle weight and size will always matter in a crash. Research in the private, public, and nonprofit sectors have demonstrated the

[80] Evans, L., "Causal Influence of Car Mass and Size on Driver Fatality Risk", American Journal of Public Health, Vol. 91, No. 7, July 2001, pp 1076-1081.

[81] Evans, L., "How to make a car lighter and safer," SAE 2004-01-1 172, Society of Automotive Engineers, 11 March 2004.

[82] In NHTSA's opinion, there are not enough vehicles made from lightweight material on the road to support an analysis using real world crash data.

[83] Filed in the United States Court of Appeals for the Second Circuit, March 21, 2008, No. 07-4342-cv(L), March 21, 2008, Green Mountain Chrysler Plymouth Jeep…, by Michele Fields and Stephen L. Oesch of IIHS.

relationship between vehicle size and weight and crash injuries. Simply put, Vermont's regulation encourages production of smaller, lighter vehicles which will lead to increased traffic fatalities." IIHS discusses research by NHTSA and IIHS that have led to the conclusion that "Vehicle downsizing has compromised safety because in most cases, smaller and lighter vehicles are less protective of their occupants than larger, heavier vehicles." IIHS calculated the vehicle death rates by make model using driver deaths per million registered vehicle years, presented this data, and ranked them. "None of the 15 vehicles with the lowest driver death rates were mini or small models. … Eleven of the 16 vehicles with the highest driver death rates were small cars and none were large or very large. … The pattern is unmistakable. There is an inverse relationship between driver death rates and vehicle size…"

Comments to the NPRM Docket

In this section we present and discuss the comments to the NPRM Docket (2008-0089).

Comment: **Insurance Institute for Highway Safety** (IIHS) 2008-0089-220.1, P1-2
IIHS was concerned that a manufacturer may increase footprint rather than add technology, or they could reduce mass, while keeping same footprint. The use of vehicle footprint will mitigate much of the potential for automakers to downweight or downsize vehicles to improve fuel economy and, hence, will help maintain the safety benefits associated with those attributes. IIHS believe that weight is a better discriminator (more direct approach) than footprint and that reducing vehicle mass typically reduces crashworthiness. Automakers could use lighter materials, maintaining the same size and structural performance, thus limiting the safety consequences.

Agency Response: We agree with most of IIHS's statements except that we believe footprint is a better attribute than weight for setting the MY 2011 CAFE standards.

Comment: **Air Resources Board**, (2008-0089-0173), pp 6-7
The Air Resource Board state that NHTSA should expand the use of weight reductions to vehicles under 5,000 pounds. They were struck by apparent dichotomy between adopting size attribute to promote vehicle safety, but yet restrict weight reduction to vehicles under 5,000 pounds. NHTSA relies on the Kahane study (which assumes that weight and size are completely correlated), but ignores more recent studies by Dynamic Research Inc. that have shown otherwise. Pg. 2 - Expert report by David Greene (Ahmad and Greene 2005) concludes that there has been no relationship between fuel economy and traffic fatalities and there should be none in the future.

Agency Response: The relationship is entirely too complex to examine by a macro analysis as was completed by Ahmad and Greene. This report is a long-term (1966-2002) time-series analysis of the annual number of crash fatalities in the United States, the average fuel economy of the vehicles on the road that year, and some other factors such as the price of fuel, the national speed limit, population, and annual vehicle miles traveled. The conclusion is that national fatalities did not increase, in fact tended to decrease, from the early 1970s forward, while fuel economy improved. Therefore, fuel economy has not had an adverse effect on safety. Suffice it to say that this is an exceedingly "macro" level to examine the relationships between fuel economy and fatality risk. Long-term time-series analyses are unlikely to separate the effects of downsizing for the other demographic, economic, and technological trends that have had an impact on fatality rates over the period. For instance, seat belt use has risen from 14 percent to 82 percent, many life-saving safety features (*e.g.*, front and side airbags) have been added to vehicles, impaired driving is not as accepted, and so forth. It is general knowledge that traffic fatalities are now lower than 1970, primarily as a result of the major safety advances just mentioned. But the relevant question in the safety/fuel economy context is, “Would fatalities have been even lower if cars had not been downsized?” To analyze that relationship accurately, it would be necessary to compare the fatality risk of small and large vehicles, not just the trend in total fatalities, over this long period.

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Comment: P3, States that Kahane’s finding that the increase in single vehicle crashes and rollover crashes was surprising and there was no clear and compelling scientific law that would predict that result.

Agency Response: There is a compelling logical example to explain the results. In a single vehicle crash, you’d rather knock a tree down than be stopped by the tree. More weight helps you knock the tree down. Lighter cars roll over at a much higher rate than heavier cars. It is easier for a lighter car to be tripped and roll over.

Comment: P3, Examined NHTSA frontal crash test data and found no correlation between vehicle weight and occupant protection.

Agency Response: Frontal crash test data is the wrong data to analyze for this comparison, because the vehicle strikes a rigid barrier, which is like a vehicle striking its own twin.

Comment: P3, Examined NHTSA data on rollover propensity and found that rollover risk increased with weight. This is entirely due to a greater propensity for light trucks to roll over. For passenger cars, there was no correlation between rollover propensity and weight, the same held within class of light trucks. This led them to suspect that it was not the vehicles themselves, but the drivers and the environment in which they were operated.

Agency Response: The Kahane study shows a direct correlation between size/weight of passenger cars and rollover propensity. Smaller cars rollover much more frequently. Kahane’s study specifically controlled by the driver and environment characteristics.

Comment: Greene reiterates a principal argument from his dissent to the 2002 NAS report, namely that mass *per se*, intuitively, should not have any safety effect other than on the relative risk of two vehicles that collide with each other. Therefore, all the empirical data showing higher fatality rates for lighter vehicles in single-vehicle crashes and elsewhere are due to something other than mass. Therefore, we may reduce mass without harming safety.

Agency response: Although mass per se, strictly speaking, may have little direct causal effect on fatality risk in most types of crashes, there are many other parameters that are naturally and historically highly correlated with mass, such as size, rigidity, structural integrity, and the driver’s perception of maneuverability, that affect the frequency and severity of crashes. Unless we can determine exactly what these parameters are and demonstrate ways to reduce mass without affecting any of these other parameters, we cannot simply ignore the empirical data showing higher fatality rates for lighter vehicles. .

Comment: The Wenzel/Ross studies show that fatality risk has less to do with a vehicle's weight than with the type of drivers who choose that vehicle. Luxury imports have low fatality risk because they have good drivers, etc.

Agency response: See our critique of the Wenzel/Ross study in our response to public comments on the 2003 report. Specifically, the analysis did not control for driver age/gender and other factors such as urbanization and region of the country. After controlling for these, most of the difference between luxury cars and other cars disappears.

Comment: Noland and Ahmad/Greene's long-term (1966-2002) time-series analyses show little correlation between downsizing and trends in fatalities. The roads are safer now than in 1966, despite downsizing during the 1970s.

Agency response: Long-term time-series analyses are unlikely to tease out the effect of downsizing from the numerous other demographic, economic and technological trends that have an impact on fatality rates.

Comment: **Alliance,** 2008-0089-0179.1 P10
Weight and safety are correlated, as NHTSA has recognized.

Comment: **Lawrence Berkley National Laboratory** (2008-0089-0194.1) pp. 4-7, 9
They disagree with NHTSA that larger or heavier vehicles are inherently safer than smaller or lighter vehicles. Kahane's analysis has flaws. Through careful design and material substitution, vehicle mass can be reduced without compromising safety.
The risk to persons other than the driver imposed by crossover SUVs decreases as size increases. There is no consistent relationship between driver fatality risk and car size for frontal crashes with another car or object. The additional protection that size provides to drivers of light trucks comes at a cost to the drivers of the cars they crash into. Driving behavior tends to be worse in subcompact and compact cars, which tends to overstate the fatality risk in smaller cars. There is no strong relationship between vehicle mass and fatality risk to drivers in a front crash with an object. They also argue that Kahane's regression analysis would likely change if updated to today's vehicles, due to advances in safety devices such as ESC and the increased prevalence of crossover SUVs.

Agency response: The commenter provides and opinion with no analysis to back it up. We don't believe they are considering the big picture – fatality increase comes from single vehicle and rollover crashes, or the incremental picture – ESC affects everyone and doesn't discriminate by weight, and lighter crossovers will be less safe than heavier crossovers.

Comment: **Mercatus Center (**2008-0089-0216.1)
Mercatus argues that NHTSA has not fully accounted for the decline in vehicle safety as a result of implementing fuel saving technologies, such as lighter vehicles that could result in higher death and injury rates.

Agency response: We believe that manufacturers can meet the CAFE requirements without making lighter vehicles, however nothing prevents them from doing so. It would be impossible for us to predict how the manufacturers might react to our requirements and market forces, thus we would have no confidence in a prediction that tried to account for a decline in safety.

Comment: **Center for Biological Diversity** (2008-0089-0222.1), pp. 12
NHTSA misrepresented the 2002 NAS findings. NHTSA fails to consider the potential benefits of lower vehicle weight. NAS found that weight reduction for vehicles over 4,000 lbs would result in a safety benefit.

Agency response: We have updated the Kahane report and the 4,000 lbs., which is what the NAS findings were based upon. See the previous discussion about 5,000 lbs.

Comment: **Sierra Club** (2008-0089-0226.1), pp. 3, 13-15
NHTSA's analysis of the relationship between vehicle weight and safety is flawed. NHTSA should revise its policy position on the weight/safety issue to take into account new materials and vehicle design options that can improve safety while reducing weight.
The industry is already demonstrating that weight reduction is a safe and effective strategy for improving fuel economy. The disparity in weights of vehicles is much more important to occupant safety than the average weight of vehicles. Specific design features play a more important role than weight. The disparity in vehicle weight has decreased dramatically, eliminating the most severe weight disparity crashes. NHTSA has not taken into account improvements in structural integrity and safety technology, such as light-weight high-strength materials. William Haddon said size is more important than weight for safety. The safety of small cars continues to improve. NHTSA recognizes the retrospective nature of the Kahane study yet continues to use it to constraint future fuel economy.

Agency response: They provide no proof that their theory is correct. We have discussed all of these issues above.

Comment: **Aluminum Association of America** (2008-0089-184)

NHTSA's weight-safety study was retrospective, looking at 1990s vehicles, and not predictive. In the future, there could be extensive use of new materials, new designs enabled by the use of these materials, and new crash-avoidance technologies that will change the distribution of crash types.

Agency response: We agree this study is based on a group of vehicles manufactured from similar materials (steel), where weight was highly correlated with size and structural strength. Relationships might conceivably be different in a future fleet where a wide variety of materials is used to build cars. We should caution, though, that the use of new materials is still at an early stage and will be for some years. NHTSA also agrees that, intuitively, substitution of strong, lightweight materials would be a less harmful to down-weight than reducing the size of the vehicles. But there is not yet sufficient evidence to conclude that material substitution is harmless, let alone beneficial to safety.

Comment: **Public Citizen** (2008-0089-0187)

NHTSA's 2003 study obfuscates findings which show that reducing weight from only the heaviest vehicles actually improves safety and overlooks the relationship between the difference in vehicle weight.

Agency response: The 2003 estimates do include the benefits of improved fleet compatibility when the heaviest vehicles are reduced in weight. Compatibility is a safety concern that NHTSA has been investigating for some time now. The commenters' point that any compatibility benefits should be weighed against any disbenefits associated with downweighting is logically correct. However, NHTSA research on compatibility has shown that compatibility is substantially influenced by factors other than mass, including vehicle geometry, stiffness, and crush space. While we do not know the precise effect of these factors, it is fair to say that simply downweighting heavier vehicles would *not* effectively address the compatibility issue. Thus, there are no currently available analyses that would allow NHTSA or anyone to quantify the compatibility benefits simply from weight reduction.

Comment: **Natural Resources Defense Council** (2008-0089-225.1)

They discuss information from the Wenzel and Ross study. NHTSA's own 2003 study demonstrates that safety would have improved if drivers had shifted from LTVs to passenger cars. Crossover SUVs have lower fatality risk than truck-based SUVs.

Agency response: This appears to be correct, based on fatal crashes per million registration years. However, the statistics presented by Wenzel and Ross should be viewed with caution because they have not been adjusted for differences in driver age and gender, urbanization and geographical region, and average miles driven per year. The unadjusted data certainly tends to favor the lighter cars while making pickup trucks look worse. It may also favor crossover SUVs if they are more popular with female drivers in urban areas of low-fatality States (relative to truck-based SUVs).

Comment: The "crossover weight" for LTVs, estimated at 5,084 pounds in NHTSA's 2003 study, will decrease over time as crash-avoidance measures such as ESC reduce single-vehicle crashes (where weight and size helps) relative to multivehicle crashes (where weight and size in the big LTV increases harm in the vehicles hit by that LTV). By restricting weight reduction to vehicles weighing 5,000 pounds or more, NHTSA is limiting the cost-effective measures that manufacturers can use to improve fuel economy.

Agency response: Wenzel and Ross' argument appears to be directionally correct. We should note, however, that weight reduction is not restricted to any particular group of vehicles. Manufacturers may reduce weight in any vehicles they want, and will be more inclined to do so if ESC reduces hazards associated with instability of lighter vehicles. The PRIA only uses the 5,000 pound criterion to determine where NHTSA believes standards can and should be more stringent than what can be achieved by cost-effective weight-neutral technologies alone.

Comment: Wenzel and Ross question the relationship between weight and safety in NHTSA's 2003 report. NHTSA's computation of the 5,000 pound crossover weight for LTVs is based on existing vehicles, and does not take into account future down-weighting, without downsizing, using lightweight high-strength materials.

Agency response: This argument appears to be directionally correct. Material substitution would presumably have less effect in single-vehicle crashes than traditional downsizing, and that could shift the crossover weight downward. But that has yet to be proven.

Comment: **Sierra Club** (2008-0089-0226.1)

Weight reduction across all vehicles is a safe and effective strategy for improving fuel economy.

Agency response: This is a persistent misconception. Fatality risk will increase in single-vehicle crashes if a given vehicle is reduced in weight, regardless what happens to other vehicles on the road. In multivehicle crashes, there is some improvement in compatibility if vehicle weights are more uniform, but there is also an overall increase in crash risk when weights are reduced across the board.

Comment: The relationship between weight and fatality risk in the 2003 report, based on the actual fatality rates of 1991-1999 vehicles across the spectrum from light to heavy, overstates the harm if weight is reduced by substitution of strong, lightweight materials.

Agency response: This argument appears to be directionally correct. Material substitution would presumably have less effect in single-vehicle crashes than weight reduction achieved by downsizing. However, we cannot quantify this future effect, because we have no crash data yet on these future vehicles. We should also note that one of the reasons for higher fatality rates in lighter cars is that they are more crash-prone, even in non-rollover crashes. We do not yet understand why this is, and therefore we cannot conclude that weight reduction through material substitution will be less harmful than other forms of weight reduction in this regard.

Views of Other Government Agencies

After our proposal was published and after the comment period had closed for the proposal, EPA published an Advance Notice of Proposed Rulemaking (ANPRM) on regulating greenhouse gas emissions under the Clean Air Act.[84] The ANPRM was accompanied by a Vehicle Technical Support Document – Mobile Source.[85] The Technical Support Document contains a discussion on pp. 15 -17 of the safety issues. EPA provided a brief summary of the issues involved and cited no new work in that area.

Agency response: The work cited by EPA has already been addressed by NHTSA within the Regulatory Impact Analysis discussion of the 2002 NAS study and within NHTSA's responses to other comments to the NPRM docket regarding the Wenzel and Ross study.

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[84] 73 FR 44354 (July 30, 2008).
[85] Docket No. EPA-HQ-OAR-2008-0318-0084.

Footprint and safety

The impact of CAFE standards on motor vehicle and passenger safety has long been recognized as an integral part of the agency's process of determining maximum feasible average fuel economy. The agency notes that there are no compelling studies that quantify the precise and separate effects of vehicle size and weight on safety, in part because there is a high degree of correlation between size and weight among vehicles now in widespread use. The agency has determined that an attribute system based on footprint with the continuous function would minimize incentives for design changes that would reduce motor vehicle safety. In a weight-based system, a manufacturer can add weight to a vehicle in order to take advantage of a category with a lower fuel economy target. As discussed above, this up-weighting can have positive and negative safety implications, with possibly negative impacts for the fleet as a whole if weight is added to heavier light trucks. A manufacturer could not as readily increase footprint as it could vehicle weight.

In order to increase footprint, a manufacturer would have to either extend a vehicle's track width, wheelbase, or both. Maintaining and increasing track width should play a positive role in limiting rollover vulnerability, whereas maintaining and increasing wheelbase should play a positive role in improving handling – especially directional stability, which is crucial in preventing unintended off-road excursions that often lead to rollovers – and maximizing crush space (though total length is probably more closely correlated with crush space than is wheelbase).

This is mentioned in Dr. Kahane's response to safety studies submitted by Dynamic Research, Inc., by Marc Ross (University of Michigan) and Tom Wenzel (Lawrence Berkeley National Laboratory), and submitted by William E. Wecker Associates.
Dr. Kahane wrote:

> ”The objective of the NHTSA study was to calibrate the historical (MY 1991-99) relationships of vehicle mass and fatality risk, after controlling for driver age/gender, geographical location, and vehicle equipment. In this type of analysis, "vehicle mass" incorporates not only the effects of mass per se but also the effects of many other size attributes that are historically and/or causally related to mass, such as wheelbase, track width and structural integrity. (As vehicles get longer and wider, they almost always get heavier.)
>
> The study does not claim that mass per se is the specific factor that increases or decreases fatality risk (except in its role in determining the relative Delta V of two vehicles that collide). On the contrary, Chapter 5 of the NHTSA report shows that certain 4,000-pound SUVs have significantly higher fatal-crash rates than 3,500-pound cars. The study only shows the historical relationship between mass – taking into account all the other size attributes that have typically varied with mass – and fatality risk, for vehicles of the same type. If historical relationships between mass and other size attributes continue, in the absence of compelling reasons that would change those relationships, future changes in mass are likely to be associated with similar changes in fatality risk. (However, the increased use of advanced restraint systems and sophisticated crash avoidance safety devices in recent and future production vehicles could have a noticeable impact on the historical relationship between vehicle mass and fatality risk in future vehicle fleets.)

> In that sense, it is irrelevant whether mass, wheelbase, track width or some other attribute is the principal causal factor on fatality risk. If you decrease mass, you will also tend to reduce wheelbase, track width and other dimensions of size. If manufacturers respond to this proposal by building lighter vehicles of constant size, the historical relationship between mass and safety would gradually weaken."

Changes in technology could influence the relationship between weight and size. There is emerging evidence that vehicle weight can be reduced without reductions in size or safety through the use of high strength, lightweight materials. Currently, we do not observe many vehicles built with lightweight materials in the historical data and therefore cannot separate the impact of size versus weight when lightweight materials are utilized. However, the impact of weight, whether it comes from reducing size or material substitution, will be the same for single vehicle impacts (rollovers and fixed and non-fixed object impacts).

Attribute-based standards eliminate the incentive for manufacturers to respond to CAFE standards in ways harmful to safety.[86] Because each vehicle model has its own target (based on the attribute chosen), attribute-based standards provide no incentive to build smaller vehicles simply to meet a fleet-wide average, because the smaller vehicles will be subject to more stringent fuel economy and emissions targets.

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[86] The 2002 NAS Report, on which NHTSA relied in reforming the CAFE program for light trucks, 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* National Academy of Sciences, "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards," ("NAS Report") National Academy Press, Washington, DC (2002), 5, finding 12. *Available at* http://www.nap.edu/openbook.php?record_id=10172&page=R1 (last accessed Dec. 2, 2007).

Fuel Economy Impacts of Other Government Emission Standards

Federal Motor Vehicle Emissions Standards

As discussed above, because the addition of weight to a vehicle is only relevant to its ability to achieve the MY 2011 CAFE standards if it occurs in that timeframe, NHTSA only considers Federal motor vehicle emissions standards that become effective during the timeframe.

In the NPRM, NHTSA explained that on December 27, 2007, EPA published a final rule for fuel economy labeling that employs a new vehicle-specific, 5-cycle approach to calculating fuel economy labels which incorporates estimates of the fuel efficiency of each vehicle during high speed, aggressive driving, air conditioning operation and cold temperatures into each vehicle's fuel economy label.[87] The rule took effect starting with MY 2008, and will not impact CAFE standards or test procedures, or add weight to a vehicle or directly impact a manufacturer's ability to meet the CAFE standards. It will, however, allow for the collection of appropriate fuel economy data to ensure that existing test procedures better represent real-world conditions, and provide consumers with a more accurate estimate of fuel economy based on more comprehensive factors reflecting real-world driving use.

CARB commented that the NPRM had not addressed certain federal and California emissions regulations that NHTSA had analyzed in previous rulemakings, and stated that "NHTSA must analyze the potential effect of these emissions regulations on its proposed standards." CARB further stated that "the NPRM must analyze the impact of California's ZEV regulations through at least MY 2011," which the commenter stated would "require NHTSA to consider the impact of rapidly shifting technologies that manufacturers will apply to meet a combination of government mandates and market conditions, most notably the electrification of vehicle drivetrains."[88]

In response, NHTSA reiterates that emissions standards that are completely phased in before MY 2011 are already accounted for in the agency's baseline for this rulemaking. EPA's "Tier 2" standards, which apply to all vehicles currently subject to CAFE and are designed to focus on reducing the emissions most responsible for the ozone and particulate matter (PM) impact from these vehicles, are scheduled to be completely phased in by 2009.[89] EPA's onboard vapor recovery (ORVR) system standards, which apply to all passenger cars and light trucks below 8,500 pounds GVWR, were completely phased in by MY 2008.[90] Thus, there is no additional effect of these emissions regulations on MY 2011 vehicles for NHTSA to analyze, beyond what manufacturers have already included in their product plans in order to comply with these regulations, which NHTSA already accounts for.[91]

NHTSA agrees with CARB, however, that portions of the ZEV standards come into effect during MY 2011, although compliance with these standards is also already accounted for in

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[87] *See* 71 FR 77872 (Dec. 27, 2006).
[88] CARB comments at 10-11, Docket No. NHTSA-2008-0089-0173.
[89] *See* 65 FR 6698 (Feb. 10, 2000).
[90] *See* 59 FR 16262 (Apr. 6, 1994).
[91] Additionally, in calculating criteria pollutant emissions factors for analyzing air quality impacts, MOBILE6.2 accounted for EPA's emission control requirements for passenger cars and light trucks, including exhaust (tailpipe) emissions, evaporative emissions, and the Tier 2 program. *See* FEIS § 3.3.2.

manufacturers' product plans and thus forms part of NHTSA's baseline analysis. The State of California has established several emission requirements under section 209(b) of the Clean Air Act as part of its Low Emission Vehicle (LEV) program. California initially promulgated these section 209(b) standards in its LEV I standards, and has subsequently adopted more stringent LEV II standards, also under section 209(b). The relevant LEV II regulations have been completely phased in for passenger cars and light trucks as of MY 2007.

The LEV II Program has requirements for "zero emission vehicles" (ZEVs) that apply to passenger cars and light trucks up to 3,750 pounds loaded vehicle weight (LVW) beginning in MY 2005, while trucks between 3,750 and 8,500 pounds are phased in to the ZEV regulation from 2007-2012. The ZEV requirements begin at 10 percent of vehicles sold by a manufacturer in California in 2005, and ramp up to 16 percent for 2018 under different paths. California will allow the 16 percent requirement to be met by greater numbers of "partial ZEVs" until 2018, which include ultra-clean gasoline-engine vehicles and hybrids.

Compliance with the ZEV requirements is most often achieved through more sophisticated combustion management, frequently involving some of the technologies considered by NHTSA in its analysis. The associated improvements and refinement in engine controls generally improve fuel efficiency and have a positive impact on fuel economy.[92] However, such gains may be diminished because the advanced technologies required by the program can affect the impact of other fuel economy improvements, primarily due to increased weight. The agency has considered this potential impact in our evaluation of manufacturer product plans, many of which voluntarily identified particular models as ZEV or PZEV-compliant. This indicates to NHTSA that the manufacturers have already included compliance with these standards in their product plans, which in turn indicates that compliance with these standards is already accounted for in the agency's baseline.

[92] NESCAUM, "White Paper: Comparing the Emissions Reductions of the LEV II Program to the Tier 2 Program," October, 2003.

V. FUEL ECONOMY ENHANCING TECHNOLOGIES AND THE VOLPE MODEL

A. The Volpe Model

In developing today's final CAFE standards, NHTSA has made significant use of results produced by the CAFE Compliance and Effects Model (commonly referred to as the Volpe model), which DOT's Volpe National Transportation Systems Center developed specifically to support NHTSA's CAFE rulemakings.

As discussed above, the agency has used the Volpe model to estimate the extent to which 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.

The model also calculates the costs, effects, and benefits of technologies it estimates could be added in response to a given CAFE standard. It calculates costs by applying the cost estimation techniques discussed above and by accounting for the number of affected vehicles. It 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, the vehicle survival and mileage accumulation forecasts, the rebound effect estimate and the fuel properties and emission factors. Considering changes in travel demand and fuel consumption, the model estimates the monetized value of accompanying benefits to society, as discussed in Chapter VIII. The model calculates both the current (*i.e.*, undiscounted) and present (*i.e.*, discounted) value of these benefits.

The Volpe model has other capabilities that facilitate the development of a CAFE standard. It can be used to fit a mathematical function forming the basis for an attribute-based CAFE standard, following the steps described below. It 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. 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.

Nothing in EPCA requires NHTSA to use the Volpe model. In principle, NHTSA could perform all of these tasks through other means. For example, in developing the MY 2011 standards promulgated today, the agency did not use the Volpe model's curve fitting routines, because they could not be modified in time to implement the changes discussed below to this aspect of the agency's analysis. In general, though, these model capabilities greatly increase the agency's ability to rapidly, systematically, and reproducibly conduct key analyses relevant to the formulation and evaluation of new CAFE standards.

NHTSA received comments from the Alliance and CARB encouraging NHTSA to examine the usefulness of other models. Examples of other models and analyses that NHTSA and Volpe Center staff have considered for the final rule include DOE's NEMS, Oak Ridge National Laboratory's (ORNL) Transitional Alternative Fuels and Vehicles (TAFV) model, Sierra Research's VEHSIM model and the California Air Resources Board's (CARB) analysis supporting California's adopted greenhouse gas emissions standards for light vehicles.

DOE's NEMS represents the light-duty fleet in terms of five car "manufacturers" and four truck "manufacturers," twelve vehicle market classes (*e.g.*, "standard pickup"), and sixteen powertrain/fuel combinations (*e.g.*, methanol fuel-cell vehicle). Therefore, as currently structured, NEMS is unable to estimate manufacturer-specific implications of attribute-based CAFE standards. The analysis of manufacturer-specific implications is useful in setting the standard, because any given standard will have differential impacts on individual manufacturers, depending on the composition of their vehicle fleets. In order to balance national-level costs and benefits, assessment of individual manufacturer's costs and compliance strategies is appropriate.[93]

TAFV accounts for many powertrain/fuel combinations, having been originally designed to aid understanding of possible transitions to alternative fueled vehicles, but it also represents the light duty fleet as four aggregated (*i.e.*, industry-wide) categories of vehicles: small cars, large cars, small light trucks, and large light trucks. Thus, again, as currently structured, TAFV is unable to estimate manufacturer-specific implications of attribute-based CAFE standards.

Sierra Research's vehicle simulation model, VEHSIM, which was originally developed by General Motors, calculates the fuel economy for a specified vehicle design over a specified driving cycle. Despite theoretical advantages in terms of explicit representation of physical phenomena underlying fuel consumption, VEHSIM has significant shortcomings as a tool for model-by-model evaluation of the *entire future* light vehicle fleet. Although submitted after the close of the comment period specified in the NPRM, comments by several state Attorneys General and other state and local official questioned the need and merits of full vehicle simulation within the context of CAFE analysis, stating that

> Computer simulation models such as VEHSIM are not practical except perhaps during vehicle development to determine the performance of specific vehicle models where all vehicle engineering parameters are known and can be accounted for in the inputs to the model. Such an exercise is extremely data intensive, and extending it to the entire fleet

[93] In principle, if all manufacturers freely traded fuel economy credits among themselves, fleetwide estimates of compliance costs and benefits would approximate the sum of individual manufacturer costs and benefits. However, major manufacturers have repeatedly indicated that they do not intend to trade credits, and statutory language prohibits NHTSA from considering the benefits of trading in setting standards.

> makes it subject to multiple errors unless the specific parameters for each vehicle model are known and accounted for in the model inputs.[94]

Nevertheless, the Volpe model could, in principle, be modified to use VEHSIM or any other vehicle simulation tool to estimate fuel consumption. However, in practice, NHTSA and Volpe Center staff are skeptical that doing so will be either feasible or meaningful as long as CAFE analysis continues to be informed by forecasts of the future vehicle market—forecasts that, though detailed, will not foreseeably contain the extensive information needed to perform full vehicle simulation. The information required for full vehicle simulation is not only exponentially greater than NHTSA currently requests of manufacturers, but for future vehicles, the information may not yet exist, as manufacturers may not have completed the design of future vehicles.

CARB's analysis of light vehicle GHG emissions standards uses two levels of accounting. First, based on a report prepared for NESCCAF, CARB represents the light-duty fleet in terms of five "representative" vehicles, each with engineering properties estimated by CARB to meaningfully typify the engineering characteristics of a given type of vehicle (*e.g.*, small cars). NHTSA is concerned that such a limited a number of such vehicles does not reasonably represent the engineering properties of individual vehicle models that vary widely both among manufacturers and within manufacturers' individual fleets. This concern was reflected in comments by the Alliance. For each of these five vehicles, NESCCAF's report contains the results of full vehicle simulation given several pre-specified technology "packages." Second, to evaluate manufacturer-specific regulatory costs, CARB represents each manufacturer's fleet as two average test weights, one for each of California's two proposed regulatory classes. Even for a flat standard such as that considered by California, NHTSA is concerned that this level of aggregation would hinder reasonable estimation of compliance costs faced by individual manufacturers. Further, use of CARB's methods would not enable NHTSA to estimate manufacturer-specific implications of the attribute-based CAFE standards. Under an attribute-based standard, the CAFE level required of a given manufacturer depends on the specific mix of vehicles sold by that manufacturer, not the average properties of that manufacturers' fleet. As noted above, it is useful to estimate national level costs and benefits of a standard applied at the level of individual manufacturer's fleets by assessing individual manufacturer's costs and compliance strategies.

On the other hand, NHTSA recognizes that a more aggregated representation of the fleet—such as CARB's five-vehicle approach—may be the only way that full vehicle simulation could be integrated into CAFE analysis. Although NHTSA has not yet been able to conduct an analysis with the advantages of both detailed representation of

[94] Attorneys General of the States of California, Arizona, Connecticut, Illinois, Maryland, Massachusetts, New Jersey, New Mexico, Oregon, and Vermont, the Executive Officer of the California Air Resources Board, the Commissioner of the New Jersey Department of Environmental Protection, the Secretary of the New Mexico Environment Department, the Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and the Corporation Counsel of the City of New York, *Supplemental Comments Regarding Alliance of Automobile Manufacturers Comments*, Docket No. NHTSA-2008-0089-0495, October 8, 2008, p. 3.

manufacturers' fleets and full integration of full vehicle simulation, the agency cannot rule out the possibility of such an analysis in the future.

Although the Volpe model has limitations, having considered other tools and analytical approaches, NHTSA concludes that for this final rule, the Volpe model is a sound and reliable tool available for the development and evaluation of potential CAFE standards. However, the agency will continue to consider other methods for evaluating potential CAFE standards in the future as well as to examine ways to improve the Volpe model.

NHTSA notes that some commenters questioned the transparency of the Volpe model, which Public Citizen and the Center for Biological Diversity (CBD) referred to as a "black box." In response to these comments, the agency notes that model documentation, which is publicly available in the rulemaking docket, explains how the model is installed, how the model inputs (all of which, except for manufacturers' confidential product plans, are available to the public) 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 and the Microsoft .NET framework installed (the latter available without charge from Microsoft). The executable version of the model is available upon request, and has been provided to manufacturers, consulting firms, academic institutions, governmental and nongovernmental organizations, research institutes, foreign government officials, and a variety of other organizations. The current version of the model was developed using Microsoft Development Environment 2003, and every line of computer code (primarily in C#.NET) has been made available to individuals who have requested the code. With the code, anyone is capable of running the model using market forecast data that they obtain or estimate on their own. Given the comprehensive disclosure of information about the Volpe model and the fact that many entities and individuals have made use of it, the characterization of the Volpe model as a "black box" is not accurate.

Although NHTSA currently uses the Volpe model as a tool to inform its consideration of potential CAFE standards, contrary to the assertions of some commenters, the Volpe model does not determine the CAFE standards 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. In addition to identifying the input assumptions underlying its decisions, NHTSA provides the rationale and justification for selecting those inputs. NHTSA also determines whether to use the model to estimate at what stringency net benefits are maximized, or to estimate other stringency levels, such as the point where total costs equal total benefits. NHTSA also determines whether to use the model to evaluate the costs and effects of stringencies that fall outside of the scope of maximum feasible. For example, the standards for the "Technology Exhaustion" Alternative examined by NHTSA and discussed later in this section, were estimated outside the model, which was subsequently used to estimate corresponding costs and effects.[95] Finally, NHTSA is guided by the statutory requirements of EPCA as amended by EISA in the ultimate selection of a CAFE standard.

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[95] By definition, the "maximum technology" scenario far exceeds the maximum feasible CAFE standard.

NHTSA does not agree with Public Citizen that the agency "does not establish what is technologically feasible and economically practicable based on an independent assessment of the current vehicle fleet and the available technology to improve the fleet, but rather accepts industry inputs, which are run through the black box of the Volpe model and a variety of 'optimization' factors, which are tied to maximizing industry-wide benefits." The manufacturers' plans are only the starting point for the agency's determination of how much technology can and should be required consistent with the statutory factors, and the Volpe model is often tested using inputs developed without reliance on manufacturers' product plans. NHTSA considers the results of analyses conducted by the Volpe model and analyses conducted outside of the Volpe model, including analysis of the impacts of carbon dioxide and criteria pollutant emissions, analysis of technologies that may be available in the long term and whether NHTSA could expedite their entry into the market through these standards, and analysis of the extent to which changes in vehicle prices and fuel economy might affect vehicle production and sales. Using all of this information—not solely that from the Volpe model—the agency considers the governing statutory factors, along with environmental issues and other relevant societal issues such as safety, and promulgates the maximum feasible standards based on its best judgment on how to balance these factors.

This is why the agency considered seven regulatory alternatives, only one of which maximizes net benefits based on the agency's determination and assumptions. The others assess alternative standards that in many cases exceed the point at which net benefits are maximized. These comprehensive analyses, which also included scenarios with different economic input assumptions as presented in the FEIS and FRIA, are intended to inform and contribute to the agency's consideration of the "need of the United States to conserve energy," as well as the other statutory factors. 49 U.S.C. § 32902(f). Additionally, the agency's analysis considers the need of the nation to conserve energy by accounting for economic externalities of petroleum consumption and monetizing the economic costs of incremental CO_2 emissions in the social cost of carbon. As mentioned above, NHTSA will continue to consider other methods for determining future CAFE standards in future rulemakings.

NHTSA retained the constrained logistic function for the final rule. The considerations included:

- A relatively flat standard for larger vehicles acts as a de facto 'backstop' for the standard in the event that future market conditions encourage manufacturers to build very large vehicles. Nothing prevents manufacturers from building larger vehicles. With a logistic curve, however, vehicles upsizing beyond some limit face a flat standard that is increasingly difficult to meet.

- A constrained logistic curve doesn't impose unachievable fuel economy standards on vehicles that have unusually small footprints, thus continuing to keep manufacturing fuel-efficient small vehicles available as a compliance option. Infeasible sections of the curve may be unimportant for the industry at large while having a particular adverse impact on manufacturers that specialize in very large or small vehicles, for example, two-seater sports car.

- The transition from the 'flat' portions of the curve to the 'slope' portions of the curve is smooth and gradual, reducing the incentive for manufacturers to achieve compliance through marginal changes in vehicle size.

- The inflection points are set by the data and can potentially vary from year to year, rather than being chosen by NHTSA.

NHTSA retained footprint as the attribute for purposes of this rulemaking's attribute-based standards in part because we believed changing a vehicle's footprint would involve significant costs for manufacturers, probably requiring a redesign of the vehicle. Congress recently mandated that NHTSA set attribute-based fuel economy standards "and express each standard in the form of a mathematical function."[96] NHTSA uses a continuous, constrained logistic function for expressing the passenger car and light truck standards, which takes the form of an S-curve, and is defined according to the following formula:

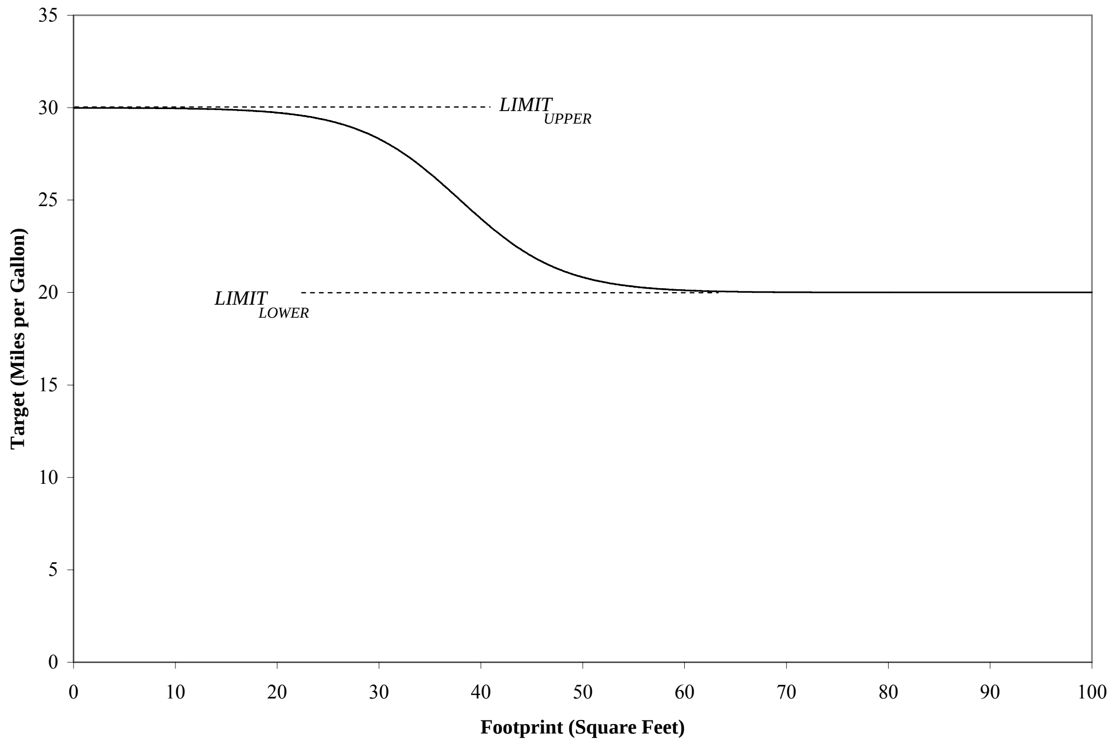
$$TARGET = \frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\frac{e^{(FOOTPRINT-c)/d}}{1+e^{(FOOTPRINT-c)/d}}}$$

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), *e* is approximately equal to 2.718,[97] *c* is the footprint (in square feet) at which the inverse of the fuel economy target falls halfway between the inverses of the lower and upper asymptotes, and *d* is a parameter (in square feet) that determines how gradually the fuel economy target transitions from the upper toward the lower asymptote as the footprint increases. Figure V-1 below shows an example of a logistic target function, where *b* = 20 mpg, *a*= 30 mpg, *c* = 40 square feet, and *d* = 5 square feet:

[96] 49 U.S.C. § 32902(a)(3)(A).

[97] *e* is the irrational *number* for which the slope of the function $y = number^x$ is equal to 1 when *x* is equal to zero. The first 8 digits of *e* are 2.7182818.

Figure V-1. Sample Logistic Curve



***Continuous function*:**

NHTSA explained in the NPRM that it examined the relative merits of both step functions and continuous functions in its rulemaking for MY 2008-2011 light trucks, and described the agency's rationale for choosing a continuous function for the CAFE program. A step function, in the CAFE context, would separate the vehicle models along the spectrum of attribute magnitudes into discrete groups, and each group would be assigned a single fuel economy target, so that the average of the groups would be the average fleet fuel economy. A continuous function, in contrast, would assign each vehicle model (and indeed, any vehicle model at any point along the spectrum) its own unique fuel economy target, based on its particular attribute magnitude. Thus, two vehicles models built by different manufacturers could have the same fuel economy target, but only if they had identical magnitudes of the attribute. In other words, a continuous function is a mathematical function that defines attribute-based targets across the entire range of possible attribute values. These targets are then applied through a harmonically-weighted formula to derive regulatory obligations for fleet averages.

The agency fit the fuel economy curves for this final rule for MY 2011 according to the following four step procedure:

In Step 1, NHTSA determined the fuel economies obtained by exhausting available technologies on each vehicle in the MY 2011 updated product plans of the seventeen manufacturers to which the standards apply (BMW, Chrysler, Daimler, Ferrari, Ford, General Motors, Honda, Hyundai, Maserati, Mitsubishi, Nissan, Porsche, Subaru, Suzuki, Tata, Toyota, Volkswagen). In exhausting technologies, the agency has focused this Step on the engineering aspects of available technologies, essentially setting aside economic considerations.

In Step 2, NHTSA determined initial values for parameters *A* and *B* for each vehicle type (passenger car and light truck) as follows. (The values of these parameters will be revised in Step 4.) For passenger cars (respectively, light trucks), NHTSA set the initial value of the parameter *A* to be the harmonic average fuel economy among the vehicles of the given vehicle type (produced by the seventeen manufacturers used Step 1) comprising the lower tenth (respectively, tenth) percentile of footprint values. NHTSA set the initial value of *B* to be the harmonic average fuel economy among the vehicles of the given vehicle type (produced by the seventeen manufacturers) comprising the upper ninth (respectively, sixth) percentile of footprint values. NHTSA set *A* and *B* in this manner, rather than fitting them, for example, through regression, in order to ensure that the upper and lower fuel economy values reflect the smallest and largest models in the fleet. NHTSA chose the percentile values it used by examining the fuel economies of the largest and smallest car and truck models, and determining its best assessment of appropriate cohorts, acknowledging that there are no canonical choices.

Figure V-2
Distribution of Passenger Car Footprint Values

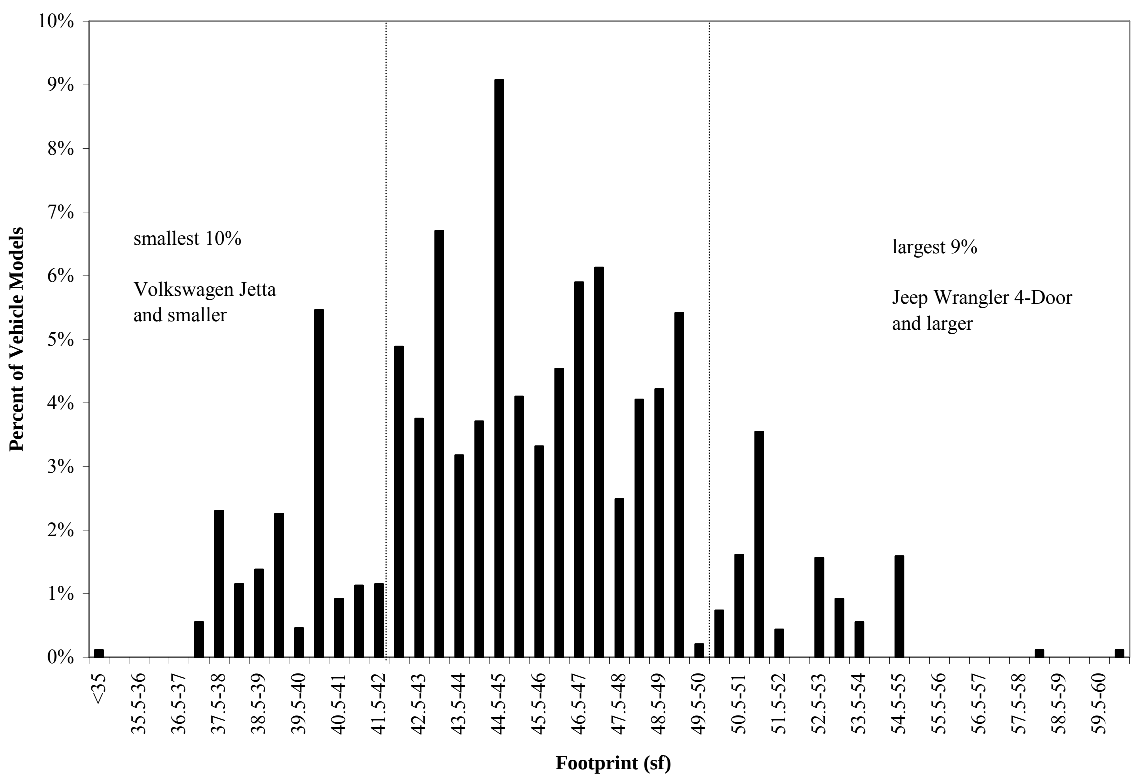
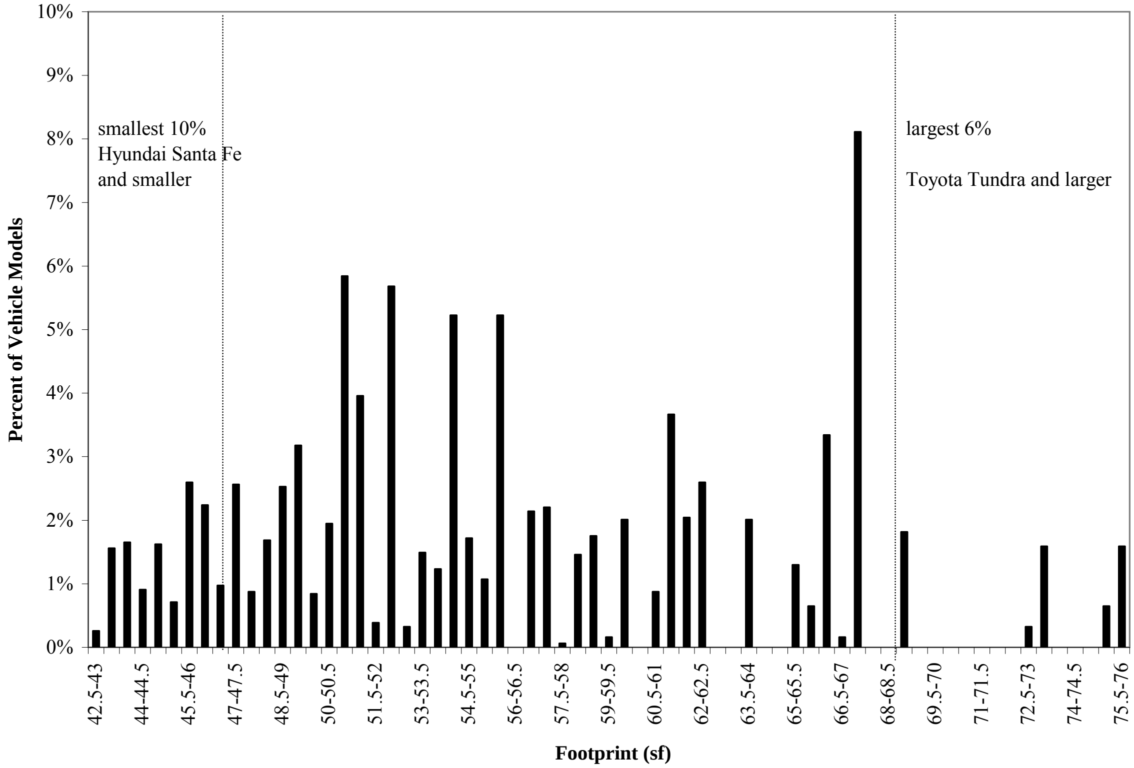


Figure V-3
Distribution of Light Truck Footprint Values



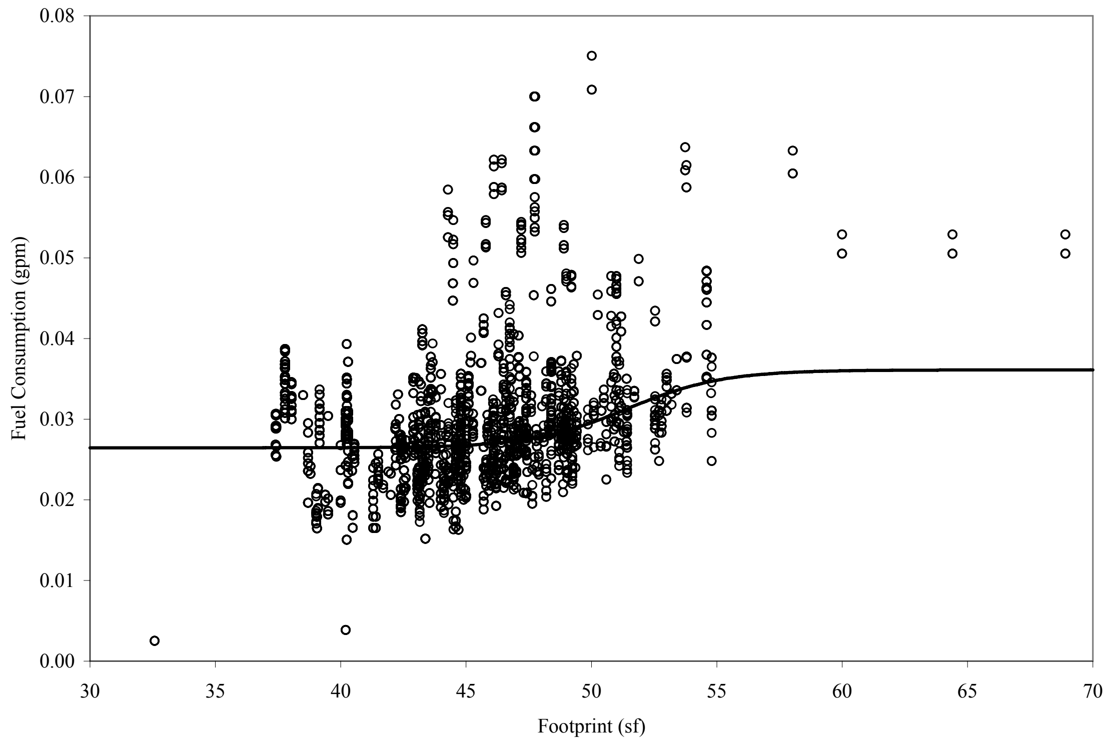
In Step 3, NHTSA determined initial values for parameters *C* and *D* for each vehicle type as follows. For a given vehicle type, NHTSA set the initial values of *C* and *D* to be the values for which the average (equivalently, sum) of the absolute values of the differences between the optimized fuel consumption from Step 1 for the given vehicle type and the values obtained by applying the following function

$$f(x) = \frac{1}{A} + \left(\frac{1}{B} - \frac{1}{A}\right)\frac{e^{(x-C)/D}}{1+e^{(x-C)/D}}$$

to the corresponding vehicle footprints is minimal, where the values of *A* and *B* are taken from those determined in Step 2 and where *e* denotes the base of the natural logarithm (which is approximately equal to 2.71828). That is, NHTSA determined *C* and *D* by minimizing the average absolute residual, commonly known as the MAD (Mean Absolute Deviation) approach, of the corresponding constrained logistic curve. NHTSA fit the curve in fuel consumption space rather than fuel economy space because the manufacturer targets are in terms of the harmonic average fuel economy, and so it is more important that the curve fit the fuel consumption data well than that it fit the fuel economy data well. NHTSA uses MAD in this Step instead of minimizing the sum of the square errors (another common approach in curve fitting) in order to lessen the influence of outliers. NHTSA believes that it is more appropriate to use unweighted data in fitting the curve rather than weighting the data by sales because of large variations in model sales and because each vehicle model contributes an equal amount of information to understanding the underlying relationship between fuel economy and footprint.

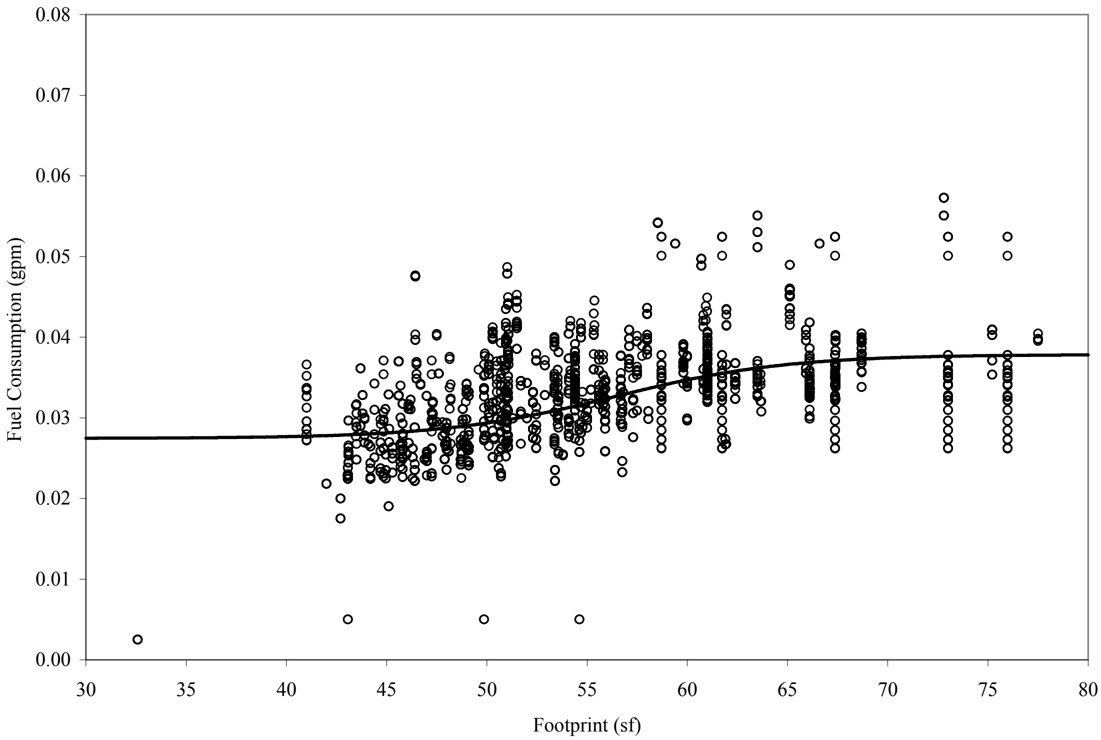
For passenger cars, this procedure yielded a curve with the following coefficients: *A* = 37.82 mpg, *B* = 27.70 mpg, *C* = 51.41 square feet, *D* = 1.91 square feet. This curve, shown below on a fuel consumption (*i.e.*, gpm) basis, produced an average absolute difference of 18 percent.

Figure V-4
Fitted Curve for Passenger Cars



For light trucks, the same procedure yielded a curve with the following coefficients: *A* = 36.43 mpg, *B* = 26.43 mpg, *C* = 56.41 square feet, and *D* = 4.28 square feet. This curve, shown below on a fuel consumption (*i.e.*, gpm) basis, produced an average absolute difference of 14 percent.

Figure V-5
Fitted Curve for Light Trucks



In Step 4, NHTSA determined for each model year and vehicle class the integer value of *t* that maximized the societal net benefits (considering the seventeen manufacturers to which the standards apply) achieved by a fuel economy standard under which fuel consumption targets were defined by the function

$$g(x) = \frac{1}{A} + \left(\frac{1}{B} - \frac{1}{A}\right)\frac{e^{(x-C)/D}}{1+e^{(x-C)/D}} + 0.0001t$$

using the values of *A* and *B* determined in Step 2, and the values of *C* and *D* determined in Step 3.[98] NHTSA reset the values of 1/*A* and 1/*B* to be 1/*A* + 0.0001*t* and 1/*B* + 0.0001*t*, respectively. That is, NHTSA set the stringency of the curves to maximize societal net benefits.

Parameter Values of the Fuel Economy Curves in This Final Rule

	Parameter Values for Passenger Cars				Parameter Values for Light Trucks			
Model	A	B	C	D	A	B	C	D
2011	31.20	24.00	51.41	1.91	27.10	21.10	56.41	4.28

The corresponding target functions are presented below graphically, and on a mile per gallon basis, for both passenger cars and light trucks:

[98] This procedure uniformly shifts the upward and downward (depending on whether *t* is positive or negative), but on the same gallon per mile basis corresponding to the harmonic averaging of fuel economy values.

Figure V-6. Final Passenger Car Target Functions

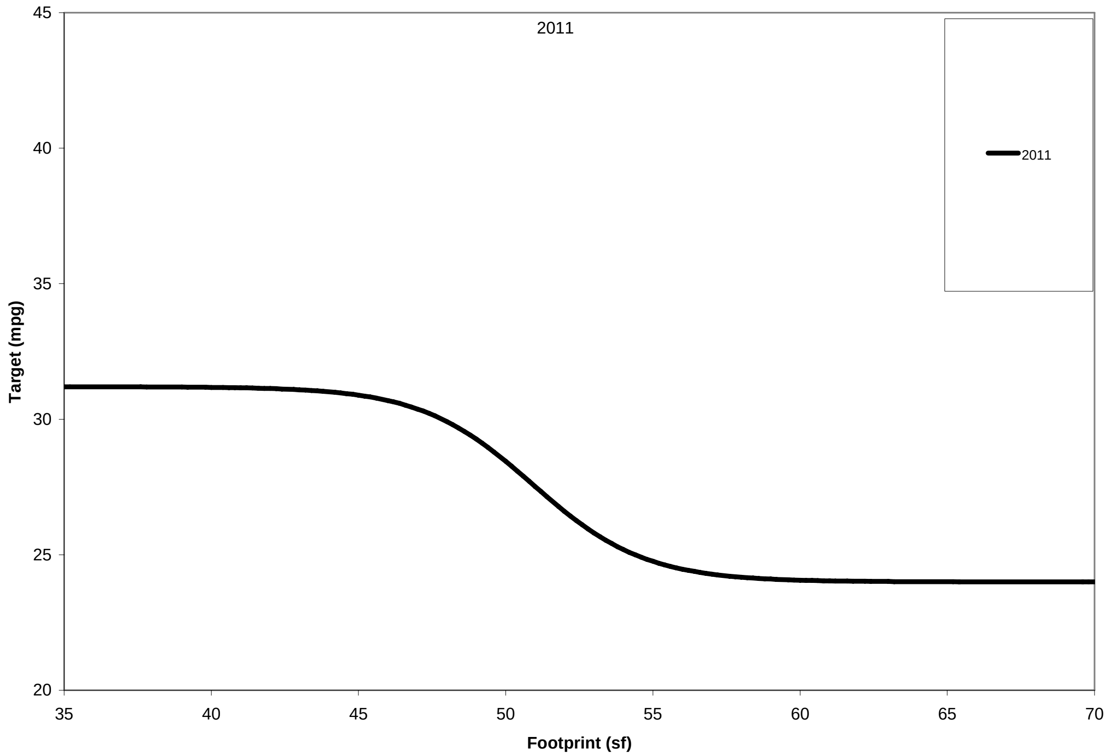
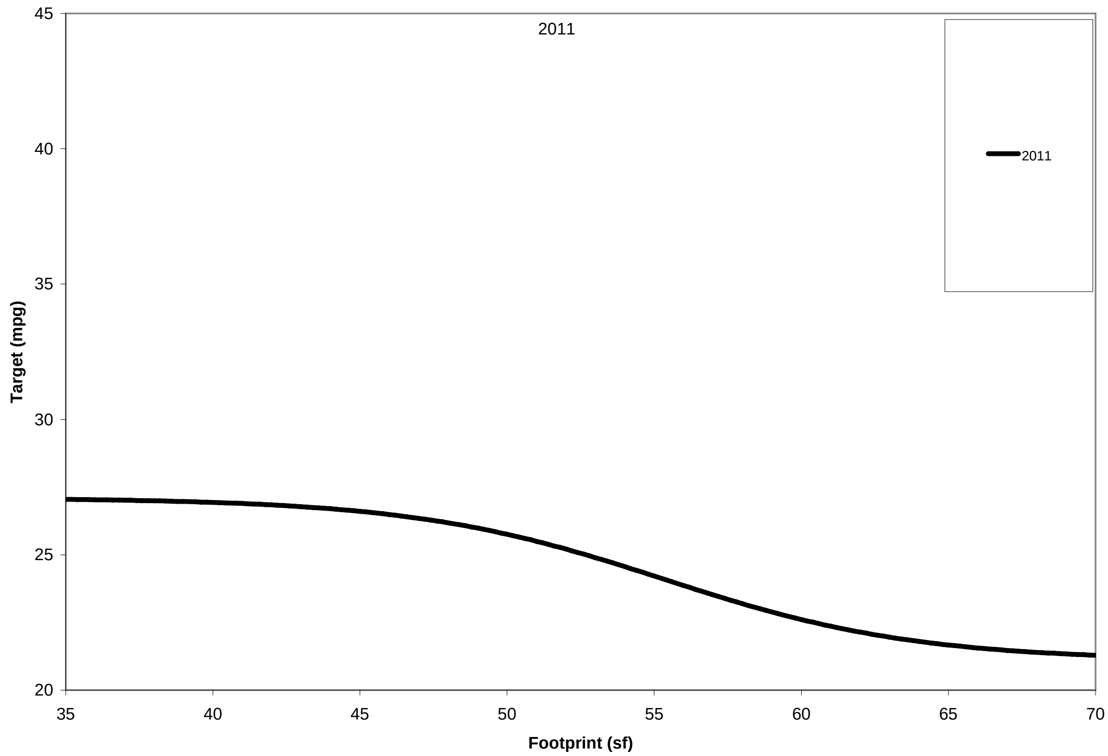


Figure V-7. Final Light Truck Target Functions



B. Technologies – Costs and Effectiveness

Fuel economy-improving technologies

As explained above, pursuant to the President's January 26, 2009 memorandum, this final rule establishes passenger car and light truck CAFE standards for one year, MY 2011. Although this final rule establishes standards for that year alone, the agency undertook a comprehensive analysis of fuel economy-improving technologies with a time horizon similar to the one considered in the 2002 National Academy of Sciences (NAS) CAFE report. Like NAS, the agency considered technologies that are readily available, well known and could be incorporated into vehicles once production decisions are made (these are referred to as "production intent" technologies). Other technologies considered, called "emerging", are beyond the research phase and under development, but are not widely used at this time. The agency did not consider technologies in the research stage because their costs and/or performance are not presently well known.

The agency has elected to include the full analysis in this final rule for several reasons. First, it supplements the analysis of fuel saving technology released by the 2002 NAS study. Second, it places in meaningful context the portion of the analysis that relates directly to MY 2011, showing which technologies are not available for that year and why. The agency typically evaluates technologies within a time context spanning more than a single model year, even if the rulemaking itself addresses only a single year as in the current rulemaking, because when manufacturers add technologies to vehicle models in order to meet CAFE standards, they tend to phase them in over several model years, consistent with vehicle redesign and refresh schedules, supplier contract procedures, the need for testing and validation of new technologies, and so forth. Consequently, although the final rule establishes standards for MY 2011 only, NHTSA believes that including the entire technology analysis will increase public understanding of the agency's estimates for MY 2011 of technology costs, effectiveness, and availability, as well as manufacturer vehicle freshening and redesign cycles.

With that in mind, the following section details the cost and effectiveness estimates completed for technologies in the production intent or emerging technology phase timeline The estimates are drawn from an analysis conducted in the summer of 2008. It relied as much as possible on published studies and confidential product plan data submitted by manufacturers on July 1, 2008 in response to the agency's NPRM request for comments published May 2, 2008. The analysis was conducted by engineers from DOT and Ricardo, an international consulting firm that specializes in automotive engineering consulting (discussed below). The engineering team used all data available at that time, along with their expert opinion to derive cost and effectiveness estimates for technologies either in production or in the emerging stage of production for purposes of this rulemaking.

The agency believes that the resulting estimates are the best available for MY 2011, given the information that existed at the time. NHTSA recognizes, however, that the analysis of and public debate over the cost and effectiveness of the various fuel saving technologies is an ongoing one. It recognizes too that aspects of its technology analysis will likely require updating or otherwise merit revision for the next CAFE rulemaking. As time progresses, new research occurs, new studies become available and product plan information changes. As with all CAFE rulemakings and pursuant to the President's memorandum, the agency will take a fresh look at all of its technology-related assumptions for the purpose of future rulemakings.

A. NHTSA analyzes what technologies can be applied beyond those in the manufacturers' product plans

One of the key statutory factors that NHTSA must consider in setting maximum feasible CAFE standards for each model year is the availability and feasibility of fuel saving technologies. When manufacturers submit their product plans to NHTSA, they identify the technologies they are planning for each vehicle model in each model year. They also provide their assessments of the costs and effectiveness of those fuel saving technologies. The agency uses the manufacturers' product plan data to ascertain the "baseline" capabilities and average fuel economy of each manufacturer. Given the agency's need to consider economic practicability in determining how quickly additional fuel saving technologies can be added to the manufacturers' vehicle planned fleets, the agency researches and develops, based on the best available information and data, its own list of technologies that it believes will be ready for implementation during the model years covered by the rulemaking. This includes developing estimates of the costs and effectiveness of each technology and lead time needs. The resultant technology assumptions form an input into the Volpe model. The model simulates how manufacturers can comply with a given CAFE level by adding technologies beyond those they planned in a systematic, efficient and reproducible manner. The following sections describe NHTSA's fuel-saving technology assumptions and methodology for estimating them, and their applicability to MY 2011 vehicles.

B How NHTSA decides which technologies to include

1. How NHTSA did this historically, and how for the NPRM

In the agency's last two CAFE rulemakings, which established light truck CAFE standards for MYs 2005-2007 and MYs 2008-2011, NHTSA relied on the 2002 National Academy of Sciences' report, "Effectiveness and Impact of Corporate Average Fuel Economy Standards"[99] ("the 2002 NAS Report") for estimating potential fuel economy effectiveness values and associated retail costs of applying combinations of technologies in 10 classes of production vehicles. The NAS study was commissioned by the agency, at the direction of Congress, in order to provide independent and peer reviewed estimates of cost and effectiveness numbers. The NAS list was determined by a panel of experts formed by the National Academy of Sciences, and was then peer-reviewed by individuals chosen for their diverse perspectives and technical expertise in accordance with procedures approved by the Report Review Committee of the National Research.

In the NPRM for the MY 2011-2015 CAFE standards, NHTSA explained that there has been substantial advancement in fuel-saving automotive technologies since the publication of the 2002 NAS Report. New technologies, *i.e.*, ones that were not assessed in the NAS report, have appeared in the market place or are expected to appear in the timeframe of the proposed rulemaking. Also, new studies have been conducted and reports issued by several other organizations providing new or different information regarding the fuel economy technologies that will be available and their costs and effectiveness values. To aid the agency in assessing these developments, NHTSA contracted with the NAS to update the fuel economy section, Chapter 3, of the 2002 NAS Report. However, as NHTSA explained, the NAS update was not available in time for this rulemaking.

Accordingly, NHTSA worked with EPA staff to update the technology assumptions, and used the results as a basis for its NPRM. EPA staff published a related report and submitted it to the NAS committee.[100]

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[99] National Research Council, "Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards," National Academy Press, Washington, DC (2002). *Available at* http://www.nap.edu/openbook.php?isbn=0309076013 (last accessed October 11, 2008).

[100] EPA Staff Technical Report: Cost and Effectiveness Estimates of Technologies Used to Reduce Light-Duty Vehicle Carbon Dioxide Emissions, EPA 420-R-08-008, March 2008.

2. NHTSA's contract with Ricardo for the final rule

NHTSA specifically sought comment on the estimates, which it had developed jointly with EPA, of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies were applied. *See* 73 FR 24352, 24367. To aid the agency in analyzing those comments and increasing the accuracy, clarity and transparency of its technology assumptions and methodologies employed in developing them, it hired an international consulting firm, Ricardo, which specializes in automotive engineering consulting. Ricardo, which describes itself as an eco-innovation technology company, is a leading independent provider of technology, product innovation, engineering solutions, software and strategic consulting. Its skill base includes the state-of-the-art in low emissions and fuel-efficient powertrain and vehicle technology. Its customers include government agencies here and abroad and the world's automotive, transport and new-energy industries.[101] For example, it has provided technical consulting on low CO_2 strategies to the UK Department for Transport (DfT).[102] Additionally, in December 2007, Ricardo completed an important study for EPA titled "A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies."[103]

Ricardo's role was as a technical advisor to NHTSA staff. In this capacity, Ricardo helped NHTSA undertake a comprehensive review of the NPRM technology assumptions and all comments received on those assumptions, based on both old and new public and confidential manufacturer information. NHTSA and Ricardo staff reviewed and compared comments on the availability and applicability of technologies, and the logical progression between them. NHTSA also reviewed and compared the methodologies used for determining the costs and effectiveness of the technologies as well as the specific estimates provided. Relying on the technical expertise of Ricardo and taking into consideration all the information available, NHTSA revised its estimates of the availability and applicability of many technologies, and revised its estimate of the order in which the technologies were applied and how they are differentiated by vehicle class, as well as the costs and effectiveness estimates and used the revised numbers in analyzing alternative levels of stringency.

While NHTSA sought Ricardo's expertise and relied significantly on their assistance as a neutral expert in developing its technical assumptions, it retained responsibility for the final estimates. The agency believes that the representation of technologies for MY 2011—that is, estimates of the availability, applicability, cost, and effectiveness of fuel-saving technologies, and the order in which the technologies were applied—used in this

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[101] More information about Ricardo's work is available at their website, http://www.ricardo.com (last accessed September 20, 2008). Its 2007 Annual Report provides a comprehensive view of some of its current work. *See* http://www.ricardo.com/investors/download/annualreport2007.pdf (last accessed September 22, 2008).

[102] Ricardo UK Ltd., "Understanding manufacturers' responses to policy measures to incentivise fuel efficiency," Oct. 5, 2007. *Available at* http://www.dft.gov.uk/consultations/closed/co2emissions/ricardoreport.pdf (last accessed Oct. 4, 2008).

[103] A slightly updated (June 2008) version of Ricardo's study for EPA is available on EPA's website, at http://www.epa.gov/otaq/technology/420r08004a.pdf (last accessed September 20, 2008).

rulemaking is more accurate than that used in the NPRM, and is the best available for purposes of this rulemaking.

C. What technology assumptions has NHTSA used for the final rule?

1. How do NHTSA's technology assumptions in the final rule differ from those used in the NPRM?

This final rule uses the same basic framework as the NPRM. However, NHTSA made several changes to its technology assumptions based on comments and information received during the rulemaking. As in the NPRM and the MY 2008-2011 light truck rule, the agency relied on the Volpe model CAFE Compliance and Effects Modeling System which was developed by the Department or Transportation's Volpe National Transportation Systems Center (Volpe Center) to apply technologies. The model, known as the Volpe model, is the primary tool the agency has used in conducting a "compliance analysis" of various CAFE stringencies. The Volpe model relied on the same types of technology related inputs as in previous rules, including market data files, technology cost and effectiveness estimates by vehicle classification, technology synergies, phase-in rates, learning curve adjustments, and technology decision trees.

Regarding the decision trees, both the structure of the trees and ordering of the technologies were revised. 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 the final rule.[104] The revised decision trees also have improved integration, accuracy, and technology representations.

In revising the decision trees, NHTSA updated, combined, split and/or renamed technologies. Several technologies were added, while others were deleted. The three technologies that were deleted because they do not appear in either public or confidential data and are primarily in the research phase of development are: Camless Valve Actuation, Lean-Burn Gasoline Direct-Injection and Homogenous Charge Compression

[104] In addition to the (simplified) decision trees, as published in this document, NHTSA also utilized "expanded" decision trees in the final rule analysis. Expanded decision trees graphically represent each unique path, considering the branch points available to the Volpe model, which can be utilized for applying fuel saving technologies. For instance, the engine decision tree shown in this document has 20 boxes representing engine technologies, whereas the expanded engine decision tree requires a total of 45 boxes to accurately represent all available application variants. Expanded decision trees presented a significant improvement, compared to the NPRM analysis, 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-2008-0177. 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 the three expanded decision trees for the Large Car subclass have been placed in the docket as an example for the reader's information.

Ignition.[105] NHTSA also added three advanced technologies based on confidential manufacturer submissions which showed these technologies as being emerging and currently under development. These technologies are: Combustion Restart, Exhaust Gas Recirculation Boost, and Plug-in Hybrids.

The Volpe model was modified to allow a non-linear phase-in rate across the five model years, rather than a constant phase-in rate as was used in the NPRM and in previous rules. Most technology applications have tighter phase-in caps in the early years to provide for additional lead time.

In the NPRM, NHTSA applied volume-based learning factors to technology costs for the first time. These learning factors were developed using the parameters of learning threshold, learning rate (decremented over two cycles), and the initial (unlearned) cost. In the NPRM, NHTSA applied a learning rate discount of 20 percent each time a technology was projected for use on 25,000 vehicles per manufacturer, which was the threshold volume for learning rate discounts. The discounts were only taken twice, at 25,000 and 50,000 vehicles. A technology was viewed as being fully learned out at 100,000 units.

The agency also reconsidered volume-based learning factors and made significant revisions. First, the volume learning is now applied on an industry basis as opposed to a manufacturer basis. This takes into account the fact that the automobile industry shares best practices and that manufacturers learn from that sharing to produce their vehicles at lower costs. For the final rule, the revised learning threshold is set to 300,000 vehicles per year by the automobile industry. This number was developed based on comments indicating that many of the publicly available technology cost estimates are based on production quantities of 900,000 to 1.5 million vehicles by at least 3 manufacturers. The agency notes, however, that none of the technologies applied in MY 2011 receive volume-based learning, due to the time frame applicable.

For the technologies applied in the final rule, a time-based learning factor was used in response to public comments from Ford and others. This learning factor was not applied in the NPRM. Time-based learning is applied to widely available, high volume, stable and mature technologies typically purchased under negotiated multi-year contractual agreement with suppliers. This type of an agreement is typical of most supplier-provided fuel saving technologies. With time-based learning, the initial cost of a technology is reduced by a fixed amount in its second and subsequent year of availability. A fixed rate 3 percent year-over-year cost reduction is applied up to a maximum of 12 percent cost reduction.

In the NPRM NHTSA divided vehicles into ten subclasses based on technology applicability: four for cars and six for trucks. NHTSA assigned passenger cars into one of the following subclasses: Subcompact, Compact, Midsize, or Large Car. NHTSA

[105] We note that GM included lean burn HCCI in its restructuring plans submitted to Congress, but the restructuring plans were submitted too late for the agency to consider them in its technology analysis, among other reasons. GM Restructuring Plan, p. 22.

assigned light trucks into one of the following subclasses: Minivan, Small SUV, Medium SUV, Large SUV, Small Pickup Truck, or Large Pickup Truck. In its 2008 NPRM for MY 2011-2015, NHTSA included some differentiation in cost and effectiveness numbers between the various classes to account for differences in technology costs and effectiveness that are observed when technologies are applied on to different classes and subclasses of vehicles.

For the final rule, NHTSA, working with Ricardo, increased the accuracy of its technology assumptions by reexamining the subclasses developed for the purpose of modeling technology application. For passenger cars, NHTSA divided vehicles into eight subclasses based on technology applicability by creating a performance class under each of the four subclasses. For trucks, NHTSA established four subclasses, including a minivan subclass, and small, midsize and large SUV/Pickup/Van subclasses. NHTSA also provided more differentiation in the costs and effectiveness values by vehicle subclass. The agency found it important to make that differentiation because the agency estimated that some technologies would have different implications for large vehicles than for smaller vehicles.

In summary, the revisions to NHTSA's methodology for technology application and cost and effectiveness estimates are designed to respond to comments, many of which focused on various inaccuracies and lack of clarity in the NPRM. NHTSA believes that the methodology for the final rule, as compared to the NPRM methodology, is much clearer, more accurate, and more representative of likely manufacturer behavior, although, of course, manufacturers are free to respond to the CAFE standards with whatever application of technology they choose. The revised technology related assumptions help substantially ensure the technological feasibility and economic practicability of the MY 2011 CAFE standards promulgated in this final rule.

2. How are the technologies applied in the model?

For the final rule, as in the NPRM, NHTSA made significant use of the CAFE Volpe model as discussed above. The NPRM contained a detailed discussion of the Volpe model and specifically stated its two primary objectives as 1) identifying technologies that manufacturers could apply in order to comply with a specified CAFE standard, and 2) calculating the cost and effects of manufacturers' technology applications. The NPRM also discussed other modeling systems and approaches that NHTSA considered to accomplish these same objectives, and also discusses why ultimately the agency chose to use the Volpe model (see 79 FR 24352, 24391). However, having done so for this final rule does not limit the agency's ability to use another approach for future CAFE rulemakings, and NHTSA will continue to consider other methods for estimating the costs and effects of adding technologies to manufacturers' future fleets.

The Volpe model relies on several inputs and data files to conduct the compliance analysis, and each of these are discussed in detail in the NPRM. Many of these inputs contain economic and environmental data required for the full CAFE analysis. However, for the purposes of applying technologies, the subject of this section, the Volpe model primarily uses three data files, one that contains data on the vehicles being manufactured, one that identifies the appropriate stage within the vehicle's life-cycle for the technology to be applied, and one that contains data/parameters regarding the available technologies the model can apply. These inputs are discussed below.

The Volpe model begins with an "initial state" of the domestic vehicle market, which in this case is the market for passenger cars and light trucks to be sold during the period covered by the final rule. The vehicle market is defined on a model, engine, and transmission basis, such that each defined vehicle model refers to a separately-defined engine and a separately-defined transmission. For the final rule, this represented roughly 5,500 cars and trucks, 700 engines, and 600 transmissions. The information, which is stored in a file called the "vehicle market forecast," is informed significantly by product plans provided to NHTSA by vehicle manufacturers.[106] However, the Volpe model does not require that the market forecast be based on confidential product plans, and the model is often tested using input files developed using only publicly- and commercially-available information. EPCA does not require NHTSA to use manufacturers' confidential product plans as a basis for setting future CAFE standards, and the agency will continue to base its market forecasts on whatever it determines is the best available information, whether from public, commercially-available, or confidential sources.

In addition to containing data about each vehicle, engine, and transmission, this file contains information for each technology under consideration as it pertains to the specific vehicle (whether the vehicle is equipped with it or not), the model year the vehicle is undergoing redesign, and information about the vehicle's subclass for purposes of technology application.

The market forecast file provides NHTSA the ability to identify, on a technology by technology basis, which technologies may already be present (manufactured) on a particular vehicle, engine, or transmission, or which technologies are not applicable (due to technical considerations) to a particular vehicle, engine, or transmission. These identifications are made on a model-by-model, engine-by-engine, and transmission-by-transmission basis. For example, if Manufacturer X advises NHTSA that Vehicle Y will be manufactured with Technology Z, then for this vehicle Technology Z will be shown as used. Or alternatively, NHTSA might conclude based on its own assessment that for a given four cylinder engine, Manufacturer A cannot utilize a particular Technology C due to an engineering issue that prohibits it. In this case, NHTSA would, in the market forecast file, indicate that Technology C should not be applied to this particular engine (*i.e.*, is unavailable). Since multiple vehicle models may be equipped with this engine, this may affect multiple models. In using this aspect of the market forecast file, NHTSA ensures the Volpe model only applies technologies in an appropriate manner, since before any application of a technology can occur, the model checks the market forecast to see if it is either already present or unavailable.

[106] The market forecast is developed by NHTSA using the product plan information provided to the agency by individual vehicle manufacturers in response to NHTSA's requests. The submitted product plans contain confidential business information (CBI), which the agency is prohibited by federal law from disclosing.

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. For instance, some technologies (*e.g.*, those that require significant revision) are nearly always applied only when the vehicle is expected to be redesigned. Other technologies can be applied only when the vehicle is expected to be refreshed or redesigned and some others 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 manufacturers' product planning practices. For each technology under consideration, NHTSA stipulates whether it can be applied any time, at refresh/redesign, or only at redesign. The data forms another input to the Volpe model, as discussed in detail below, called the Technology Refresh and Redesign Application table. Each manufacturer identifies its planned redesign model year for each of its vehicles, and this data is also stored in the market forecast file.

NHTSA assigns one of 12 subclasses to each vehicle manufactured in the rulemaking period. The vehicle subclass data is used for the purposes of technology application. Each vehicle's class is stored in the market forecast file. When conducting a compliance analysis, if the Volpe 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, which it then uses to reference another input called the technology input file.

In the technology input file, NHTSA has developed a separate set of technology data variables for each of the twelve vehicle subclasses. Each set of variables is referred to as an "input sheet," so for example, the subcompact input sheet holds the technology data that is appropriate for the subcompact subclass. Each input sheet contains a list of technologies available for members of the particular vehicle subclass. The following items are provided for each technology: a brief description, its abbreviation, the decision tree with which it is associated, the (first) year in which it is available, the upper and lower cost and effectiveness (fuel consumption reduction) estimates, the learning type and rate, the cost basis, its applicability, and the phase-in values.

The input sheets are another method NHTSA uses to determine how to properly apply, or in some cases constrain, a technology's application, as well as to establish the costs and fuel consumption changes that occur as it is applied. Examples of how technologies are applied (or constrained) include the "Applicability" variable: if it is set to "TRUE," then the technology can be applied to all members of the vehicle subclass (a value of "FALSE" would prevent the Volpe model from applying the technology to any member). Another example would be the "Year Available" variable, which if set to "2012" means the model can apply it to MY 2012 and later members, but cannot apply the technology to MY 2011 models. The "Learning Type" and "Learning Rate" define reductions in technology costs, if any are appropriate, that the Volpe model may apply under certain conditions, as discussed in the Learning Curve section below. "Phase-in Values" are intended to address the various constraints that limit a manufacturer's ability to apply technologies within a short period of time. For phase-ins, once the model applies a given technology to a percentage of a given manufacturers' fleet up to a specified phase-in cap, the model then ceases to apply it further instead applying other technologies.

Perhaps the most important data contained in the input sheets are the cost and effectiveness information associated with each technology. One important concept to understand about the cost and effectiveness values is that they are "incremental" in nature, meaning that the estimates are "referenced" to some prior technology state in the decision tree in which the applied technology is represented, typically the preceding technology. Therefore, when considering values shown in the input sheet, the reader must understand that in all but a few cases they cannot fully deduce the accumulated or "NET" cost and effectiveness, referenced back to the base condition (*i.e.*, start of the decision tree), without performing a more detailed analysis. The method for conducting this analysis, and a brief example of how it is done, is discussed in the Decision Tree section below. For the final rule, to help readers better understand Volpe model net or accumulated costs and fuel consumption reductions, NHTSA has published net values to key technology locations on the decision trees (*e.g.*, to diesel engine conversion, or a strong hybrid). See the Tables showing Approximate Net Technology Costs and Approximate Net Technology Effectiveness. The tables have been produced for each of the four vehicle subclasses in the passenger car, performance passenger car, and light truck vehicle groups.

The incremental costs of some technologies are dependent on certain factors specific to the vehicle to which they are applied. For instance, when the Material Substitution technology is applied, the cost of application is based on a cost per unit weight reduction, in dollars per pound, since the weight removed is a percentage of the curb weight of the vehicle (which differs from one vehicle to the next). Similarly, some engine technologies need to be calculated on a cost per cylinder basis, or a cost per configuration basis (*i.e.*, a cost per bank basis, so that a V-configured engine would cost twice as much as an in-line, single bank engine). For each technology, the input sheet also contains a Cost Basis variable which indicates whether the costs need to be adjusted in this manner. This functionality, some of which is new for the final rule, allows NHTSA to estimate more accurately the costs of technology application, since in the NPRM the vehicles in a subclass were assumed to have common cylinder counts and configurations (thus the costs were underestimated for some vehicles and overestimated for others).

Lastly for the technology input file, the term "synergy" as it applies to the Volpe modeling process refers to the condition that occurs when two or more technologies are applied to a vehicle and their effects interact with each other, resulting in a different net effect than the combination of the individual technologies. The term synergy usually connotes a positive interaction (*e.g.*, 1 + 1 is more than 2), but as used here it also includes negative interactions (*e.g.*, 1 + 1 is less than 2). Synergies are discussed in greater detail below, and the values for the synergy factors NHTSA used in the final rule are stored in the technology input file.

In some cases more than one decision tree path can lead to a subsequently applied technology. For example, the power split hybrid technology can be reached from one of two prior transmission technologies (CVT or DCTAM). Accordingly the incremental cost and effectiveness for applying the technology may vary depending on the path and the modifications made in the prior technology. To ensure accurate tracking of net costs and effectiveness, the Volpe model utilizes path correction factors, as discussed further in the decision tree discussion below. This functionality is an improvement to the final rule, and the specific factors used are stored in the technology input sheets. A copy of the final rule input sheets, titled "2011-2015_LV_CAFE_FinalRuleInputSheets20081019.pdf," can be obtained from the final rule docket.

One additional concept to understand about how the Volpe model functions is called an "engineering constraint," a programmatic method of controlling technology application that is independent of those discussed above. NHTSA has determined that some technologies are only suitable or unsuitable when certain vehicle, engine, or transmission conditions exist. For example, secondary axle disconnect is only suitable for 4WD vehicles, and cylinder deactivation is unsuitable for any engine with fewer than 6 cylinders, while material substitution is only available for vehicles with curb weights greater than 5,000 pounds. Additionally, in response to comments received, an engineering constraint was added for purposes of the final rule to prevent the cylinder deactivation technology from being applied to vehicles equipped with manual transmissions, due primarily to driveability and NVH concerns documented by the commenter. Where appropriate and required, NHTSA has utilized engineering constraints to ensure accurate application of the fuel saving technologies.

3. Technology application decision trees

Several changes were made to the Volpe model between the analysis reported in the NPRM and the final rule. This section will discuss two of those changes: first, the updates to the set of technologies; and second, the updates to the logical sequence for progressing through these technologies, which NHTSA describes as "decision trees."

As discussed above, the set of technologies considered by the agency has evolved since the NPRM. The set of technologies now included in the Volpe model is shown below in Table V-1, with abbreviations used by the model to refer to each technology in the interest of brevity.

Table V-1. Revised Final Rule Technology Set for Volpe Model

Technology	Abbreviation
Low Friction Lubricants	LUB
Engine Friction Reduction	EFR
VVT - Coupled Cam Phasing (CCP) on SOHC	CCPS
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS
Cylinder Deactivation on SOHC	DEACS
VVT - Intake Cam Phasing (ICP)	ICP
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
Cylinder Deactivation on OHV	DEACO
VVT - Coupled Cam Phasing (CCP) on OHV	CCPO
Discrete Variable Valve Lift (DVVL) on OHV	DVVLO
Conversion to DOHC with DCP	CDOHC
Stoichiometric Gasoline Direct Injection (GDI)	SGDI
Combustion Restart	CBRST
Turbocharging and Downsizing	TRBDS
Exhaust Gas Recirculation (EGR) Boost	EGRB
Conversion to Diesel (from CBRST)	DSLC
Conversion to Diesel (from TRBDS)	DSLT
Electric Power Steering	EPS
Improved Accessories	IACC
12V Micro-Hybrid	MHEV
Higher Voltage/Improved Alternator	HVIA
Integrated Starter Generator	ISG
6-Speed Manual/Improved Internals	6MAN
Improved Auto. Trans. Controls/Externals	IATC
Continuously Variable Transmission	CVT
6/7/8-Speed Auto. Trans with Improved Internals	NAUTO
Dual Clutch or Automated Manual Transmission	DCTAM
Power Split Hybrid	PSHEV
2-Mode Hybrid	2MHEV
Plug-in Hybrid	PHEV
Material Substitution (1%)	MS1
Material Substitution (2%)	MS2
Material Substitution (5%)	MS5
Low Rolling Resistance Tires	ROLL
Low Drag Brakes	LDB
Secondary Axle Disconnect	SAX
Aero Drag Reduction (10%)	AERO

As in the NPRM, 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 Volpe model uses to apply technologies sequentially during the compliance analysis. The decision trees were designed and configured to allow the Volpe model to apply technologies in a cost-effective, logical order that also considers ease of implementation. For example, effective 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.

Each technology within the decision trees has an incremental cost and an incremental effectiveness estimate associated with it, and the estimates are specific to a particular vehicle subclass. Each technology's incremental estimate takes into account its position in the decision tree path. 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 and 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 vital that the estimates are evaluated 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 provided by commenters can be considered an "apples-to-apples" comparison with those used by the Volpe model, since in some cases the order of application, or included technology content, is inconsistent with that assumed in the decision tree.

For the final rule, significant revisions have been made to the sequence of technology applications within the decision trees, and in some cases the paths themselves have been modified and additional paths have been added. 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 now 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. Commenters pointed out several instances in the NPRM where double-counting appeared to have occurred, and the accounting approach used in the final rule resolves these concerns.

In reviewing NPRM comments, NHTSA noted several questions regarding the retention of previously applied technologies when more advanced technologies (*i.e.*, those further down the decision tree) were applied. In response, NHTSA has clarified the final rule discussions on this issue. In both the NPRM and final rule, as appropriate and feasible, previously-applied technologies are retained in combination with the new technology being applied, but this is not always the case. For instance, one exception to this would be the application of diesel technology, where the entire engine is assumed to be replaced, so gasoline engine technologies cannot carry over. This exception for diesels, along with a few other technologies, is documented below in the detailed discussion of changes to each decision tree and corresponding technologies.

As the Volpe 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. To help readers better understand the accumulation process, and in response to comments expressing confusion on this subject, the following examples demonstrate how the Volpe model calculates net values.

Accumulation of net cost is explained first as this is the simpler process. This example uses the Electrification/Accessory decision tree sequentially applying the EPS, IACC, MHEV, HVIA and ISG technologies to a subcompact vehicle using the cost and effectiveness estimates from its input sheet. As seen in Table V-2 below, the input sheet cost estimates have a lower and upper value which may be the same or a different value (*i.e.*, a single value or a range) as shown in columns two and three. The Volpe model first averages the values (column 4), and then sums the average values to calculate the net cost of applying each technology (column 5). Accordingly, the net cost to apply the MHEV technology for example would be ($112.50 + $192.00 + $372.00 = $676.50). Net costs are calculated in a similar manner for all the decision trees.

Table V-2. Sample Volpe Model Net Cost Calculation

Example Net Cost Calculation: Elect./Acc. Path, Subcompact Vehicle Subclass				
Tech. Abrev.	**Lower INCR Cost**	**Upper INCR Cost**	**Avg. INCR Cost**	**NET Cost**
EPS	$ 105.00	$ 120.00	$ 112.50	**$ 112.50**
IACC	$ 173.00	$ 211.00	$ 192.00	**$ 304.50**
MHEV	$ 372.00	$ 372.00	$ 372.00	**$ 676.50**
HVIA	$ 84.00	$ 84.00	$ 84.00	**$ 760.50**
ISG	$ 1,713.00	$ 1,713.00	$ 1,713.00	***$ 2,473.50***

The same decision tree, technologies, and vehicle are used for the example demonstrating the model's net effectiveness calculation. Table V-3 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 EPS technology with incremental effectiveness of 1.5 percent (or 0.015 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 – 0.015) = 0.985,[107] or mathematically 0.985*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 IACC technology is applied, the vehicle's fuel consumption is already reduced to 0.985 of its original value. Therefore the reduction for an additional incremental 1.5 percent results in a new fuel consumption value of 0.9702, or a net 2.98 percent effectiveness, as shown in the table. Net effectiveness is calculated in a similar manner for the all decision trees. It should be noted that 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.

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[107] 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.

Table V-3. Sample Volpe Model Net Effectiveness Calculation

Example Net Effectiveness Calculation: Elect./Acc. Path, Subcompact Vehicle Subclass				
Tech. Abrev.	**Avg. INCR Eff. %**	**Avg. INCR Eff. (decimal)**	**Multiplicative FC Reduction Current FC * (1-Avg INCR)**	**Net Effect. (1 - Red)**
EPS	1.50%	0.0150	1 * (1 - 0.015) = 0.985	1.50%
IACC	1.50%	0.0150	0.985 * (1 - 0.015) = 0.9702	2.98%
MHEV	1.95%	0.0195	0.9702 * (1 - 0.0195) = 0.9513	4.87%
HVIA	0.55%	0.0055	0.9513 * (1 - 0.0055) = 0.9461	5.39%
ISG	6.10%	0.0610	0.9461 * (1 - 0.061) = 0.8884	11.16%

To improve the accuracy of accumulating net cost and effectiveness estimates for the final rule, "path-dependent corrections" were employed. The NPRM analysis had the potential to either overestimate or underestimate net cost and effectiveness depending on which decision tree path the Volpe model followed when applying the technologies. For example, if in the 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 correct this issue, the final rule analysis has added path-dependent correction tables to the input sheets. The model uses these tables 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.[108] Path-dependent corrections were used when applying cylinder deactivation (on the DOHC path), turbocharging and downsizing, diesel and strong hybrids. This is essentially an accounting issue and the path-dependent corrections are meant to remedy the accuracy issues reported in the NPRM comment responses.

The following paragraphs explain, in greater detail, the revisions to the decision trees and technologies from the NPRM to the final rule. Revisions were made in response to comments received and pursuant to NHTSA's analysis, and were made to improve the accuracy of the Volpe compliance analysis, or to correct other concerns from the NPRM analysis.

Engine Technology Decision Tree

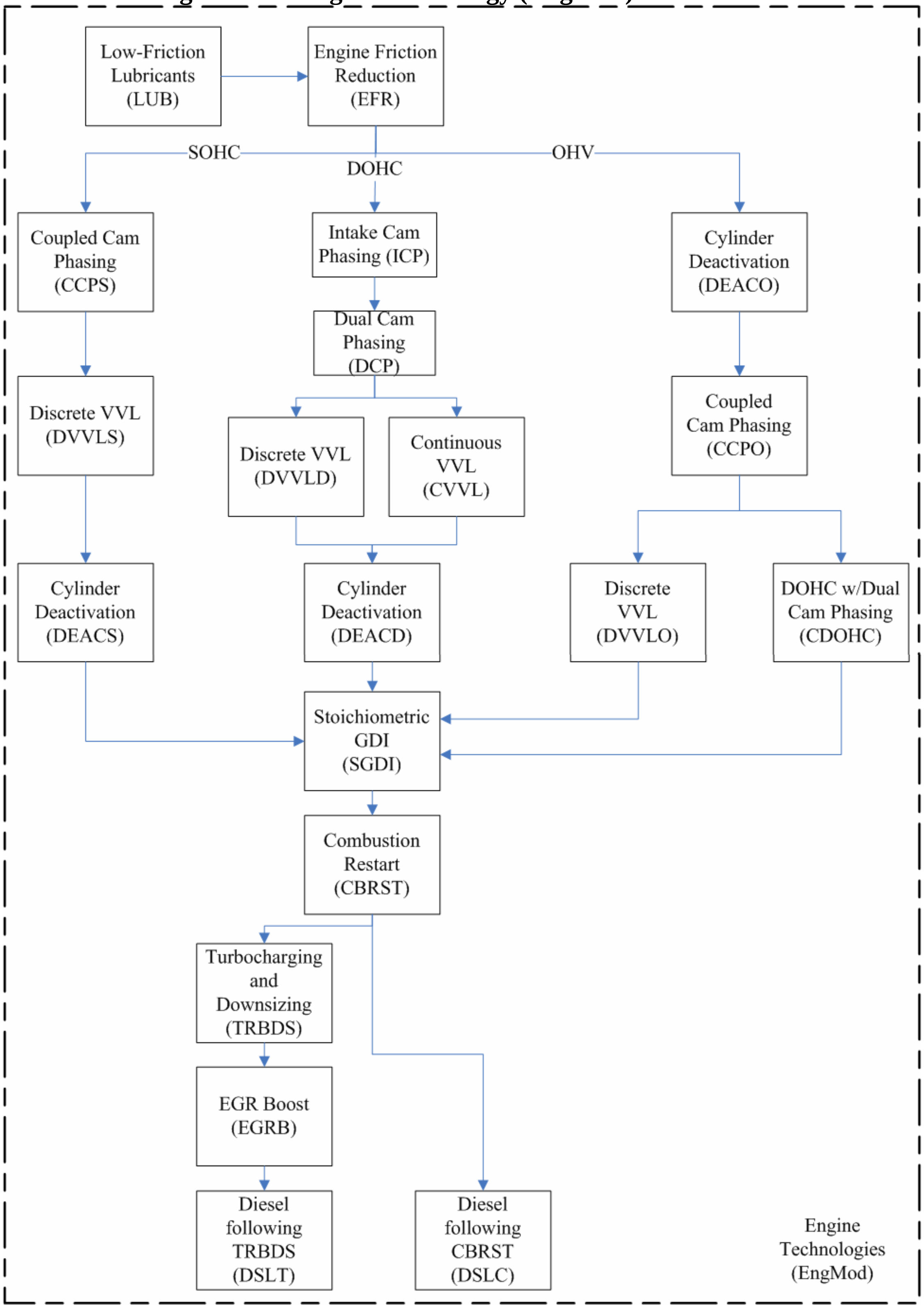
Figure V-8 below shows the final rule decision tree for the engine technology

[108] The correction tables are used for path deviations within the same decision tree. However, there is one exception to this rule, specifically that the tables are used to keep the model from double-counting cost and effectiveness estimates when both the CBRST and MHEV are applied to the same vehicle. Both technologies try to accomplish the same goal of reducing fuel consumption, by limiting idle time, but through different means. If either of these technologies exists on a vehicle and the Volpe model applies the other, the correction tables are used to remove the cost and effectiveness estimates for CBRST, thus ensuring that double-counting does not occur.

category. For the final rule, NHTSA removed camless valve actuation (CVA), lean-burn GDI (LBDI), and homogenous charge compression ignition (HCCI) from the decision trees because these technologies were determined to be still in the research phase of development. NHTSA did not receive any new information or comments that suggested these technologies are under development, so NHTSA removed them from the decision trees. At the top of the engine decision tree Low Friction Lubricants (LUB) and Engine Friction Reduction (EFR) technologies are retained as utilized in the NPRM.

As stated above, SOHC, DOHC and OHV engines have separate paths, whereas as the NPRM only made the distinction between OHC and OHV engines. The separation of SOHC and DOHC engines allowed the model to more accurately apply unique path-dependent valvetrain technologies including variations of Variable Valve Timing (VVT), Variable Valve Lift (VVL) and cylinder deactivation that are tailored to either SOHC or DOHC engines. This separation also allowed for a more accurate method of accounting for net cost and effectiveness compared to the NPRM. For both the SOHC and DOHC paths, VVL technologies were moved upstream of cylinder deactivation in response to comments from the Alliance, additional confidential manufacturer comments and submitted product plan trends, and NHTSA's analysis. Confidential comments stated that applying cylinder deactivation to an OHC engine is more complex and expensive than applying it to an OHV engine. The Alliance additionally stated that cylinder deactivation is very application-dependent, and is more effective when applied to vehicles with high power-to-weight ratios. Taking in account the application-specific nature of cylinder deactivation and the fact the VVL technologies are more suitable to a broader range of applications, NHTSA moved VVL technologies "upstream" of cylinder deactivation on the SOHC and DOHC to more accurately represent how a manufacturer might apply these technologies.

Figure V-8. Engine Technology (EngMod) Decision Tree



On the OHV path, the ordering of cylinder deactivation (DEACO) then Coupled Cam Phasing (CCPO), which is opposite the order of the SOHC and DOHC paths, was retained as defined in the NPRM. This ordering depicts most accurately how manufacturers would actually implement these technologies and was reflected in the submitted product plans for OHV engines, which are largely used on trucks with high power-to-weight ratios. After the application of CCPO on the OHV decision tree, the model chooses between Discrete Variable Valve Lift (DVVLO) and the conversion to a dual overhead camshaft engine (CDOHC). This conversion now includes Dual Cam Phasing (DCP) instead of Continuously Variable Valve Lift (CVVL) because it is assumed that DCP, with its higher application rates, would more likely be applied than CVVL, with its lower application rates.

At this stage, and similar to the NPRM, the decision tree paths all converge into Stoichiometric Gasoline Direct Injection (SGDI). All previously applied technologies are retained with the assumption that SGDI is applied in addition to the pre-existing engine technologies. After SGDI, a newly defined technology, Combustion Restart (CBRST), has been added.

The "branch point" after CBRST has been limited to two paths instead of the three paths in NPRM. This is due to the removal of HCCI from the final rule decision trees. The final rule engine decision tree allowed the model to apply either Turbocharging and Downsizing (TRBDS) or the conversion to diesel (DSLC). TRBDS is considered to be a completely new engine that has been converted to DOHC, if not already converted, with only LUB, EFR, DCP, SGDI and CBRST applied.

The conversion to diesel is also considered to be a completely new engine that replaces the gasoline engine (although it carries over the LUB and EFR technologies). If the model chooses to follow the TRBDS path, the next technology that can be applied is another newly-added technology, EGR Boost (EGRB). After EGRB, the model is allowed to then convert the engine to diesel (DSLT). It should be noted that the path-dependent variations of diesel, (DSLC) and (DSLT), result in the exact same technology. The net cost and effectiveness estimates are the same for both but DSLT's incremental cost and effectiveness estimates are slightly lower to account for the TRBDS and EGRB technologies that have already been applied.

Electrification/Accessory Technology Decision Tree

This path, shown in Figure V-9, was named simply "Accessory Technology" in the NPRM. Electric Power Steering (EPS) is now the first technology in this decision tree, since it is a primary enabler for both mild and strong hybrids. Improved Accessories (IACC) has been redefined to include only an intelligent cooling system and follows EPS (in the NPRM, IACC was the first technology in the tree). The 42-volt Electrical System (42V) technology has been removed because it is no longer viewed as the voltage of choice by manufactures and is being replaced by higher voltage systems. Micro-Hybrid (MHEV), which follows IACC, has been added as a 12-volt stop/start system to replace Integrated Starter/Generator with Idle-Off (ISGO), which was on the "Transmission/Hybrid Technology" decision tree in the NPRM. Higher Voltage /

Improved Alternator (HVIA), a higher efficiency alternator that can incorporate higher voltages (greater than 42V) follows MHEV. Integrated Starter Generator Hybrid (ISG) replaced IMA/ISAD/BSG Hybrid (which was also on the Transmission/Hybrid Technology decision tree in the NPRM) as a higher voltage hybrid system with limited regenerative capability. ISG takes into account all the previously applied Electrification/Accessory technologies and is the final step necessary in order to convert the vehicle to a (full) strong hybrid. All Electrification/Accessory technologies can be applied to both automatic and manual transmission vehicles.

Transmission Technology Decision Tree

This decision tree, shown in Figure V-9, contains two paths: one for automatic transmissions and one for manual transmissions. On the automatic path, the Aggressive Shift Logic (ASL) and Early Torque Converter Lockup (TORQ) technologies from the NPRM have been combined into an Improved Auto Trans Controls/Externals (IATC) technology, as both these technologies typically include only software or calibration-related transmission modifications. This technology was moved to the top of the decision tree since it was deemed to be easier and less expensive to implement than a major redesign of the existing transmission. The 5-Speed Automatic Transmission (5SP) technology from the NPRM has been deleted due to several factors. First, the updated decision tree logic seeks to optimize the current hardware as an initial step, instead of applying an expensive redesign technology. Second, NHTSA determined an industry trend of 4-speed automatics going directly to 6-speed automatics, as reflected in the submitted product plans. And finally, confidential manufacturer comments indicated that in some cases 5-speed transmissions offered little or no fuel economy improvement over 4-speed transmissions (primarily due to higher internal mechanical and hydraulic losses, and increased rotating mass), making the technology less attractive from a cost and effectiveness perspective. In the final rule, both 4-speed and 5-speed automatic transmissions get the IATC technology applied first, before progressing through the rest of the transmission decision tree.

After IATC the decision tree splits into a “Unibody only” and “Unibody or Ladder Frame” paths, which is identical to the NRPM version of the decision tree. Both of these paths represent a conversion to new and fully optimized designs. The Unibody only path contains the Continuously Variable Transmission (CVT) technology, while the Unibody or Ladder Frame path has the 6-Speed Automatic Transmission (6SP) technology being replaced by 6/7/8-Speed Automatic Transmission with Improved Internals (NAUTO). The NAUTO technology represents a new generation of automatics with lower internal losses from gears and hydraulic systems.

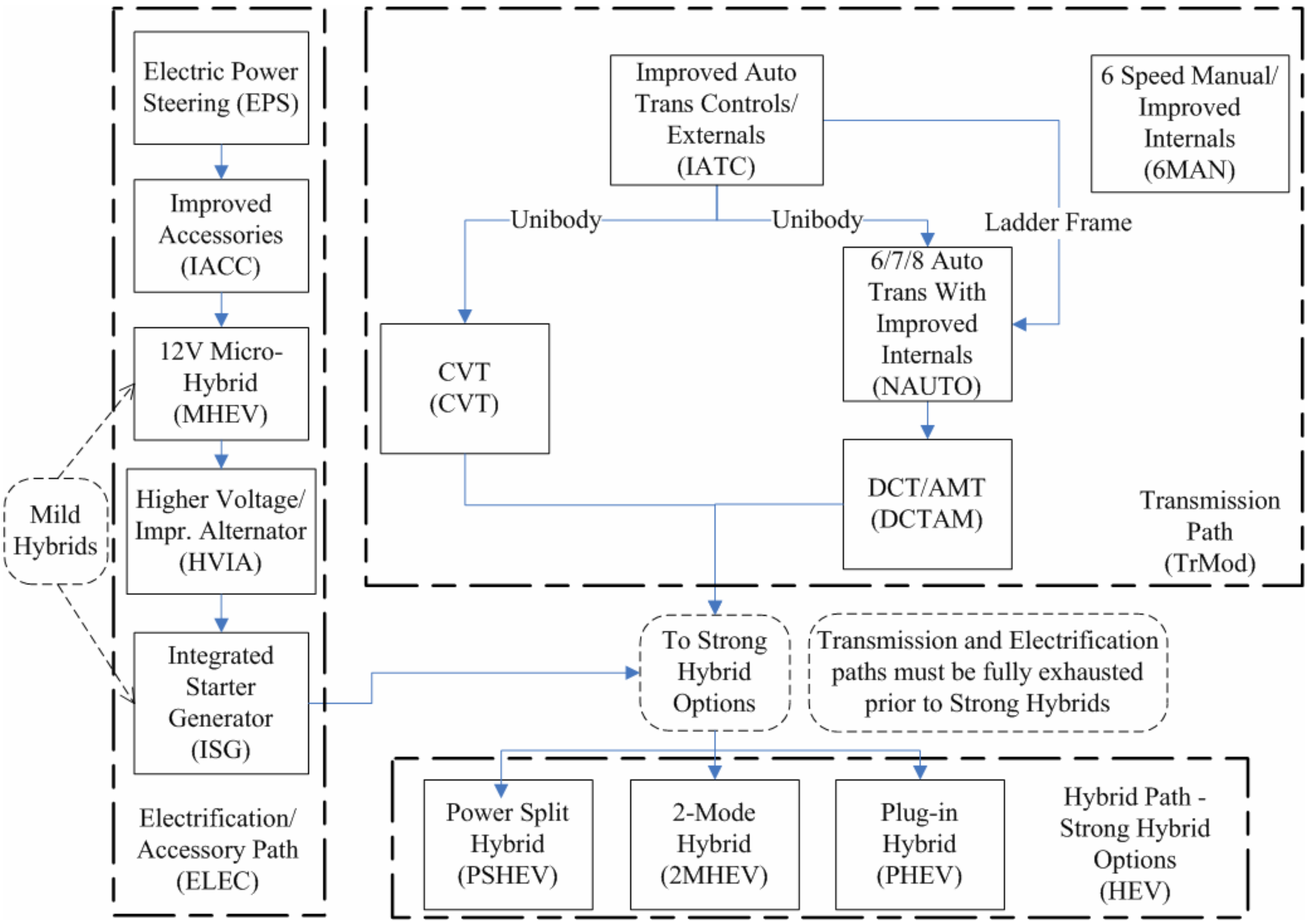
The NPRM technology “Automated Manual Transmission (AMT)” has been renamed Dual Clutch Transmission/Automated Manual Transmission (DCTAM) to more accurately reflect the true intent of this technology to be a Dual Clutch Transmission (DCT). The NPRM’s use of the abbreviation “AMT” was confusing to many commenters, including the Alliance, BorgWarner, Chrysler, Ford and General Motors, and appeared to indicate that the NPRM analysis applied true automated manual transmissions, which exhibit a torque interrupt characteristic that many in the industry feel will not be customer acceptable. DCT does not have the torque interrupt concern. The technology DCTAM for the final rule assumes the use of a DCT type transmission only.

The manual transmission path only has one technology application, like the NPRM. However, the technology being applied has been defined as conversion to a 6-Speed Manual with Improved Internals (6MAN) instead of a conversion to a 6/7/8-Speed Manual Transmission as defined in the NRPM. Extremely limited use of manual transmissions with more than 6 speeds is indicated in the updated product plans, so NHTSA believes this is a more accurate option for replacing a 4 or 5-speed manual transmission.

Hybrid Technology Decision Tree

The strong hybrid options, 2-Mode (2MHEV) and Power Split (PSHEV), are no longer sequential as defined in the NPRM's Transmission/Hybrid decision tree. For the final rule, the model only applies strong hybrid technologies when both the Electrification/Accessory and Transmission (automatic transmissions only) technologies have been fully added to the vehicle, as seen in Figure V-9. The final rule analysis and logic ensures that the model does not double-count the cost and effectiveness estimates for previously applied technologies that are included (*e.g.*, EPS) or replaced (*e.g.*, transmission) by strong hybrid systems, which is responsive to General Motors' comment stating that the NPRM analysis had the potential to double-count effectiveness estimates when applying strong hybrids. For the final rule analysis, when the Volpe model applies strong hybrids it now takes into account that some of the fuel consumption reductions have already been accounted for when technologies like EPS or IACC have been previously applied. Once all the Electrification/Accessory and Transmission technologies have been applied, the model is allowed to choose between the application of 2MHEV, PSHEV and the newly added Plug-in Hybrid Vehicle (PHEV). The NPRM decision tree required the Volpe model to step through 2MHEV in order to apply PSHEV. This updated final rule decision tree is a more realistic representation of how manufacturers might apply strong hybrids, and allows the Volpe model to choose the strong hybrid that is most appropriate for each vehicle based on its vehicle subclass or the most cost-effective technology application. The PHEV technology was added to the decision tree in the final rule based upon information in the public domain and submitted product plans showing that limited quantities of these vehicles will be available from some manufacturers in this timeframe.

Figure V-9. Electrification/Accessory, Transmission and Hybrid Technology Decision Tree



Vehicle Technology Decision Tree

Material Substitution (MS1), (MS2) and (MS5) are now located on dedicated material substitution path in the Vehicle Technology Decision Tree, shown in Figure V-10. Low Rolling Resistance Tires (ROLL), Low Drag Brakes (LDB) and Secondary Axle Disconnect (SAX) now reside as a separate path, due to the relocation of material substitution technologies. Secondary Axle Disconnect has been redefined for the final rule to apply to 4WD vehicles only to more accurately reflect feasible applications of this technology. Aerodynamic Drag Reduction (AERO) remains a separate tree, and is now a 10 percent reduction for both car and truck classes (excluding performance cars, which are exempt).

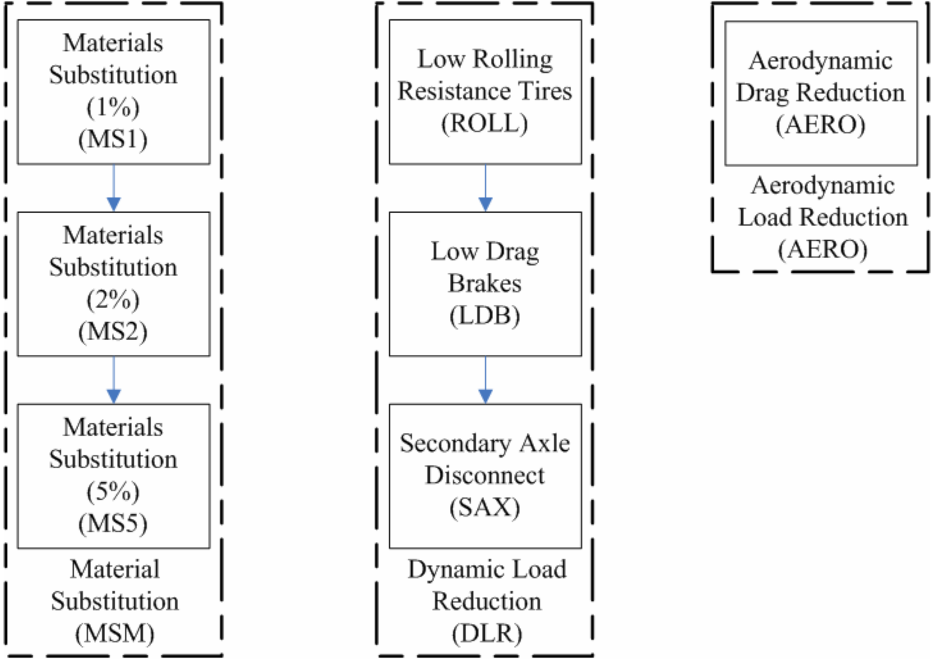


Figure V-10. Vehicle Technology Decision Tree

4. Division of vehicles into subclasses based on technology applicability, cost and effectiveness

In assessing the feasibility of technologies under consideration, the agency evaluated whether each of these technologies could be implemented on all types and sizes of vehicles and whether some differentiation is necessary with respect to the potential to apply certain technologies to certain types and sizes of vehicles, and with respect to the cost incurred and fuel consumption achieved when doing so. The 2002 NAS Report differentiated technology application using ten vehicle classes (4 cars classes and 6 truck classes, including subcompact cars, compact cars, midsize cars, large cars, small SUVs, midsize SUVs, large SUVs, small pickups, large pickups, and minivans), but did not determine how cost and effectiveness values differ from "class" to "class." 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. This vehicle differentiation is done solely for the purpose of applying technologies to vehicles and assessing their incremental costs and effectiveness, and should not be confused with, the regulatory classifications pursuant to 49 CFR Part 523 discussed in Chapter XI.

The Volpe model, which NHTSA has used to perform analysis supporting today's notice, 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. Therefore, the model's estimates of the cost to improve the fuel economy of each vehicle model depend upon the subclass to which the vehicle model is assigned.

In its MY 2005-2007 and MY 2008-2011 light truck CAFE standards as well as NPRM, NHTSA performed analysis using the same vehicle classes defined by NAS in its 2002 Report. In its 2008 NPRM for MY 2011-2015, NHTSA included some differentiation in cost and effectiveness numbers between the various classes to account for differences in technology costs and effectiveness that are observed when technologies are applied on to different classes and subclasses of vehicles. The agency found it important to make that differentiation because the agency estimated that, for example, engine turbocharging and downsizing would have different implications for large vehicles than for smaller vehicles. For the final rule, NHTSA, working with Ricardo, increased the accuracy of its technology assumptions by reexaming the subclasses developed for the purpose of modeling technology application and by providing more differentiation in the costs and effectiveness values by vehicle subclass.

In the request for comments accompanying the NPRM, NHTSA asked manufacturers to identify the style of each vehicles model they submit in their product plans from eight possible groupings (convertible, coupe, hatchback, pickup, sedan, sport utility, van, or wagon) or sixteen possible market segments (cargo van, compact car, large car, large pickup, large station wagon, midsize car, midsize station wagon, mini-compact, minivan, passenger van, small pickup, small station wagon, special purpose, sport utility truck, subcompact car, and two-seat car). NHTSA also requested that manufacturers identify many specific characteristics relevant to each vehicle model, such as the number of cylinders of the vehicle's engine and other engine, transmission and vehicle characteristics. This information was evaluated by NHTSA staff, entered in NHTSA's market data file, and used by NHTSA to assess how to divide the vehicles into subclasses for purposes of differentiating the applicability, effectiveness, and cost of available technologies.

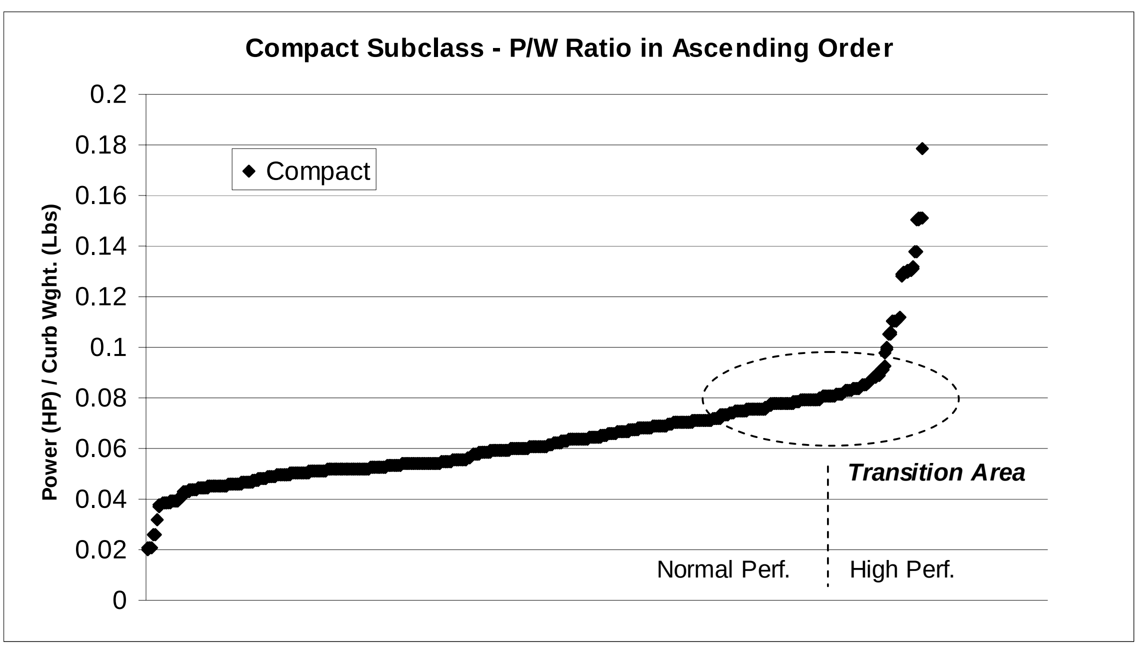
In response to the NPRM, the Alliance commented that NHTSA's classification approach is not robust enough. With regard to subclasses of cars, the Alliance stated that NHTSA did not distinguish high-performance and sports cars which cannot accommodate certain technologies without changing the purpose and configuration of the vehicle. With regard to subclasses of trucks, the Alliance argued that SUVs were not adequately distinguished by size. The Alliance further stated the classification used by Sierra Research in its report to distinguish groups of like vehicles for technology application purposes was more realistic and representative of differences in market segments than NHTSA's classification. The Alliance suggested that NHTSA consider the classes identified by Sierra Research in the final rule.

NHTSA is not adopting Sierra's approach to classification for the following reasons. First, Sierra's classification scheme is too dependent on vehicle characteristics for which NHTSA often did not receive complete information from manufacturers. For example, although NHTSA requested that manufacturers provide estimates of the aerodynamic drag coefficient of each vehicle model planned for MY2011-2015, the agency received no estimates for many vehicles. NHTSA believes manufacturers are too far from production on many vehicles to confidently provide such estimates. Second, Sierra's classification scheme is, for NHTSA's purposes, excessively fine-grained. Sierra's analysis relied on 25 subclasses in total, 13 for cars and 12 for trucks. While their report provided tables comparing their classes to those of NHTSA's and cited product examples for each class, it did not provide a reason for why this detailed differentiation would significantly improve the outcome. NHTSA's review of the Sierra report did not reveal many differences in technology-application between these subclasses. In addition, the agency does not believe that the effort required by the agency to create a more detailed yet more complex modeling structure based on 25 subclasses would result in significant improvement in the accuracy of the results. Sierra may have found this additional differentiation important for the full vehicle simulation approach that the Alliance claimed should be used throughout NHTSA's analysis. However, as discussed below, NHTSA has concluded that this approach is neither necessary nor practical for CAFE analysis.

The agency agrees with the Alliance, however, that some refinement in the classification approach used by NHTSA in the NPRM is merited in order to ensure the practicability of technologies being added. The agency also believes that the limited differentiation in costs and effectiveness values by vehicle class needs to be expanded in order to better account for fuel savings and costs.

For the final rule, NHTSA first reexamined the Volpe model technology output files from the NPRM to identify where and why technologies may have been inappropriately applied by the model. Where this reexamination revealed logical errors, the Volpe model was revised accordingly. However, the review revealed that most of the observed inaccuracies resulted from the manner in which vehicles were assigned to subclasses for the purpose of technology applications. NHTSA also reviewed the confidential vehicle level information received from manufacturers, how manufacturers classified their vehicles by style or market segment groupings requested by NHTSA and the specific engine, transmission and other vehicle characteristics identified by the manufacturers for each vehicle model. This conclusion was among those that led NHTSA to assign more staff to perform quality control when reviewing and integrating manufacturers' product plans.

In order to improve the accuracy of technology application modeling, NHTSA examined at the car and truck segments separately. First, for the car segment, NHTSA plotted the footprint distribution of vehicles in the product plans 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, as the Alliance pointed out, some vehicles in each group were sports or high-performance models. Since different technologies and cost and effectiveness estimates are appropriate for these vehicles, NHTSA created a performance subclass within each car class to maximize the accuracy of technology application. To determine which cars would be assigned to the performance subclasses, NHTSA graphed (in ascending rank order) the power-to-weight ratio for each vehicle in a class. An example of the Compact subclass plot is shown below. The subpopulation was then manually reviewed by NHTSA staff to determine an appropriate transition point between "performance" and "non-performance" models within each class.



A total of eight classes (including performance subclasses) were identified for the car segment: Subcompact, Subcompact Performance, Compact, Compact Performance, Midsize, Midsize Performance, Large, Large Performance. In total, the number of cars that were ultimately assigned to a performance subclass was less than 10 percent. The table below shows the difference in the classification between the NPRM and Final Rule and provides examples of the types of vehicles assigned to each.

NPRM Car Subclasses

Class	Example vehicles
Subcompact	**Chevy Aveo, Chevy Corvette, Ford Mustang (V8), Honda Civic, Mazda Miata, Saturn Sky**
Compact	**Audi S4 Quattro, Chevy Camaro (V6), Chevy Cobalt, Daimler CL600, Mazda RX8, Nissan Sentra**
Midsize	**Bentley Arnage, Cadillac CTS, Honda Accord, Nissan Altima & G37 Coupe, Toyota Camry**
Large	**Audi A8, Cadillac DTS, Hyundai Azera**

Final Rule Car Subclasses

Class	Example vehicles
Subcompact	**Chevy Aveo, Honda Civic**
Subcompact Performance	**Mazda Miata, Saturn Sky**
Compact	**Chevy Cobalt, Nissan Sentra and Altima**
Compact Performance	**Audi S4 Quattro, Mazda RX8**
Midsize	**Chevy Camaro (V6), Toyota Camry, Honda Accord, Hyundai Azera**
Midsize Performance	**Chevy Corvette, Ford Mustang (V8), Nissan G37 Coupe**
Large	**Audi A8, Cadillac CTS and DTS**
Large Performance	**Bentley Arnage, Daimler CL600**

For light trucks, in reviewing the updated manufacturer product plans and in reconsidering how to divide trucks into classes and subclasses based on technology applicability, NHTSA found less of a distinction between SUVs and pickup trucks than appeared to exist in earlier rulemakings. Manufacturers appear to be planning fewer ladder-frame and more unibody pickups, and many pickups will share common powertrains with SUVs. Consequently, NHTSA condensed the classes available to trucks, such that SUVs and pickups are no longer divided. Recognizing structural differences between various types of "Vans," NHTSA revisited how it assigned the different types of "Vans." Instead of merging minivans, cargo vans, utility and multi-passenger type vans under the same class, as it did for the NPRM and in previous rules, NHTSA formed a separate minivan class, because minivans (*e.g.*, the Honda Odyssey) are expected to remain closer in terms of structural and other engineering characteristics than vans (*e.g.*, Ford's E-Series—also known as Econoline—vans) intended for more passengers and/or heavier cargo.

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 classes—minivans and small, medium, and large SUVs/Pickups/Vans. The table below shows the difference in the classification between the NPRM and Final Rule

NPRM Truck Subclasses

Class	Example vehicles
Minivans	**Dodge Caravan, Ford Econoline, Toyota Sienna**
Small Truck	**Chevy Colorado, Toyota Tacoma, Ford Ranger**
Large Truck	**Chevy Silverado**
Small SUV	**Ford Escape, Nissan Rouge**
Midsize SUV	**Jeep Wrangler 4-door, Volvo XC70**
Large SUV	**Toyota Sequoia**

Final Rule Truck Subclasses

Class	Example vehicles
Minivans	**Dodge Caravan, Toyota Sienna**
Small SUV/Pickup/Van	**Ford Escape & Ranger, Nissan Rogue,**
Midsize SUV/Pickup/Van	**Chevy Colorado, Jeep Wrangler 4-door, Volvo XC70, Toyota Tacoma**
Large SUV/Pickup/Van	**Chevy Silverado, Ford Econoline, Toyota Sequoia**

Based on a close review of detailed output from the Volpe model, NHTSA has concluded that its revised classification for purposes of technology applicability substantially improves the overall accuracy of the results as compared to the system employed in the NPRM. The new method uses footprint as a first indicator for both the car and truck segments, and all are then manually reviewed for the types of technologies applicable to them and revised by NHTSA to ensure that they have been properly assigned. The addition of the performance subclasses in the car segment and the condensing of classes in the truck segment further refine the system. The new method increases the accuracy of technology application without overly complicating the Volpe modeling process, and the revisions address comments received in response to the NPRM.

5. How did NHTSA develop technology cost and effectiveness estimates for the final rule?

In the NPRM, NHTSA employed technology cost and effectiveness estimates developed in consultation with EPA. They represented NHTSA and EPA staff's best assessment of the costs for each technology considered based on the available public and confidential information and data sources that the agencies had back in 2007 when the rulemaking was initiated. EPA also published a report and submitted it to the NRC committee on fuel economy of light-duty vehicles.[109]

Public comments on the NPRM's technology cost estimates generally fell into four categories: (1) that costs are underestimated because NHTSA did not account for all changes/costs required to apply a technology or because although NHTSA correctly identified all the changes required, it did not cost those changes appropriately; (2) that costs are underestimated because the Retail Price Equivalent (RPE) factors have been applied incorrectly to technologies; (3) that costs are either over- or underestimated because learning curves have been applied incorrectly to technologies; and (4) that cost assumptions are overly simplified as applied to the full range of fleet vehicles and do not properly account for the differences in cost impacts across vehicle and engine types (*e.g.*, technologies applied to a sub-compact car will be unique to those same technologies applied to a large SUV). Many commenters also stated that they found it difficult to understand how NHTSA and EPA had derived the cost estimates. In addition to commenting on NHTSA's methodology, many commenters, particularly manufacturers, also submitted their own cost estimates for each technology and requested that NHTSA consider them for the final rule.

As explained above, NHTSA contracted with Ricardo to aid the agency in analyzing the comments on the technology assumptions used in the NPRM, and relied considerably on Ricardo's expertise in developing the final technology cost and effectiveness estimates based on that analysis. For every technology included in NHTSA's analysis of technology costs and effectiveness, Ricardo and NHTSA engineers reviewed the comments thoroughly and exercised their expertise in assessing the merits of the comments, and in resolving the differences and determining which estimates should be used for the final rule.

For each technology, NHTSA relied on Ricardo's experience with "bill of materials" (BOM) costing. Some commenters criticized NHTSA for not using a BOM as the basis for its cost analysis. The 2008 Martec report,[110] which updated the Martec report on which the 2004 NESCCAF study was based, was submitted by auto industry commenters to NHTSA's NPRM docket for the agency's consideration. This report provides cost estimates developed on a "bill of materials" basis and methodology. NHTSA, with Ricardo's assistance, reviewed the "bill of materials" methodology in the Martec report and found it to be, compared to the methodology used in the NPRM, a more defensible and transparent basis for evaluating the costs of applicable technologies.

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[109] 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.
[110] Martec, "Variable Costs of Fuel Economy Technologies," June 1, 2008.

A bill of materials in a general sense is a list of components that make up a system—in this case, an item of fuel economy-improving technology. In order to determine what a system costs, one of the first steps is to determine its components and what they cost. In cases in which it was not practicable for the agency and Ricardo to estimate the cost of each component on a BOM basis because there was a shift to a more advanced technology and or because of difficulty in accounting for the sum of costs of all added components less the sum of costs of all deleted components (*e.g.*, in the transition from a gas engine to a diesel engine), incremental costs were estimated to be those of the entire new technology platform (in this example, the diesel engine) less those of the entire old technology platform (in this example, the gas engine). This "net difference" process was only used where developing a ground-up description of all component changes necessitated by the incremental technology was deemed to be impracticable.

With that framework in mind, Ricardo and NHTSA engineers proceeded with reviewing cost information for each major component of each technology. They compared the multiple sources available in the docket and assessed their validity. While NHTSA and Ricardo engineers relied considerably on the 2008 Martec Report for costing contents of some technologies, they did not do so for all. When relevant publicly available information and data sets, including the 2008 Martec report, were determined to be incomplete or non-existent, NHTSA looked to prior published data, including the NPRM, or to values provided to NHTSA by commenters familiar with the material costs of the described technologies.

Generally, whenever cost information for a technology component existed in a non-confidential and publicly available report submitted to the NPRM docket and that information agreed with Ricardo's independent review of cost estimates based on Ricardo's historical institutional knowledge, Ricardo and NHTSA cited that information. Ricardo and NHTSA were able to take that approach frequently, as is evident in the explanation of the cost figures of each technology. When that approach was not possible, but there was confidential manufacturer data that had been submitted to NHTSA in response to the NPRM, and those costs were consistent with Ricardo's independently-reviewed cost estimates, NHTSA and Ricardo cited those data. When multiple confidential data sources differed greatly and conflicted with the Martec valuation or when the technical assumptions described by NHTSA for purposes of this rulemaking did not match exactly with the content costed by either Martec or other commenters, NHTSA and Ricardo engineers used component-level data to build up a partial cost, substituting Ricardo's institutional knowledge for the remaining gaps in component level data.

Occasionally, NHTSA and Ricardo found that some cost information submitted by the public was either not very clearly described or revealed a lack of knowledge on the part of the commenter about NHTSA's methodology. In those cases, and in cases for which no cost data (either public or confidential) was available, NHTSA worked with Ricardo either to confirm the estimates it used in the NPRM, or to revise and update them.

In several cases, values described in the NPRM were simply adjusted from 2006 dollars to 2007 dollars, using a ratio of GDP values for the associated calendar years.[111] In many instances, an RPE factor of 1.5 was determined to have been omitted from the cost estimates provided in the NPRM, so NHTSA applied the multiplier where necessary to calculate the price to the consumer.

Finally, in response to comments stating that cost estimates for individual technologies should be varied, based on the type and size of vehicle to which they are applied, NHTSA worked with Ricardo to account for that. Additionally, application of some technologies might be more or less expensive, depending on content (*e.g.*, with or without a noise attenuation package), for particular vehicles. In these cases, NHTSA and Ricardo described a range of costs for this technology, and referred to sources that indicate the appropriate boundaries of that range.

The agency notes that several technologies considered in the final rule have been updated with substantially different cost estimates relative to those costs described in the NPRM. For example, RPE estimates for turbocharging and downsizing (TRBDS), diesel technologies (DSLT) and hybrid technologies (like ISG) are much higher than the costs cited in the NPRM for those technologies. This is due in large part to the updated cost estimates of the 2008 Martec Report and others, referenced in the final rule, which reflect the dramatic rise of global costs for raw materials associated with the above technologies since the 2004 Martec report and other prior referenced cost estimates were conducted. The NPRM costs were not updated to reflect that rise in commodities prices. As described in the 2008 Martec Report, advanced battery technologies with substantial copper, nickel or lithium content, and engine technologies employing high temperature steels or catalysts with considerable platinum group metals usage, have experienced tremendous inflation of raw material prices since the cost studies referenced in the NPRM were conducted. As of the time the sources were developed, prices of nickel, platinum, lithium, copper, dysprosium and rhodium had demonstrated cost inflation amounting to between 300 and 750 percent of global prices at the time of the original NESCCAF study[112] and this is reflected in the higher costs described in the 2008 Martec report, and thus in the final rule. NHTSA is aware that commodity prices, like those for steel and platinum group metals described above, have dropped over the last several months. However, there is little information in the record to determine how prices of components used in MY 2011 could be impacted by the prices of metals and other commodities over the last few years. It is not clear whether the prices of components built and used in MY 2011 are more likely to reflect the high price of commodities in the years prior to 2008, the current low prices of commodities, the prices of commodities closer to MY 2011, or some mixture of these. The agency notes, though, as mentioned above, that manufacturers' product plans were submitted along with manufacturers' indications that these plans were generally informed by expectations that relatively high commodity prices would prevail in the future. Therefore, in the expectation that economic conditions will improve by MY 2011, the agency relies on the

[111] NHTSA examined the use of the CPI multiplier instead of GDP for adjusting these dollar values, but found the difference to be exceedingly small – only $0.14 over $100.
[112] 2008 Martec report, at 13-20.

commodity prices reflected in, for example, the 2008 Martec report. However, the agency further notes that these decisions are limited to the MY 2011 rulemaking. We intend to monitor commodity prices carefully and will adjust affected technology costs as appropriate in future rulemakings.

Some commenters referenced the price differential between vehicles with advanced technologies and more standard versions as evidence of those advanced technologies' costs, and argued that NHTSA should consider these price differentials in its cost estimation process. In response, NHTSA believes that the "bottom-up, material cost based" cost estimation methodology employed for the final rule is preferable to estimating costs based on manufacturer price differentials between versions of vehicle models. Wherever possible, technologies were costed based on the estimation of variable material cost impacts to vehicle manufacturers at a fixed point in time (in 2007 dollar terms) for a prescribed set of component changes anticipated to be required in implementing the technology on a particular platform (*e.g.*, wastegate turbo, increased high nickel alloyed exhaust manifolds, air charge cooler, etc. for TRBDS). The content assumptions are modified or scaled to account for differences across the range of vehicle sizes and functional requirements and associated material cost impacts are adjusted to account for the revised content. The material cost impacts to the vehicle manufacturers are then summed and converted to retail price equivalent impacts by multiplying by 1.5 to account for fixed costs and other overheads incurred in the implementation of new vehicle technologies but not contained in the variable material price impacts to the manufacturers.

In employing this methodology, NHTSA relied on information provided to NHTSA by the suppliers and vehicle manufacturers themselves. Though this estimation process relies on often confidential data and employs a simplifying assumption in relating all variable material costs to retail impacts through the use of a consistent 1.5 RPE, the methodology is preferable to a "top-down, retail price based" methodology as might be used by comparing retail price differences of vehicles with different technologies. The "bottom-up" approach offers the benefits of providing a consistent and reasonable assessment of true, total costs for all technologies independent of geographic, or strategic pricing policies by vehicle manufacturers that could result in selling products at sub-standard or even negative margins. For many vehicle manufacturers, contribution to corporate profit varies dramatically across vehicle segment. Given that vehicle pricing is often decoupled from true costs and will vary with sales cycle, product maturity, geography, vehicle class, and marque, a "top-down" approach, while offering improved data transparency, is inherently limited in providing a consistent means of cost estimation. As such, NHTSA has adopted the described "bottom-up" cost estimation approach and has attempted to mitigate transparency issues with a reliance on Martec 2008 (where in agreement with other provided cost data), because it provides a detailed description of the costed content. Fundamentally, NHTSA believes that a "bottom-up" cost estimation methodology with a common RPE adjustment factor offers an intuitive, consistent process across all technologies, whether mature or otherwise, that avoids the pitfalls of reliance on significantly more variable and volatile pricing policies.

Regarding estimates for technology effectiveness, NHTSA, working with Ricardo, also reexamined its NPRM estimates and those in the EPA Staff Technical Report,[113] which largely mirrored NHTSA's NPRM estimates. We compared these estimates to estimates provided in comments, reports and confidential data received in response to our NPRM. Comments on the NPRM's effectiveness estimates generally fell into three categories: (1) that NHTSA did not account sufficiently for fuel economy or performance impacts because it used the Volpe model approach rather than full vehicle simulation; (2) that the synergy values used did not properly account for technology interactions; and (3) that NHTSA made errors when using estimates provided by manufacturers. In addition to commenting on NHTSA's methodology, many commenters, particularly manufacturers, also submitted their own fuel consumption reduction estimates for each technology and requested that NHTSA consider them for the final rule.

For each technology, NHTSA also relied on Ricardo's experience with "bill of materials" (BOM) technology descriptions. Some commenters argued that the same BOM used as the basis for the cost analysis could and should be used to define the technologies being studied for effectiveness. In fact, Ricardo's methodology for cost and effectiveness estimates for this rule was to define a vehicle class-specific BOM or BOMs, depending upon the number of variants possible within a class and within a decision tree. These BOMs were defined for the baseline configuration for each class and then for each incremental step in the decision tree. Use of a consistently-defined BOM is very important to estimating the impacts of technologies accurately, as it helps to ensure that technologies are not applied to baseline vehicles that already contain the technology (with the exception of items that are not well-defined such as aerodynamic drag reduction, reduced rolling resistance tires, weight reduction, and engine friction reduction.)

In defining these BOMs, Ricardo relied on its experience working with industry over many years and its recent experience preparing the December 2007 study for EPA. Ricardo built on its vehicle simulation work for EPA to help NHTSA evaluate appropriate effectiveness values for individual fuel-saving technologies. In considering the comments, NHTSA and Ricardo evaluated the 10 "vehicle subclasses" used in the NPRM for applicability of technologies and determined that the cost and effectiveness estimates could be more accurate by revising the "vehicle subclasses" as described above so that they better represented the parameters of the vehicles they included. This, in turn, enabled NHTSA and Ricardo to distinguish more clearly the differences in fuel consumption reduction occurring when a technology is added to different vehicles.

Then, with the BOM framework applied to more precisely-defined vehicle subclasses, NHTSA and Ricardo engineers reviewed effectiveness information from multiple sources for each technology. Together, they compared the multiple sources available in the docket and assessed their validity, taking care to ensure that common BOM definitions and other vehicle attributes such as performance, refinement, and drivability were not compromised.

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[113] 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.

Generally, whenever relevant effectiveness information for a technology component existed in a non-confidential and publicly-available report submitted to the NPRM docket, and that information agreed with Ricardo's independent review of estimates based on Ricardo's historical institutional knowledge, NHTSA and Ricardo cited that information. NHTSA and Ricardo were able to take that approach frequently, as is evident in the explanation of the effectiveness for each technology. When that approach was not possible, but there was confidential manufacturer data that had been submitted to NHTSA in response to the NPRM, and those values were consistent with Ricardo's independently-reviewed estimates, NHTSA and Ricardo cited those data. When multiple confidential data sources differed greatly or when the technical assumptions described by NHTSA for purposes of this rulemaking did not match the content included in Ricardo's study for EPA or in other comments, NHTSA and Ricardo engineers relied on Ricardo's experience and an understanding of the maximum theoretical losses that could be eliminated by particular technologies to build up an effectiveness estimate, substituting Ricardo's institutional knowledge for the remaining gaps in data.

Occasionally, NHTSA and Ricardo found that some fuel consumption reduction information submitted by the public was either not very clearly described or revealed a lack of knowledge on the part of the commenter about NHTSA' methodology. In those cases, and in cases for which no effectiveness data (either public or confidential) was available, NHTSA worked with Ricardo either to confirm the estimates it used in the NPRM, or to revise and enhance them. In other cases, the commenters appeared unsure how to evaluate the data from the NPRM, and so NHTSA and Ricardo provided more detailed explanations on the process used or the components involved.

In response to comments stating that estimates for individual technologies should be varied based on the type and size of vehicle to which they are applied, NHTSA worked with Ricardo to account for those differences mostly through the refined vehicle subclass definitions. However, even after making these adjustments, there are still some classes that require spanning different engine architectures and performance thresholds. Just as the application of some technologies might be more or less expensive, depending on content (*e.g.*, with or without a noise attenuation package), particular vehicle technologies may have more or less impact between classes where maintaining equivalent performance led to a reduced effectiveness. In these cases, NHTSA and Ricardo described a range of effectiveness values for this technology, and referred to sources that indicate the appropriate boundaries of that range.

With Ricardo's assistance, the technology cost and effectiveness estimates for the final rule were developed consistently, using this systematic approach. While NHTSA still believes that the ideal estimates for the final rule would be those that have been through a peer-reviewed process such as that used for the 2002 NAS Report, and will continue to work with NAS, as required by EISA, to update the technology cost and effectiveness estimates for subsequent CAFE rulemakings, this approach, combined with the BOM methodology for cost and effectiveness, expanded number and types of vehicle subclasses and the changes to the synergistic effects described below, not only help to address the concerns raised by commenters, but also represent a considerable improvement in terms of accuracy and transparency over the approach used to develop the cost and effectiveness estimates in the NPRM.

6. Learning curves

As explained in the NPRM, historically NHTSA did not explicitly account for the cost reductions a manufacturer might realize through learning achieved from experience in actually applying a technology. However, based on its work with EPA, in the NPRM NHTSA employed a learning factor for certain newer, emerging technologies. The "learning curve" describes the reduction in unit incremental production costs as a function of accumulated production volume and small redesigns that reduce costs. The NPRM implemented technology learning curves by using three parameters: (1) the initial production volume that must be reached before cost reductions begin to be realized (referred to as "threshold volume"); (2) the percent reduction in average unit cost that results from each successive doubling of cumulative production volume (usually referred to as the "learning rate"); and (3) the initial cost of the technology. The majority of technologies considered in the NPRM did not have learning cost reductions applied to them.

NHTSA assumed that learning-based reductions in technology costs occur at the point that a manufacturer applies the given technology to the first 25,000 cars or trucks, and are repeated a second time as it produces another 25,000 cars or trucks for the second learning step.[114] NHTSA explained that the volumes chosen represented the agency's best estimate for where learning would occur, and that they were better suited to NHTSA's analysis than using a single number for the learning curve factor, because each manufacturer would implement technologies at its own pace in the rule, rather than assuming that all manufacturers implement identical technology at the same time.

NHTSA further assumed that after having produced 25,000 cars or trucks with a specific part or system, sufficient learning will have taken place such that costs will be lower by 20 percent for some technologies and 10 percent for others. For those technologies, NHTSA additionally assumed that another cost reduction would be realized after another 25,000 units. If a technology was already in widespread use (*e.g.*, on the order of several million units per year) or expected to be so by the MY 2011-2012 time frame, NHTSA assumed that the technology was "learned out," and that no more cost reductions were available for additional volume increases. If a technology was not estimated to be available until later in the rulemaking period at that time, like MY 2014-2015, NHTSA did not apply learning for those technologies until those model years. Most of the technologies for which learning was applied after MY 2014 were adopted from the 2004 NESCCAF study, which was completed by Martec. Whenever source data, like the 2004 NESCCAF study, indicated that manufacturer cost reduction from future learning would occur, NHTSA took that information into account.

Comments received regarding NHTSA's approach to technology cost reductions due to manufacturer learning generally disagreed with the agency's method. The Alliance, AIAM, Honda, GM, and Chrysler all commented that NHTSA had substantially

[114] NHTSA treated car and truck volumes separately for determining those sales volumes.

overestimated, and essentially "double-counted," learning effects by applying learning reductions to component costs, specifically Martec estimates, which were already at high volume. The Alliance submitted the 2008 Martec Report, which stated that NHTSA had "misstated" Martec's approach to cost reductions due to learning in the NPRM. As Martec explained,

> Martec did not ask suppliers to quote prices that would be valid for three years, and Martec did not receive cost reductions from suppliers for some components in years two and three. Rather, industry respondents were asked to establish mature component pricing on a forward basis given the following conditions: at least three (3) manufacturers demanding 500,000 units per year and at least three (3) globally-capable suppliers available to supply the needs of each manufacturer.
> In no case did Martec ask industry respondents to provide low volume, launch or transition costs for fuel consumption/CO_2 reducing technologies. Martec specifically designed the economic parameters in order to capture the effects of learning which is a reality in the low margin, high capital cost, high volume, highly competitive global automotive industry. Applying additional reductions attributable to "learning" based on 25,000 unit improvements in cumulative volume after production launch (as described on pages 118-125 of the NHTSA NPRM) on top of Martec's mature costs is an error. Martec's costs are based on 1.5-2.0 equivalent modules of powertrain capacity (500,000 units/year) so 25,000 unit incremental changes in cumulative production, as defined by NHTSA, will have no effect on costs.

The 2008 Martec Report also stated that current industry practice consists of using competitive bidding based on long-term, high-volume contracts that are negotiated before technology implementation decisions are made. Martec stated that this practice considers the effects of volume, learning, and capital depreciation. Martec also indicated that most of the technologies evaluated in the study are in high volume production in the global automotive industry today, and thus this forms a solid basis from which to estimate future costs.

Honda also commented on NHTSA's 25,000 unit (per manufacturer per year) volume threshold stating that, in their experience, costs were only likely to decrease due to learning at volumes exceeding about 300,000 units per year per manufacturer. GM agreed, stating that suppliers do not respond to, change processes, or change contract terms for relatively small volume changes like NHTSA's 25,000 unit increment, thus volume changes of this magnitude have no effect on component pricing. GM also commented that its learning cycles are based on time, not volume, and agreed with Martec's assessment that contracts with suppliers typically specify volumes and costs over a period, which are usually equal to a product life cycle, a 4- to 5-year period.

Ford commented that base costs in the automotive industry are determined by a target setting process, where manufacturers develop pricing with suppliers for a set period, and manufacturers receive cost reductions from the suppliers due to learning as time passes, apparently at a set amount year over year for several years. Ford also commented that NHTSA's approach to learning curves had not accounted for current economic factors, like increases in commodity and energy prices, and cited the example of costs of batteries for hybrids and PHEVs which Ford stated "are not likely to depend solely on experience learned, but, to a large extent, on the additional energy and material costs they incur relative to the vehicles without the new technology." Ford commented that NHTSA should account for these costs, and the factor of declining vehicle sales, in its learning curve approach.

BorgWarner, a components supplier, commented that learning-related costs savings are valid for technologies that "*start at low* volume" (commenter's emphasis). BorgWarner argued, however, that NHTSA's assumed learning curve would not apply to the technologies it supplies to manufacturers,[115] since these components are well-developed and in high volume use already, and are thus already "learned out." BorgWarner further commented that an increase in demand could in fact lead to higher prices if demand for raw materials exceeded supply.

UCS, in contrast, commented that NHTSA had not accounted for *enough* cost reductions due to learning. UCS stated that NHTSA should have provided "source data" for manufacturer-specific learning curves, and argued that NHTSA's approach was "fundamentally flawed" for two primary reasons: first, because NHTSA had not considered the fact that manufacturers engage in joint ventures to develop new technologies, and second, because manufacturers may also learn from one another "through the standard practice of tearing down competitors' products." UCS argued that NHTSA's learning-based cost reductions should account for these methods of learning. UCS further stated that NHTSA should not "treat[] car and truck sales volumes separately when estimating learning curves" because there may be much overlap in terms of technology application, especially for vehicles like crossovers which may be either cars or trucks. UCS concluded that NHTSA should use EPA's suggested learning factor of 20 percent, citing EPA's Staff Technical Report.

Public Citizen agreed that NHTSA should account for economies of scale, but argued that NHTSA should not have relied on initial cost estimates from industry, which the commenter stated were "often overestimated." Public Citizen cited a 1997 briefing paper by the Economic Policy Institute in support of this point, and argued that compliance cost estimates were often much lower than actual costs. Public Citizen concluded that NHTSA's use of learning curve factors "impedes transparency" in NHTSA's analysis.

Agency response: Based on the comments received and on its work with Ricardo, NHTSA has revised its approach to accounting for technology cost reductions due to manufacturer learning. The method of learning used in the NPRM has been retained, but the threshold volume has been revised and is now calculated on an industry-wide production basis. However, learning of this type, which NHTSA now refers to as "volume-based" learning, is not applicable to any technologies for MY 2011. Additionally, NHTSA has adopted a fixed rate, year-over-year (YOY) cost reduction for

[115] BorgWarner manufacturers and supplies turbochargers, dual clutch transmissions, variable valve timing systems, diesel engine components (EGR and starting), aggressive shift logic and early torque convertor lockup systems.

widely-available, high-volume, mature technologies, in response to comments from Ford and others. NHTSA refers to this type cost reduction as "time-based" learning. For each technology, if learning is applicable, only one type of learning would be applied, either volume-based or time-based (*i.e.*, the types are independent of each other). These revisions are discussed below.

For volume-based learning, NHTSA considered comments from UCS and decided to revise the method used to calculate the threshold volume from a per-manufacturer to an industry-wide production volume basis. NHTSA agreed with UCS' comment that cars and trucks may share common components—this is true across many makes and models which share common engines, transmissions, accessory systems, and mild or strong hybrid systems, all of which can potentially utilize the technologies under consideration. These systems are often manufactured by suppliers who contract with multiple OEMs, all of whom benefit (in the form of cost reductions for the technology) from the supplier's learning. The 2008 Martec Report and the BorgWarner comments additionally both indicated that when manufacturers demand components in high volumes, suppliers are able to pass on learning-based savings to all manufacturers with whom they contract. Thus, it made sense to NHTSA to revise its method of determining whether the threshold volume has been achieved from an annual per-manufacturer to an annual industry-wide production volume basis.

NHTSA also changed the threshold volume for volume-based learning from 25,000 to 300,000 units. The 2008 Martec Report and comments from multiple manufacturers indicated that 25,000 units was far too small a production volume to affect component costs. In response, NHTSA began with the Martec estimate that technologies were fully learned-out at 1.5 million units of production (which met the production needs of three manufacturers, according to that report). NHTSA then applied two cycles of learning in a reverse direction to determine what the proper threshold volume would be for these conditions. One cycle would be applied at 750,000 units (1.5 million divided by 2, which would represent the second volume doubling) and one at 375,000 units (750,000 divided by 2, which would represent the first volume doubling). NHTSA thus estimated that the Martec analysis would suggest a threshold volume of 375,000 units. However, the agency notes that Martec stated that it chose the 1.5 million units number specifically because Martec knew it was well beyond the point where learning is a factor, which means that 1.5 million was beyond the cusp of the learning threshold. NHTSA therefore concluded that 375,000 units should represent the upper bound for the threshold volume for Martec's analysis.

Having determined this, NHTSA sought to establish a lower bound for the threshold volume. The 2008 Martec report indicated that production efficiencies are maximized at 250,000-350,000 units (which averages to 300,000 units), and that manufacturers consequently target this range when planning and developing manufacturing operations. Honda also cited this production volume. Thus, for three manufacturers, the annual volume requirement would be 900,000 units.[116] NHTSA concluded this could also

[116] An industry volume of 900,000 would imply a threshold volume of 225,000 units according to NHTSA's analysis. This is still nine times the value used at the NPRM.

represent high volume where learned costs could be available, and considered it as a lower bound estimate. With the upper and lower values established, and given that Martec specifically indicated that 1.5 million did not represent the cusp of the learning threshold, NHTSA chose the mid-point of 1.2 million units as the best estimate of annual industry volumes where learned costs would be experienced. For proper forward learning, this would mean the first learning cycle would occur at 300,000 and the second at 600,000. Accordingly NHTSA has established the threshold volume for the final rule at 300,000 industry units per year.

Having established the threshold volume, NHTSA next considered which technologies to apply volume learning to. Comments confirmed that NHTSA had been correct in the NPRM to assume that learning would be applicable to low-volume, emerging technologies that could benefit from economies of scale, so NHTSA consulted confidential product plans to determine the volumes of technologies to be applied by manufacturers during the rulemaking period. If the product plans indicated that the technologies would be in high-volume use (*i.e.*, above 600,000 units produced annually for cars and trucks by all manufacturers) at the beginning of its first year of availability, then volume-based learning was not considered applicable, since at this volume the technology would be available at learned cost. If the volume was below 600,000 units annually, then NHTSA also looked at the Volpe model's application of the technology. If the model applied more than 600,000 units within the first year of availability, NHTSA did not apply volume-based learning. If neither manufacturers nor the model applied more than 600,000 units within the first year, then volume learning was applied to the technology.

Based on this analysis, NHTSA determined that volume-based learning would be applicable to three technologies for purposes of the final rule: integrated starter generator, 2-mode hybrid, and plug-in hybrid. For these three technologies, and where the agency's initial cost estimates reflected full learning, NHTSA reverse-learned the cost by dividing the estimate by the learning rate twice to properly offset the learned cost estimate. NHTSA used a 20 percent learning rate in the NPRM for these technologies, and concluded that that rate was still applicable for the final rule. This learning rate was validated using manufacturer-submitted current and forecast cost data for advanced-battery hybrid vehicle technology, and accepted industry forecasts for U.S. sales volumes of these same vehicles. This limited study indicated that cost efficiencies were approximately 20 percent for a doubling of U.S. market annual sales of a particular advanced battery technology, and the learning rate was thus used as a proxy for other advanced vehicle technologies.

Commenters also indicated that learning-related cost reductions could occur not only as a result of production volume changes, but also as a function of time. For example, Ford stated that technology cost reductions were negotiated as part of the contractual agreement to purchase components from suppliers, a target-setting process which Ford described as common in the automotive industry. In this arrangement suppliers agree to reduce costs on a fixed percentage year over year according to negotiated terms. GM described a cost reduction process that occurs over the course of a product life cycle, typically no less than 4-5 years, where costs are reduced as production experience increases. GM stated that its cost reductions included engineering, manufacturing, investment, and material costs, and were also defined through supplier contracts that anticipate volume and costs over the whole period. The components involved are assumed to be high volume, mature technologies being used in current vehicle production. These are the types of components that would typically be subject to "cost-down"[117] efforts that target savings through small, incremental design, manufacturing, assembly, and material changes on a recurring or periodic basis.

In response to these comments, NHTSA has adopted this approach as an additional type of learning related cost reduction, referring to it as "time-based" learning. For purposes of the final rule, time-based learning is applied to high-volume, mature technologies likely to be purchased by OEMs on a long-term contractual basis. This would include most of the fuel-saving technologies under consideration, except those where volume-based learning is applied, or those where components might consist of commodity materials, such as oil or rubber, where pricing fluctuations prevent long-term or fixed value contracts. NHTSA has used a 3 percent reduction rate for time-based learning, based on confidential manufacturer information and NHTSA's understanding of current industry practice. Thus, if time-based learning is deemed applicable, then in year two of a technology's application, and in each subsequent year (if any), the initial cost is reduced by 3 percent. This approach is responsive to comments about compliance costs estimation, and improves the accuracy of projecting future costs compared to the NPRM.

With regard to the comments from UCS, NHTSA recognizes that joint-venture collaboration and competitor tear-downs are methods used by manufacturers for designing and developing new products and components, but notes that these methods are used prior to the manufacturing stage, and thus are not considered manufacturing costs. NHTSA has received no specific manufacturer learning curve-related data, and thus has no "source data" to disclose. NHTSA continues to use a 20 percent learning factor for volume-based learning, which is consistent with EPA's learning factor recommended by UCS for NHTSA's use.

With regard to the comments from Public Citizen, although NHTSA reviewed the paper cited by the commenter, the agency found its analysis largely irrelevant to NHTSA's estimation of cost reduction factors due to automobile manufacturer learning, and thus declines to adopt its findings.

Table V-4 below shows the applicability and type of learning applied in the final rule.

[117] Cost-down efforts are a common practice in competitive manufacturing environments like the automotive industry.

Table V-4—Application of learning-related cost reductions for technologies

Technology	Abbr.	Learning Type	Learning Rate
Low Friction Lubricants	LUB		
Engine Friction Reduction	EFR		
VVT - Coupled Cam Phasing (CCP) on SOHC	CCPS	TIME	3%
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	TIME	3%
Cylinder Deactivation on SOHC	DEACS	TIME	3%
VVT - Intake Cam Phasing (ICP)	ICP	TIME	3%
VVT - Dual Cam Phasing (DCP)	DCP	TIME	3%
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	TIME	3%
Continuously Variable Valve Lift (CVVL)	CVVL	TIME	3%
Cylinder Deactivation on DOHC	DEACD	TIME	3%
Cylinder Deactivation on OHV	DEACO	TIME	3%
VVT - Coupled Cam Phasing (CCP) on OHV	CCPO	TIME	3%
Discrete Variable Valve Lift (DVVL) on OHV	DVVLO	TIME	3%
Conversion to DOHC with DCP	CDOHC	TIME	3%
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	TIME	3%
Combustion Restart	CBRST	TIME	3%
Turbocharging and Downsizing	TRBDS	TIME	3%
Exhaust Gas Recirculation (EGR) Boost	EGRB	TIME	3%
Conversion to Diesel following CBRST	DSLC	TIME	3%
Conversion to Diesel following TRBDS	DSLT	TIME	3%
Electric Power Steering	EPS	TIME	3%
Improved Accessories	IACC	TIME	3%
12V Micro-Hybrid	MHEV	TIME	3%
Higher Voltage/Improved Alternator	HVIA	TIME	3%
Integrated Starter Generator	ISG	VOLUME	20%
6-Speed Manual/Improved Internals	6MAN	TIME	3%
Improved Auto. Trans. Controls/Externals	IATC	TIME	3%
Continuously Variable Transmission	CVT	TIME	3%
6/7/8-Speed Auto. Trans with Improved Internals	NAUTO	TIME	3%
Dual Clutch or Automated Manual Transmission	DCTAM	TIME	3%
Power Split Hybrid	PSHEV	TIME	3%
2-Mode Hybrid	2MHEV	VOLUME	20%
Plug-in Hybrid	PHEV	VOLUME	20%
Material Substitution (1%)	MS1		
Material Substitution (2%)	MS2		
Material Substitution (5%)	MS5		
Low Rolling Resistance Tires	ROLL		
Low Drag Brakes	LDB	TIME	3%
Secondary Axle Disconnect – 4WD	SAX	TIME	3%
Aero Drag Reduction	AERO	TIME	3%

7. Technology 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.[118] This may occur because one or 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 for purposes of this rulemaking as a "synergy." Synergies may be positive (increased fuel consumption reduction compared to the product of the individual effects) or negative (decreased fuel consumption reduction).

For the NPRM, the Volpe model was modified to estimate the interactions of technologies using estimates of incremental synergies associated with a number of technology pairs identified by NHTSA. The use of discrete technology pair incremental synergies is similar to that in DOE's National Energy Modeling System (NEMS).[119] Inputs to the Volpe model incorporate NEMS-identified pairs, as well as additional pairs for the final rule from the set of technologies considered in the Volpe model. However, to maintain an approach that was consistent with the technology sequencing developed by NHTSA, new incremental synergy estimates for all pairs were obtained from a first-order "lumped parameter" analysis tool created by EPA.[120]

The lumped parameter tool is a spreadsheet model that 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 engine, drivetrain and vehicle characteristics that are averaged over the EPA fuel economy drive cycle. Results of this analysis were generally consistent with those of full-scale vehicle simulation modeling performed by Ricardo, Inc. However, 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

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[118] More specifically, the products of the differences between one and the technology-specific levels of effectiveness in reducing fuel consumption. 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 combined effectiveness of 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.

[119] U.S. Department of Energy, Energy Information Administration, *Transportation Sector Module of the National Energy Modeling System: Model Documentation 2007*, May 2007, Washington, DC, DOE/EIA-M070(2007), at 29-30. *Available at* http://tonto.eia.doe.gov/ftproot/modeldoc/m070(2007).pdf (last accessed Oct. 24, 2008).

[120] 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.

simulation.

Many comments were received that stated this and pointed to errors in the synergies listed in the NPRM being in some cases inaccurate or even directionally incorrect. NHTSA recognizes that the estimated synergies applied for the NPRM were not all correct, and has reevaluated all estimated synergies applied in the analysis supporting today's final rule. In response to commenters calling for NHTSA to use full vehicle simulation, either in the first instance or as a check on the synergy factors that NHTSA developed, the agency has concluded that the vehicle simulation analyses conducted previously by Ricardo provide a sufficient point of reference, especially considering the time constraints for establishing the final rule. NHTSA did, however, improve the predictive capability of the lumped parameter tool.

The lumped parameter tool was first updated with the new list of technologies and their associated effectiveness values. Second, NHTSA conducted a more rigorous qualitative analysis of the technologies for which a competition for losses would be expected, which led to a much larger list of synergy pairings than was present in the NRPM. The types of losses that were analyzed were tractive effort, transmission/drivetrain, engine mechanical friction, engine pumping, engine indicated (combustion) efficiency and accessory (see Table V-5). As can be seen from Table V-5, engine mechanical friction, pumping and accessory losses are improved by various technologies from engine, transmission, electrification and hybrid decision trees and must be accounted for within the model with a synergy value. The updated lumped parameter model was then re-run to develop new synergy estimates for the expanded list of pairings. That list is shown in Tables IV-6a-d. The agency notes that synergies that occur within a decision tree are already addressed within the incremental values assigned and therefore do not require a synergy pair to address. For example, all engine technologies take into account incremental synergy factors of preceding engine technologies, and all transmission technologies take into account incremental synergy factors of preceding transmission technologies. These factors are expressed in the fuel consumption improvement factors in the input files used by the Volpe model.

For applying incremental synergy factors in separate path technologies, the Volpe model uses an input table (see Tables IV-6a-d) which 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 Volpe 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 Volpe model) are summed and applied to the fuel consumption improvement factor of the technology being applied. Synergies for the strong hybrid technology fuel consumption reductions are included in the incremental value for the specific hybrid technology block since 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 hybrid technologies.

As another possible alternative to using synergy factors, NHTSA has also considered modifying the Volpe model to apply inputs—for each vehicle model—specifying the share of total fuel consumption attributable to each of several energy loss mechanisms. The agency has determined that this approach, discussed in greater detail below, cannot be implemented at this time because the requisite information is not available.

Table V-5. Loss Factors Considered in Synergy Analysis

Lumped Parameter Synergy Analysis	VEHICLE Tractive Effort	TRANS Drivetrain Losses	ENGINE Mechanical Friction	ENGINE Pumping Losses	ENGINE Accessory Losses	ENGINE Indicated Efficiency
ENGINE						
Low Friction Lubricants			+			
Engine Friction Reduction			+			
VVT - Coupled Cam Phasing (CCP) on SOHC			-	+		+
Discrete Variable Valve Lift (DVVL) on SOHC			-	+		
Cylinder Deactivation on SOHC			+	+		
VVT - Intake Cam Phasing (ICP)			-	+		+
VVT - Dual Cam Phasing (DCP)			-	+		+
Discrete Variable Valve Lift (DVVL) on DOHC			-	+		
Continuously Variable Valve Lift (CVVL)			-	+		
Cylinder Deactivation on DOHC			+	+		
Cylinder Deactivation on OHV			+	+		
VVT - Coupled Cam Phasing (CCP) on OHV			-	+		+
Discrete Variable Valve Lift (DVVL) on OHV			-	+		
Conversion to DOHC with DCP			-	+		+
Stoichiometric Gasoline Direct Injection (GDI)						+
Combustion Restart			+	+	+	
Turbocharging and Downsizing			-	+		
Exhaust Gas Recirculation (EGR) Boost						+
Conversion to Diesel				+		+
ELECTRIFICATION/ACCESSORY						
Electric Power Steering					+	
Improved Accessories					+	
12V Micro-Hybrid			+	+	+	
Higher Voltage/Improved Alternator					+	
Integrated Starter Generator			+	+	+	
TRANSMISSION (MANUAL)						
6-Speed Manual/Improved Internals		+		+		
TRANSMISSION (AUTOMATIC)						
Improved Auto. Trans. Controls/Externals		+		+		
Continuously Variable Transmission		-		+		
6/7/8-Speed Auto. Trans with Impr. Internals		+		+		
Dual Clutch/Automated Manual Transmission		+				
(STRONG) HYBRID						
Power Split Hybrid		+	+	+	+	
2-Mode Hybrid		+	+	+	+	
Plug-in Hybrid		+	+	+	+	
VEHICLE						
Material Substitution (1%)	+					
Material Substitution (2%)	+					
Material Substitution (5%)	+					
Low Rolling Resistance Tires	+					
Low Drag Brakes	+					
Secondary Axle Disconnect - 4WD		+				
Aero Drag Reduction	+					

+ Technology has a positive effect on fuel consumption
- Technology has a negative effect on fuel consumption

Table V-6a. Synergy pairings and values

Synergies		Fuel Consumption Improvement Synergy values by Vehicle Subclass Positive values are positive synergies, negative values are dissynergies.					
Technology A	Technology B	Subcompact PC	Subcompact Perf. PC	Compact PC	Compact Perf. PC	Midsize PC	Midsize Perf. PC
CCPS	6MAN	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
CCPS	IATC	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CCPS	CVT	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%
CCPS	NAUTO	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
CCPS	MHEV	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
CCPS	ISG	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%
DVVLS	6MAN	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
DVVLS	IATC	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%
DVVLS	CVT	-1.4%	-1.4%	-1.4%	-1.4%	-1.4%	-1.4%
DVVLS	NAUTO	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
DVVLS	MHEV	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%
DVVLS	ISG	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
DEACS	6MAN	n.a.	n.a.	n.a.	-0.2%	n.a.	-0.2%
DEACS	IATC	n.a.	n.a.	n.a.	-0.6%	n.a.	-0.6%
DEACS	CVT	n.a.	n.a.	n.a.	-1.7%	n.a.	-1.7%
DEACS	NAUTO	n.a.	n.a.	n.a.	-0.9%	n.a.	-0.9%
DEACS	MHEV	n.a.	n.a.	n.a.	-0.9%	n.a.	-0.9%
DEACS	ISG	n.a.	n.a.	n.a.	-1.1%	n.a.	-1.1%
ICP	6MAN	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
ICP	IATC	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
ICP	CVT	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%
ICP	NAUTO	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
ICP	MHEV	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
ICP	ISG	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%
DCP	6MAN	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
DCP	IATC	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
DCP	CVT	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%
DCP	NAUTO	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
DCP	MHEV	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%
DCP	ISG	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
DVVLD	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
DVVLD	IATC	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
DVVLD	CVT	-1.8%	-1.8%	-1.8%	-1.8%	-1.8%	-1.8%
DVVLD	NAUTO	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
DVVLD	MHEV	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%
DVVLD	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
DEACD	6MAN	n.a.	n.a.	n.a.	-0.2%	n.a.	-0.2%
DEACD	IATC	n.a.	n.a.	n.a.	-0.6%	n.a.	-0.6%
DEACD	CVT	n.a.	n.a.	n.a.	-1.8%	n.a.	-1.8%
DEACD	NAUTO	n.a.	n.a.	n.a.	-1.0%	n.a.	-1.0%
DEACD	MHEV	n.a.	n.a.	n.a.	-0.9%	n.a.	-0.9%
DEACD	ISG	n.a.	n.a.	n.a.	-1.1%	n.a.	-1.1%
CVVL	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CVVL	IATC	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
CVVL	CVT	-1.8%	-1.8%	-1.8%	-1.8%	-1.8%	-1.8%
CVVL	NAUTO	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
CVVL	MHEV	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%
CVVL	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%

Table V-6b. Synergy pairings and values

Synergies		Fuel Consumption Improvement Synergy values by Vehicle Subclass Positive values are positive synergies, negative values are dissynergies.					
Technology A	**Technology B**	**Subcompact PC**	**Subcompact Perf. PC**	**Compact PC**	**Compact Perf. PC**	**Midsize PC**	**Midsize Perf. PC**
DEACO	6MAN	n.a.	n.a.	n.a.	-0.1%	n.a.	-0.1%
DEACO	IATC	n.a.	n.a.	n.a.	-0.5%	n.a.	-0.5%
DEACO	CVT	n.a.	n.a.	n.a.	-1.4%	n.a.	-1.4%
DEACO	NAUTO	n.a.	n.a.	n.a.	-0.8%	n.a.	-0.8%
DEACO	MHEV	n.a.	n.a.	n.a.	-0.9%	n.a.	-0.9%
DEACO	ISG	n.a.	n.a.	n.a.	-1.2%	n.a.	-1.2%
CCPO	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CCPO	IATC	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
CCPO	CVT	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%
CCPO	NAUTO	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%
CCPO	MHEV	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
CCPO	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
DVVLO	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
DVVLO	IATC	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
DVVLO	CVT	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%
DVVLO	NAUTO	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
DVVLO	MHEV	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
DVVLO	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
CDOHC	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CDOHC	IATC	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
CDOHC	CVT	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%	-2.0%
CDOHC	NAUTO	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
CDOHC	MHEV	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
CDOHC	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
CBRST	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CBRST	IATC	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
CBRST	CVT	-1.8%	-1.8%	-1.8%	-1.8%	-1.8%	-1.8%
CBRST	NAUTO	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
CBRST	MHEV	-2.1%	-2.1%	-2.1%	-2.1%	-2.1%	-2.1%
CBRST	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
CBRST	EPS	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CBRST	IACC	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
CBRST	HVIA	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%
TRBDS	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
TRBDS	IATC	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
TRBDS	CVT	-2.4%	-2.4%	-2.4%	-2.4%	-2.4%	-2.4%
TRBDS	NAUTO	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%
TRBDS	MHEV	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
TRBDS	ISG	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%
DSLC	6MAN	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%
DSLC	IATC	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
DSLC	CVT	-2.9%	-2.9%	-2.9%	-2.9%	-2.9%	-2.9%
DSLC	NAUTO	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%
DSLC	MHEV	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
DSLC	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
DSLT	6MAN	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%
DSLT	IATC	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
DSLT	CVT	-2.9%	-2.9%	-2.9%	-2.9%	-2.9%	-2.9%
DSLT	NAUTO	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%
DSLT	MHEV	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
DSLT	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%

Table V-6c. Synergy pairings and values

Synergies		Fuel Consumption Improvement Synergy values by Vehicle Subclass Positive values are positive synergies, negative values are dissynergies.					
Technology A	**Technology B**	**Large PC**	**Large Perf. PC**	**Minivan LT**	**Small LT**	**Midsize LT**	**Large LT**
CCPS	6MAN	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
CCPS	IATC	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CCPS	CVT	-0.8%	n.a.	-0.8%	-0.8%	-0.8%	n.a.
CCPS	NAUTO	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
CCPS	MHEV	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	n.a.
CCPS	ISG	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	n.a.
DVVLS	6MAN	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
DVVLS	IATC	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%	-0.5%
DVVLS	CVT	-1.4%	n.a.	-1.4%	-1.4%	-1.4%	n.a.
DVVLS	NAUTO	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
DVVLS	MHEV	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%	n.a.
DVVLS	ISG	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	n.a.
DEACS	6MAN	-0.2%	-0.2%	-0.2%	n.a.	-0.2%	-0.2%
DEACS	IATC	-0.6%	-0.6%	-0.6%	n.a.	-0.6%	-0.6%
DEACS	CVT	-1.7%	n.a.	-1.7%	n.a.	-1.7%	n.a.
DEACS	NAUTO	-0.9%	-0.9%	-0.9%	n.a.	-0.9%	-0.9%
DEACS	MHEV	-0.9%	-0.9%	-0.9%	n.a.	-0.9%	n.a.
DEACS	ISG	-1.1%	-1.1%	-1.1%	n.a.	-1.1%	n.a.
ICP	6MAN	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
ICP	IATC	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
ICP	CVT	-0.8%	n.a.	-0.8%	-0.8%	-0.8%	n.a.
ICP	NAUTO	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
ICP	MHEV	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	n.a.
ICP	ISG	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	n.a.
DCP	6MAN	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%	-0.1%
DCP	IATC	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%	-0.4%
DCP	CVT	-1.3%	n.a.	-1.3%	-1.3%	-1.3%	n.a.
DCP	NAUTO	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
DCP	MHEV	-0.8%	-0.8%	-0.8%	-0.8%	-0.8%	n.a.
DCP	ISG	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	n.a.
DVVLD	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
DVVLD	IATC	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
DVVLD	CVT	-1.8%	n.a.	-1.8%	-1.8%	-1.8%	n.a.
DVVLD	NAUTO	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
DVVLD	MHEV	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	n.a.
DVVLD	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.
DEACD	6MAN	-0.2%	-0.2%	-0.2%	n.a.	-0.2%	-0.2%
DEACD	IATC	-0.6%	-0.6%	-0.6%	n.a.	-0.6%	-0.6%
DEACD	CVT	-1.8%	n.a.	-1.8%	n.a.	-1.8%	n.a.
DEACD	NAUTO	-1.0%	-1.0%	-1.0%	n.a.	-1.0%	-1.0%
DEACD	MHEV	-0.9%	-0.9%	-0.9%	n.a.	-0.9%	n.a.
DEACD	ISG	-1.1%	-1.1%	-1.1%	n.a.	-1.1%	n.a.
CVVL	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CVVL	IATC	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
CVVL	CVT	-1.8%	n.a.	-1.8%	-1.8%	-1.8%	n.a.
CVVL	NAUTO	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%
CVVL	MHEV	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	n.a.
CVVL	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.

Table V-6d. Synergy pairings and values

Synergies		Fuel Consumption Improvement Synergy values by Vehicle Subclass Positive values are positive synergies, negative values are dissynergies.					
Technology A	**Technology B**	**Large PC**	**Large Perf. PC**	**Minivan LT**	**Small LT**	**Midsize LT**	**Large LT**
DEACO	6MAN	-0.1%	-0.1%	-0.1%	n.a.	-0.1%	-0.1%
DEACO	IATC	-0.5%	-0.5%	-0.5%	n.a.	-0.5%	-0.5%
DEACO	CVT	-1.4%	n.a.	-1.4%	n.a.	-1.4%	n.a.
DEACO	NAUTO	-0.8%	-0.8%	-0.8%	n.a.	-0.8%	-0.8%
DEACO	MHEV	-0.9%	-0.9%	-0.9%	n.a.	-0.9%	n.a.
DEACO	ISG	-1.2%	-1.2%	-1.2%	n.a.	-1.2%	n.a.
CCPO	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CCPO	IATC	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
CCPO	CVT	-1.7%	n.a.	-1.7%	-1.7%	-1.7%	n.a.
CCPO	NAUTO	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%	-0.9%
CCPO	MHEV	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	n.a.
CCPO	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.
DVVLO	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
DVVLO	IATC	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
DVVLO	CVT	-2.0%	n.a.	-2.0%	-2.0%	-2.0%	n.a.
DVVLO	NAUTO	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
DVVLO	MHEV	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	n.a.
DVVLO	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.
CDOHC	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CDOHC	IATC	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
CDOHC	CVT	-2.0%	n.a.	-2.0%	-2.0%	-2.0%	n.a.
CDOHC	NAUTO	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
CDOHC	MHEV	-1.0%	-1.0%	-1.0%	-1.0%	-1.0%	n.a.
CDOHC	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.
CBRST	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
CBRST	IATC	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%	-0.6%
CBRST	CVT	-1.8%	n.a.	-1.8%	-1.8%	-1.8%	n.a.
CBRST	NAUTO	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%
CBRST	MHEV	-2.1%	-2.1%	-2.1%	-2.1%	-2.1%	n.a.
CBRST	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.
CBRST	EPS	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	n.a.
CBRST	IACC	-0.4%	-0.4%	-0.4%	-0.4%	n.a.	n.a.
CBRST	HVIA	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	n.a.
TRBDS	6MAN	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%	-0.2%
TRBDS	IATC	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%	-0.7%
TRBDS	CVT	-2.4%	n.a.	-2.4%	-2.4%	-2.4%	n.a.
TRBDS	NAUTO	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%
TRBDS	MHEV	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.
TRBDS	ISG	-1.3%	-1.3%	-1.3%	-1.3%	-1.3%	n.a.
DSLC	6MAN	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%
DSLC	IATC	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
DSLC	CVT	-2.9%	n.a.	-2.9%	-2.9%	-2.9%	n.a.
DSLC	NAUTO	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%
DSLC	MHEV	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.
DSLC	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.
DSLT	6MAN	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%	-0.3%
DSLT	IATC	2.5%	2.5%	2.5%	2.5%	2.5%	2.5%
DSLT	CVT	-2.9%	n.a.	-2.9%	-2.9%	-2.9%	n.a.
DSLT	NAUTO	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%	-1.7%
DSLT	MHEV	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.
DSLT	ISG	-1.1%	-1.1%	-1.1%	-1.1%	-1.1%	n.a.

8. How does NHTSA use full vehicle simulation?

For regulatory purposes, the fuel economy of any given vehicle is determined by placing the vehicle on a chassis dynamometer (akin to a large treadmill that puts the vehicle's wheels in contact with one or more rollers, rather than with a belt stretched between rollers) in a controlled environment, driving the vehicle over a specific driving cycle (in which driving speed is specified for each second of operation), measuring the amount of carbon dioxide emitted from the vehicle's tailpipe, and calculating fuel consumption based on the density and carbon content of the fuel.

One means of determining the effectiveness of a given technology as applied to a given vehicle model would be to measure the vehicle's fuel economy on a chassis dynamometer, install the new technology, and then re-measure the vehicle's fuel economy. However, most technologies cannot simply be "swapped out," and even for those that can, simply doing so without additional engineering work may change other vehicle characteristics (*e.g.*, ride, handling, performance, etc.), producing an "apples to oranges" comparison.

Some technologies can also be more narrowly characterized through bench or engine dynamometer (*i.e.*, in which the engine drives a generator that is, in turn, used to apply a controlled load to the engine) testing. For example, engine dynamometer testing could be used to evaluate the brake-specific fuel consumption (*e.g.*, grams per kilowatt-hour) of a given engine before and after replacing the engine oil with a less viscous oil. However, such testing does not provide a direct measure of overall vehicle fuel economy or changes in overall vehicle fuel economy.

For a vehicle that does not yet exist, as in NHTSA's analysis of CAFE standards applicable to future model years, even physical testing can provide only an estimate of the vehicle's eventual fuel economy. Among the alternatives to physical testing, automotive engineers involved in vehicle design make use of computer-based analysis tools, including a powerful class of tools commonly referred to as "full vehicle simulation." Given highly detailed inputs regarding vehicle engineering characteristics, full vehicle simulation provides a means of estimating vehicle fuel consumption over a given drive cycle, based on the explicit representation of the physical laws governing vehicle propulsion and dynamics. Some vehicle simulation tools also incorporate combustion simulation tools that represent the combustion cycle in terms of governing physical and chemical processes. Although these tools are computationally intensive and required a great deal of input data, they provide engineers involved in vehicle development and design with an alternative that can be considerably faster and less expensive than physical experimentation and testing.

Properly executed, methods such as physical testing and full vehicle simulation can provide reasonably (though not absolutely) certain estimates of the vehicle fuel economy of specific vehicles to be produced in the future. However, when analyzing potential CAFE standards, NHTSA is not actually designing specific vehicles. The agency is considering implications of new standards that will apply to the average performance of manufacturers' entire production lines. For this type of analysis, precision in the estimation of the fuel economy of individual vehicle models is not essential; although it is important that the agency avoid systematic upward or downward bias, uncertainty at the level of individual models is mitigated by the fact that compliance with CAFE standards is based on average fleet performance.

As discussed above, the Volpe Model, which the agency has used to perform the analysis supporting today's final rule, applies an incrementally multiplicative approach to estimating the fuel savings achieved through the progressive addition of fuel-saving technologies. NAS' use of the same approach in its 2002 report was, at the time and henceforth, criticized by a small number of observers as being prone to systematic overestimation of available fuel savings. This assertion was based on the fact that, among the technologies present on any given vehicle, more than one may address the same energy loss mechanism (notably, pumping losses on throttled engines). Once all energy losses of a given type are eliminated, even theoretical improvements attributable to that loss mechanism are no longer available.

The most direct critique of NAS' methods appeared in a 2002 SAE paper by four General Motors researchers (Patton, *et al.*), who compared some of NAS' calculations to fuel consumption estimates obtained through vehicle testing and simulation, and concluded that, as increasing numbers of technologies were applied, NAS' estimates became increasingly subject to overestimation of available fuel consumption reductions.[121]

In response to such concerns, which had also been raised as the NAS committee performed its analysis, the NAS report concluded that vehicle simulation performed for the committee indicated that the report's incremental fuel savings estimates were "quite reasonable" for the less aggressive two of the three product development paths it evaluated. The report did, however, conclude that uncertainty increased with consideration of more technologies, especially under the more aggressive "path 3" evaluated by the committee. The report did not, however, mention any directional bias to this uncertainty.[122]

Notwithstanding this prior response to concerns about the possible overestimation of available fuel savings, and considering that analyses supporting the development of the NPRM, the Volpe model applies "synergy factors" that adjust fuel savings calculations when some pairs of technologies are applied to the same vehicle. These factors reduce uncertainty and the potential for positive or negative biases in the Volpe model's estimates of the effects of technologies.

As an alternative to estimating fuel consumption through incremental multiplication and the application of "synergy" factors to address technology interactions, NHTSA considered basing its analysis of fuel economy standards on full vehicle simulation at

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[121] Patton, K.J., et al., General Motors Corporation, *"Aggregating Technologies for Reduced Fuel Consumption: A Review of the Technical Content in the 2002 National Research Council Report on CAFE"*, 2002-01-0628, Society of Automotive Engineers, Inc., 2002.
[122] NRC (2002), *op. cit.*, p. 151.

every step. However, considering the nature of CAFE analysis (in particular, the analysis of fleets projected to be sold in the future by each manufacturer), as well as the quantity and availability of information required to perform vehicle simulation, the agency explained that it believed detailed simulation when analyzing the entire fleet of future vehicles is neither necessary nor feasible. Still, when estimating synergies between technologies, the agency did make use of vehicle simulation studies, as discussed above. The agency has also done so when re-estimating synergies before performing the analysis supporting today's final rule.

NHTSA also considered estimating changes in fuel consumption by explicitly accounting for each of several energy loss mechanisms—that is, physical mechanisms to which the consumption of (chemical) energy in fuel may be attributed. This approach would be similar to that proposed in 2002 by Patton *et al*. The agency invited comment on this approach, requested that manufacturers submit product plans disaggregating fuel consumption into each of nine loss mechanisms, and sought estimates of the extent to which fuel-saving technologies affect each of these loss mechanisms.

In response to the NPRM, the Alliance presented a detailed analysis by Sierra Research, which used a modified version of VEHSIM (a vehicle simulation tool) to estimate the fuel consumption resulting from the application of various vehicle technologies to 25 vehicle categories intended to represent the fleet. The Alliance commented that this simulation-based approach is more accurate than that applied by NHTSA, and indicated that Sierra's ability to perform this analysis demonstrates that NHTSA should be able to do the same.

General Motors also raised questions regarding the multiplicative approach to fuel consumption estimation NHTSA has implemented using the Volpe model. GM indicated that the Volpe model should be enhanced with modifications to "take into account the basic physics of vehicles."[123] Although GM's comments did not explicitly mention vehicle simulation, GM did express full support for the Alliance's comments.

The California Air Resources Board (CARB) presented comparisons of different simulation studies, commenting that these demonstrate that the VEHSIM model used by Sierra Research "cannot accurately simulate vehicles that use advanced technologies such as variable valve timing and lift and advanced transmissions."[124] CARB also questioned Sierra Research's simulation capabilities and suggested that, in support of actual product development, manufacturers neither contract with Sierra Research for such services nor make use of VEHSIM. CARB further commented that both AVL (which performed simulation studies for CARB's evaluation of potential greenhouse gas standards) and

[123] GM comments at 2, Docket No. NHTSA-2008-0089-0162.

[124] CARB comments at 5, Docket No. NHTSA-2008-0089-0173. In developing potential greenhouse gas (GHG) emissions standards for light vehicles, CARB made significant use of vehicle simulation results presented in *"Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles"*, which was published in 2004 by the Northeast States Center for a Clean Air Future (NESCCAF). As NHTSA discussed in the NPRM, CARB's and NESCCAF's approach, which effectively reduces each manufacturer's fleet to five "representative" vehicles and two average vehicle weights, is too limited for purposes of CAFE analysis.

Ricardo (which has recently performed simulation studies and related analysis for both EPA and NHTSA) provide such services to manufacturers.[125]

However, the Alliance and GM have criticized technical aspects of the AVL and Ricardo vehicle simulation studies mentioned by CARB. Regarding the AVL vehicle simulations CARB utilized, GM raised concerns that, among other things, some of AVL's simulations assumed the use of premium-grade gasoline, and some effectively assume vehicle performance and utility would be compromised.[126] Similarly, the Alliance raised concerns that some of the simulations performed by Ricardo for EPA assumed the use of premium fuel, and that many of the simulations assumed vehicle performance would be reduced.[127] The Alliance also indicated that the five vehicles analyzed by Ricardo for EPA were not representative of all vehicles in the fleet, leading to overstatement of the degree of improvement potentially available to vehicles that already use technologies not present in the vehicles examined by EPA. The Alliance further argued that the report did not reveal sufficient detail regarding important simulation details (related, *e.g.*, to cylinder deactivation), that it failed to account for some parasitic and accessory loads, and that EPA directed Ricardo to unrealistically assume universal improvements in aerodynamics, tire efficiency, and powertrain friction.[128]

Although submitted after the close of the comment period specified in the NPRM, comments by several state Attorneys General and other state and local official questioned the need and merits of full vehicle simulation within the context of CAFE analysis, stating that

> Computer simulation models such as VEHSIM are not practical except perhaps during vehicle development to determine the performance of specific vehicle models where all vehicle engineering parameters are known and can be accounted for in the inputs to the model. Such an exercise is extremely data intensive, and extending it to the entire fleet makes it subject to multiple errors unless the specific parameters for each vehicle model are known and accounted for in the model inputs.[129]

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[125] California Air Resources Board, *"Air Resources Board Staff Comments on Sierra and Martec NRC Presentations"*, p. 2.
[126] Testimony of Kenneth Patton (GM); Testimony of Kevin McMahon (Martec); Plaintiffs' Proposed Findings of Fact, June 15, 2007, pp. 103 -113.
[127] Alliance of Automobile Manufacturers, *"Detailed Technical Comments on Ricardo 'Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies' Report"*, March 6, 2008.
[128] For the reader's reference, Ricardo's study for EPA was based on specific EPA-defined requirements, such as performing full vehicle simulations of 26 different technology packages on the EPA-specified 5 baseline vehicles. Thus, to the extent that Ricardo's numbers do not reflect specific differences in technology effectiveness by vehicle model, in conducting the analysis for NHTSA's final rule, NHTSA and Ricardo drew on Ricardo's knowledge to develop incremental benefits based in part on Ricardo's simulation work. Ricardo also noted differences between its report for EPA and the EPA Staff Technical Report in terms of the incremental benefits for individual technologies developed by EPA based on Ricardo's simulation.
[129] Attorneys General of the States of California, Arizona, Connecticut, Illinois, Maryland, Massachusetts, New Jersey, New Mexico, Oregon, and Vermont, the Executive Officer of the California Air Resources Board, the Commissioner of the New Jersey Department of Environmental Protection, the Secretary of the New Mexico Environment Department, the Secretary of the Commonwealth of Pennsylvania Department of Environmental Protection, and the Corporation Counsel of the City of New York, *Supplemental*

Considering the comments summarized above, the analyses to which they refer, and the nature of the analysis the agency performs when evaluating potential CAFE standards, NHTSA has concluded that full vehicle simulation, though useful to manufacturers' own product development efforts, remains neither necessary nor feasible for the MY 2011 CAFE analysis. NHTSA's basis for this conclusion is as follows:

Full vehicle simulation involves estimating the fuel consumption (and, typically, emissions) of a specific vehicle over a specific driving cycle. Many engineering characteristics of the vehicle must be specified, including, but not limited to weight, rolling resistance, tire radius, aerodynamic drag coefficient, frontal area, engine maps[130] and detailed transmission characteristics (gear ratios, shift logic, etc.), other drivetrain characteristics, and accessory loads. Additional engine test data would also be required in order to update engine maps when evaluating the application of advanced engine technologies. Driving cycles—vehicle speeds over time—are specified on a second-by-second (or more finely-grained) basis. Using full vehicle simulation to estimate average fuel consumption under the test procedures relevant to CAFE involves many simulations to capture all the potential combinations of technologies that could be used.

Given all of the requisite data representing a specific vehicle, full vehicle simulation can provide a powerful means of estimating vehicle performance while accounting for interactions between various vehicle components and systems. Full simulation can also provide a means of estimating vehicle performance under driving conditions not represented by the fuel economy test procedures. For an engineer involved in the design of a specific vehicle or vehicle component or system, or a manufacturer making specific decisions regarding the fleet of vehicles it will produce, vehicle simulation can be a powerful tool. However, even the most detailed simulation involving full combustion cycle simulation is not the "gold standard" for product design. Chrysler, for example, has portrayed simulation as one of several tools in its CAFE planning process, which also involves physical testing (*i.e.*, bench testing, chassis dynamometer testing) of actual components and assembled vehicles.[131]

In purpose and corresponding requirements, NHTSA's evaluation of regulatory options is fundamentally different from the type of product planning and development that a manufacturer conducts. A manufacturer must make specific decisions regarding every component that will be installed in every vehicle it plans to produce, and it must ultimately decide how many of each vehicle it will produce. Although manufacturers have some ability to make "mid-course adjustments," that ability is limited by a range of factors, such as contracts and tooling investments. By comparison, NHTSA attempts

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Comments Regarding Alliance of Automobile Manufacturers Comments, Docket No. NHTSA-2008-0089-0495, October 8, 2008, p. 3.

[130] An engine map specifies the engine's efficiency under many different operating conditions, each of which is defined in terms of rotational speed (*i.e.*, revolutions per minute, or RPM) and load (*i.e.*, torque).

[131] Fodale, F., Chrysler LLC, *"Fuel Economy/Fuels—Presented to NRC Committee on Fuel Economy of Light-Duty Vehicles",* November 27, 2007.

only to estimate how a given manufacturer *might* attempt to comply with a potential CAFE standard; given the range of options available to each manufacturer, NHTSA has little hope of predicting specifically what a given manufacturer *will* do. CAFE standards require average levels of performance, not specific technology outcomes. Therefore, while it is important that NHTSA avoid systematic bias when estimating the potential to increase the fuel economy of specific vehicle models, it is not important that the agency's estimates precisely forecast results for every future vehicle.

Furthermore, NHTSA evaluates the impact of CAFE standards on all manufacturers, based on a forecast of specific vehicle models each manufacturer will produce for sale in the U.S. in the future. An analysis for MY 2011 can involve thousands of unique vehicle models, hundreds of unique engines, and hundreds of unique transmissions. Model-by-model representation, as used in the analysis for this final rule, allows the agency to, among other things, account for technologies expected to be present on each vehicle under "business as usual" conditions, thereby avoiding errors regarding the potential to add further technologies.

Because of the intense informational and computational requirements, industry-wide studies that rely on vehicle simulation reduce the fleet to a limited number of "representative" vehicles. This reduction limits the ability to account for technological and other heterogeneity of the fleet, virtually ensuring the overestimation of improvements available to some vehicles (*e.g.*, vehicles that begin with a great deal of technology) and some manufacturers (*e.g.*, manufacturers that sell many high-technology vehicles). AVL's analysis for NESCCAF and Ricardo's analysis for EPA, each of which considered only five vehicle models, are both, therefore, of severely limited use for the kind of fleetwide analysis used in this final rule, although both provide useful information regarding the range of fuel savings achieved by specific technologies and "packages" of technologies.

The analysis conducted by Sierra Research for the Alliance considers a significantly greater number (25) of "representative" vehicles, drawing important distinctions between similarly-sized cars based on performance. Sierra was able to do so in part because it analyzed historical vehicles. For example, Sierra indicates that model year 1998 engines were used to supply VEHSIM with baseline, "blended" engine maps applied universally (rather than specific maps for each manufacturer and vehicle model) for vehicle model years out to 2020. Considering that, even without increases in CAFE standards, many vehicles produced for sale in the U.S. during the time period considered in a CAFE rulemaking are likely to have technologies such as VVLT and cylinder deactivation, NHTSA doubts "blended" 1998 engines are as representative as implied by Sierra's analysis.

Although NHTSA could, in principle, integrate full vehicle simulation of every vehicle model into its analysis of the future fleet, the agency expects that manufacturers would be unable to provide much of the required information for future vehicles. Even if manufacturers were to provide such information, using full vehicle simulation to estimate the effect of further technological improvements to future vehicles would involve uncertain detailed estimates, such as valve timing, cylinder deactivation operating conditions, transmission shift points, and hybrid vehicle energy management strategies for each specific vehicle, engine, and transmission combination. Even setting aside the vast increases in computational demands that would accompany the use of full vehicle simulation in model-by-model analysis of the entire fleet, the agency remains convinced that the availability of underlying information and data would be too limited for this approach to be practical.

As a third alternative, one that might be more explicitly "physics-based" than the use of synergy factors and vastly more practical than full vehicle simulation, NHTSA requested comment on the use of partitioned fuel consumption accounting. Aside from GM's nonspecific recommendation that the Volpe model be modified to account for the "basic physics of vehicles," NHTSA did not receive comments regarding the relative merits of partitioning fuel consumption into several energy loss mechanisms for purposes of estimating the effects of fuel-saving technologies, even though the concept is similar to that proposed by Patton, *et al.* in 2002.[132] Some manufacturers provided some of the information that would have been necessary for the implementation of this approach. However, as a group, manufacturers that submitted product plan information to the agency provided far too little disaggregated fuel consumption information to support the development of this approach. Although NHTSA continues to believe that partitioning fuel consumption into various loss mechanisms could provide a practical and sound basis for future analysis, the information required to support this approach is not available at this time.

In conclusion, NHTSA observes that with respect to the CAFE analysis prepared for this final rule, full vehicle simulation could theoretically be used at three different levels. First, full vehicle simulation could be used only to provide specific estimates, that, combined with other data (e.g., from bench testing) would provide a basis for estimates of the effectiveness of specific individual technologies. While NHTSA will continue considering this type of analysis, the agency anticipates that it will continue to be feasible and informative to make somewhat greater use of full vehicle simulation. Second, full vehicle simulation could be fully integrated into NHTSA's model-by-model analysis of the entire fleet to be projected to be produced in future model years. NHTSA expects, however, that this level of integration will remain infeasible considering the size and complexity of the fleet. Also, considering the forward-looking nature of NHTSA's analysis, and the amount of information required to perform full vehicle simulation, NHTSA anticipates that this level of integration would involve misleadingly precise estimates of fuel consumption, even for MY 2011. Finally, full vehicle simulation can be used to develop less complex representations of interactions between technologies (such as was done using the lumped parameter model to develop the synergies for the final rule), and to perform reference points to which vehicle-specific estimates may be compared. NHTSA views this as a practical and productive potential use of full vehicle

[132] Patton, *et al.*, present an energy balance calculation that disaggregates fuel consumption into six energy loss categories, indicating that "an accounting of the effects of individual technologies on energy losses within these categories provides a practical, physically-based means to evaluate and compare the fuel consumption effects of the various technologies." (Patton, *et. al.*, (2002), *op. cit.*, p. 11.)

simulation, and will consider following this approach in the future. NHTSA has contracted with NAS to, among other things, evaluate the potential use of full vehicle simulation and other fuel consumption estimation methodologies. Nevertheless, in addition to considering further modifications to the Volpe model, NHTSA will continue to consider other methods for evaluating the cost and effect of adding technology to manufacturers' fleets.

9. Refresh and redesign schedule

In addition to, and as discussed below, developing analytical methods that address limitations on overall rates at which new technologies can be expected to feasibly penetrate manufacturers' fleets, the agency has also developed methods to address the feasible scheduling of changes to specific vehicle models. In the Volpe model, which the agency has used to support the current rulemaking, these scheduling-related methods were first applied in 2003, in response to concerns that an early version of the model would sometimes add and then subsequently remove some technologies.[133] By 2006, these methods were integrated into a new version of the model, one which explicitly "carried forward" technologies added to one vehicle model to succeeding vehicle models in the next model year, and which timed the application of many technologies to coincide with the redesign or freshening of any given vehicle model.[134]

Even within the context of the phase-in caps discussed below, NHTSA considers these model-by-model scheduling constraints 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 free, every vehicle model could be redesigned every year. In reality, however, every vehicle redesign consumes resources simply to address the redesign. Phase-in caps, which are applied at the level of manufacturer's entire fleet, do not 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 (*e.g.*, for strong hybrids).

In the automobile industry there are two terms that describe when changes to vehicles occur: redesign and refresh (*i.e.*, freshening). Vehicle redesign usually encompasses changes to a vehicle's appearance, shape, dimensions, and powertrain, and is traditionally associated with the introduction of "new" vehicles into the market, which is often characterized as the next generation of a vehicle. In contrast, vehicle refresh usually encompasses only changes to a vehicle's appearance, and may include an upgraded powertrain. Refresh is traditionally associated with mid-cycle cosmetic changes to a vehicle, within its current generation, to make it appear "fresh." Vehicle refresh traditionally occurs no earlier than two years after a vehicle redesign or at least two years before a scheduled redesign. In the NPRM, NHTSA tied the application of the majority of the technologies to a vehicle's refresh/redesign cycle, because their application was significant enough that it could involve substantial engineering, testing, and calibration work.

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[133] 68 FR 16874 (Apr. 7, 2003).
[134] 71 FR 17582 (Apr. 6, 2006).

NHTSA based the redesign and refresh schedules used in the NPRM as inputs to the Volpe model on a combination of manufacturers' confidential product plans and NHTSA's engineering judgment. In most instances, NHTSA reviewed manufacturers' planned redesign and refresh schedules and used them in the same manner it did in past rulemakings. However, in NHTSA's judgment, manufacturers' planned redesign and refresh schedules for some vehicle models were unrealistically slow considering overall market trends. In these cases, the agency re-estimated redesign and refresh schedules more consistent with the agency's expectations, as discussed below. Also, if companies did not provide product plan data, NHTSA used publicly available data about vehicle redesigns to project the redesign and refresh schedules for the vehicles produced by these companies.[135]

Unless a manufacturer submitted plans for a more rapid redesign and refresh schedule, NHTSA assumed that passenger cars would normally be redesigned every 5 years, based on the trend over the last 10-15 years showing that passenger cars are typically redesigned every 5 years. These trends were reflected in the manufacturer product plans that NHTSA used in the NPRM analysis, and were also confirmed by many automakers in meetings held with NHTSA to discuss various general issues regarding the rulemaking.

NHTSA explained that it believes that the vehicle design process has progressed and improved rapidly over the last decade and that these improvements have made it possible for some manufacturers to shorten the design process for some vehicles in order to introduce vehicles more frequently in response to competitive market forces. Although manufacturers have likely already taken advantage of most available improvements, according to public and confidential data available to NHTSA, almost all passenger cars will be on a 5-year redesign cycle by the end of the decade, with the exception being some high performance vehicles and vehicles with specific market niches.

NHTSA also stated in the NPRM that light trucks are currently redesigned every 5 to 7 years, with some vehicles (like full-size vans) having longer redesign periods. In the most competitive SUV and crossover vehicle segments, the redesign cycle currently averages slightly above 5 years. NHTSA explained that it is expected 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 model year 2014 and later, NHTSA projected a 5-year redesign cycle. Exceptions were made for high performance vehicles and other vehicles that traditionally had longer than average design cycles. For those vehicles, NHTSA attempted to preserve their historical redesign cycle rates.

NHTSA discussed these assumptions with several manufacturers at the NPRM stage, before the current economic crisis. Two manufacturers indicated at that time that their vehicle redesign cycles take at least five years for cars and 6 years and longer for trucks because they rely on those later years to earn a profit on the vehicles. They argued that

[135] Sources included, but were not limited to manufacturers' web sites, industry trade publications (*e.g.*, Automotive News), and commercial data sources (*e.g.*, Wards Automotive, etc.).

they would not be able to sustain their business if forced by CAFE standards to a shorter redesign cycle. The agency recognizes that some manufacturers are severely stressed in the current economic environment, and that some manufacturers may be hoping to delay planned vehicle redesigns in order to conserve financial resources. However, consistent with its forecast of the overall size of the light vehicle market from MY 2011 on, the agency currently expects that the industry's status will improve, and that manufacturers will typically redesign both car and truck models every 5 years in order to compete in that market.

NHTSA received relatively few comments regarding its refresh/redesign schedule assumptions. UCS commented that redesign schedules should be shortened to 3 years, based on recent public statements by Ford that they intended to move to that cycle, and based on other recent manufacturer behavior.

Although NHTSA agrees with UCS that remarks by one Ford official at a January 2008 conference suggest that that company was then hoping to accelerate its vehicle "cycle time" to 3 years, the agency questions the context, intended meaning and scope, and representation of those remarks.[136] Further, the agency notes that the article referenced by UCS also indicates that "most manufacturers make changes to their vehicle lines every four years or more, depending on the segment of the market, with mid-cycle freshenings every two years or so."[137] Although some manufacturers have, in their product plans, indicated that they plan to redesign some vehicle models more frequently than has been the industry norm, all manufacturers have also indicated that they expect to redesign some other vehicle models considerably less frequently. The CAR report submitted by the Alliance, prepared by the Center for Automotive Research and EDF, states that "For a given vehicle line, the time from conception to first production may span two and one-half to five years," but that "The time from first production ("Job #1") to the last vehicle off the line ("Balance Out") may span from four to five years to eight to ten years or more, depending on the dynamics of the market segment." The CAR report then states that "At the point of final production of the current vehicle line, a new model with the same badge and similar characteristics may be ready to take its place, continuing the cycle, or the old model may be dropped in favor of a different product."[138]

NHTSA believes that this description, which states that a vehicle model will be redesigned or dropped after 4-10 years, is consistent with other characterizations of the redesign and freshening process, and supports its 5-year redesign assumption and its 2-3 year refresh cycle assumptions.[139] Thus, for purposes of the final rule, NHTSA is retaining the 5-year redesign/2-3 year refresh assumptions employed in the NPRM. However, NHTSA will continue to monitor manufacturing trends and will reconsider these assumptions in subsequent rulemakings if warranted.

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[136] Zoia, D.E. 2008. Ford to cut cycle times to three years. Online at http://www.wardsauto.com. January 24.
[137] *Id*.
[138] *See* NHTSA-2008-0089-0170.1, Attachment 16, at 8 (393 of pdf).
[139] *See id.*, at 9 (394 of pdf).

For purposes of the final rule, NHTSA has also considered confidential product plans where applicable and industry trends on refresh and redesign timing as discussed above, to apply specific technologies at redesign, refresh, or any model years as shown in Table V-7 below.

Table V-7. Technology Refresh and Redesign Application

Technology	Redesign only	Redesign or Refresh	Anytime
Low Friction Lubricants			X
Engine Friction Reduction		X	
VVT - Coupled Cam Phasing (CCP) on SOHC		X	
Discrete Variable Valve Lift (DVVL) on SOHC	X		
Cylinder Deactivation on SOHC		X	
VVT - Intake Cam Phasing (ICP)		X	
VVT – Dual Cam Phasing (DCP)		X	
Discrete Variable Valve Lift (DVVL) on DOHC	X		
Continuously Variable Valve Lift (CVVL)	X		
Cylinder Deactivation on DOHC		X	
Cylinder Deactivation on OHV		X	
VVT - Coupled Cam Phasing (CCP) on OHV		X	
Discrete Variable Valve Lift (DVVL) on OHV	X		
Conversion to DOHC with DCP	X		
Stoichiometric Gasoline Direct Injection (GDI)	X		
Combustion Restart		X	
Turbocharging and Downsizing	X		
Exhaust Gas Recirculation (EGR) Boost	X		
Conversion to Diesel following CBRST	X		
Conversion to Diesel following TRBDS	X		
Electric Power Steering		X	
Improved Accessories		X	
12V Micro-Hybrid	X		
Higher Voltage/Improved Alternator		X	
Integrated Starter Generator	X		
6-Speed Manual/Improved Internals	X		
Improved Auto. Trans. Controls/Externals		X	
Continuously Variable Transmission	X		
6/7/8-Speed Auto. Trans with Improved Internals	X		
Dual Clutch or Automated Manual Transmission	X		
Power Split Hybrid	X		
2-Mode Hybrid	X		
Plug-in Hybrid	X		
Material Substitution (1%)		X	
Material Substitution (2%)	X		
Material Substitution (5%)	X		
Low Rolling Resistance Tires		X	
Low Drag Brakes		X	
Secondary Axle Disconnect		X	
Aero Drag Reduction		X	

As the table shows, most technologies are applied by the Volpe model when a specific vehicle is due for a redesign or refresh. However, for low friction lubricants, the model is not restricted to applying it during a refresh/redesign year and thus it was made available for application at any time. Low friction lubricants are very cost-effective, can apply to multiple vehicle models/platforms and can be applied across multiple vehicle models/platforms in one year. Although they can also be applied during a refresh/redesign year, they are not restricted to that timeframe because their application is not viewed as necessitating a major engineering redesign and associated testing/calibration.

For several technologies estimated in the NPRM to be available for application during any model year, NHTSA now estimates that these technologies will be available only at refresh or redesign. Those technologies include aggressive shift logic, improved accessories, low rolling resistance tires and low drag brakes. Aggressive shift logic is now one of the technologies included under improved automatic transmission controls. This technology requires a recalibration specific to each vehicle, such that it can therefore be applied only at refresh or redesign model years. The "improved accessories" technology has been redefined to include intelligent engine cooling systems, which require a considerable change to the vehicle and engine cooling system; therefore, improved accessories also can be applied only at refresh or redesign model years. Also, NHTSA concurs with manufacturers' confidential statements that indicating that low drag brakes and low rolling resistance tires can be applied only at refresh or redesign model years due to the need for vehicle testing and calibration (*e.g.*, to ensure safe handling and braking) when these technologies are applied.

10. Phase-in caps

In 2002, NHTSA proposed the first increases in CAFE standards in six years due to a previous statutorily-imposed prohibition on setting new standards. That proposal, for MY 2005-2007 light truck standards, relied, in part, on a precursor to the current Volpe model. This earlier model used a "technology application algorithm" to estimate the technologies that manufacturers could apply in order to comply with new CAFE standards.

NHTSA received more than 65,000 comments on that proposal. Among those were many manufacturer comments concerning lead time and the potential for rapid widespread use of new technologies. The agency noted that DaimlerChrysler and Ford "argued that the agency had underestimated the lead time necessary to incorporate fuel economy improvements in vehicles, as well as the difficulties of introducing new technologies across a high volume fleet." Specific to Volpe's technology application algorithm, the agency noted that General Motors took issue with the algorithm's "application of technologies to all truck lines in a single model year."[140]

In response to those concerns, Volpe's algorithm was modified "to recognize that capital costs require employment of technologies for several years, rather than in a single

[140] 68 FR 16874 (Apr. 7, 2003).

year."[141] Those changes moderated the rates at which technologies were estimated to penetrate manufacturers' fleets in response to the new (MY 2005-MY 2007) CAFE standards. These changes produced more realistic estimates of the technologies manufacturers could apply in response to the new standards, and thereby produced more realistic estimates of the costs of those standards.

Prior to the next rulemaking, the Volpe model underwent significant integration and improvement, including the accommodation of explicit "phase-in caps" to constrain the rates at which each technology would be estimated to penetrate each manufacturer's fleet in response to new CAFE standards.[142] As documented in 2006, the agency's final standards for light trucks sold in MY 2008-MY 2011 were based on phase-in caps ranging from 17 percent to 25 percent (corresponding to full penetration of the fleet within 4 to 6 years) for most technologies, and from 3 percent to 10 percent (full penetration within 10 to 33 years) for more advanced technologies such as hybrid electric vehicles.[143] The agency based these rates on consideration of comments and on the 2002 NAS Committee's findings that "widespread penetration of even existing technologies will probably require 4 to 8 years" and that for emerging technologies "that require additional research and development, this time lag can be considerably longer".[144]

In its 2008 NPRM proposing new CAFE standards for passenger cars and light trucks sold during MY 2011-MY 2015, NHTSA considered manufacturers' planned product offerings and estimates of technology availability, cost, and effectiveness, as well as broader market conditions and technology developments. The agency concluded that many technologies could be deployed more rapidly than it had estimated during the prior rulemaking.[145] For most engine technologies, the agency increased these caps from 17 percent to 20 percent, equivalent to reducing the estimated time for potential fleet penetration from 6 years to 5 years. For stoichiometric gasoline direct injection (GDI) engines, the agency increased the phase-in cap from 3 percent to 20 percent, equivalent to estimating that such engines could potentially penetrate a given manufacturer's fleet in 5 years rather than the previously-estimated 33 years. However, as in its earlier CAFE rulemakings, the agency continued to recognize that myriad constraints prohibit most technologies from being applied across an entire fleet of vehicles within a year, even if those technologies are available in the market.

In addition to requesting further explanation of NHTSA's use of phase-in caps, commenters addressing phase-in caps generally asserted one of three themes: (1) that hybrid phase-in caps were much lower than market trends or manufacturer

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[141] *Id*., at 16885.
[142] These caps constrain the extent to which additional technology is applied by the model, beyond the levels projected in each manufacturer's baseline fleet. Also, because manufacturers' fleets are comprised of vehicles, engines, and transmissions sold in discrete volumes, phase-in caps cannot be applied as precise limits. In some cases (when a phase-in cap is small or a manufacturer has a limited product line), doing so would prevent the technology from being applied at all. Therefore, the Volpe model enforces each phase-in cap constraint as soon as it has been exceeded by application of technologies to manufacturers.
[143] 71 FR 17572, 17679 (Apr. 6, 2006).
[144] *Id*. at. 17572. *See also* 2002 NAS Report, at 5.
[145] 73 FR 24387-88 (May 2, 2008).

announcements would otherwise suggest; (2) that the phase-in caps proposed in the NPRM were too high in the early years of the rulemaking and did not reflect the very small (from a manufacturing perspective) amount of lead-time between the final rule and the MY 2011 standards, and/or were too low in the later years of the rulemaking given the relatively-increased amount of lead-time for those model years; (3) that there are insufficient resources (either in terms of capital or engineering) to implement the number of technologies implied by the phase-in caps simultaneously.

Agency response: NHTSA continues to recognize that many factors constrain the rates at which manufacturers will be able to feasibly add fuel-saving technologies to the fleets they will sell in the United States. For a given technology, examples of these factors may include, but would not be limited to the following:

- Is the technology ready for commercial use? For example, can it operate safely and reliably under real-world driving conditions for several years and many miles?
- If the technology requires special infrastructure (*e.g.*, new electrical generation and charging facilities), how quickly will that be put in place?
- How quickly can suppliers ramp up to produce the technology in mass quantities? For example, how quickly can they obtain the materials, tooling, and engineering resources they will need?
- Are original equipment manufacturers (OEMs) ready to integrate the technology into vehicles? For example, how quickly can they obtain the necessary tooling (*e.g.*, retool factories), engineering, and financial resources?
- How long will it take to establish failure and warranty data, and to make sure dealers and maintenance and repair businesses have any new training and tooling required in order to work with the new technology?
- Will OEMs be able to reasonably recoup prior investments for tooling and other capital?
- To what extent are suppliers and OEMs constrained by preexisting contracts?

NHTSA cannot explicitly and quantitatively evaluate every one of these and other factors with respect to each manufacturer's potential deployment of each technology available during the production intent or emerging technology framework. Attempting to do so would require an extraordinary effort by the agency, and would likely be subject to tremendous uncertainties. For example, in the current economic and market environment, the agency expects that it would be impossible to reliably predict specific characteristics of future supply chains. Therefore, the agency has concluded that it is appropriate to continue using phase-in caps to apply the agency's best judgment of the extent to which such factors combine to constrain the rates at which technologies may feasibly be deployed. We note, however, that many of the assumptions about phase-in caps made in this final rule apply to years beyond MY 2011, because as the NAS Committee and commenters indicated, technologies are phased in over several years, so the agency evaluated the phasing-in of technologies over the five-year period proposed in the NPRM. NHTSA provides these assumptions both in response to comments and to provide context for the agency's decisions regarding MY 2011 phase-in caps. We emphasize that all assumptions for years other than MY 2011 will be reconsidered for future rulemakings and may be subject to change at that time.

Considering the above-mentioned comments, NHTSA has concluded that the phase-in caps it applied during its analysis documented in the 2008 NPRM resulted in technology penetration rates that were unrealistically high in the earlier model years covered by its proposal, particularly for MY 2011. This was a significant basis for the proposed standards' "front loading" about which manufacturers expressed serious concerns. In response, and based on this conclusion, the Volpe model was modified for purposes of the final rule analysis to use phase-in caps for each technology that vary from one year to the next, and that in many cases would have increased more rapidly in the later years of the agency's analysis than in earlier years. In making these changes, particularly to the MY 2011 phase-in caps, the agency has been mindful of the need to provide manufacturers sufficient lead time to add technologies to their fleets. In the agency's judgment, its revised approach more realistically represents manufacturers' capabilities and therefore produces more realistic estimates of the costs of new CAFE standards.

For some technologies, NHTSA also concluded that slower overall rates of fleet penetration are more likely than the rates shown in the NPRM. The agency estimates that cylinder deactivation, stoichiometric GDI, and turbocharging with downsizing would be able to potentially be added to 12-14 percent of the fleet per year on average, rather than the 20 percent phase-in caps used in the NPRM for these technologies. Considering manufacturers' comments and some aspects of its reevaluation of the incremental benefits of available engine technologies, the agency has concluded that these technologies will, for some engines, require more significant hardware changes and certification burden than previously recognized, such that feasible deployment is likely to be somewhat slower than estimated in the NPRM.

NHTSA has also concluded, considering the complexities involved in deploying strongly hybridized vehicles (*i.e.*, power split, two mode, and plug-in hybrids), it is unrealistic to expect that, in response to new CAFE standards, manufacturers can produce more of such vehicles in MY 2011 than they are already planning. Therefore, NHTSA has set the MY 2011 phase-in cap for strong hybrids to zero in that model year. Based on new information regarding engineering resources entailed in developing new power split and two-mode hybrid vehicles, the agency estimated in its analysis that these technologies could be added to up to 11 percent and 8 percent, respectively, of a given manufacturer's long run fleet, rather than the 15 percent the agency estimated for the NPRM. The agency also considered a less aggressive 1 percent longer run phase-in cap for plug-in hybrids, in part because although the agency expects that plug-in hybrids will rely on lithium-ion batteries, it is not clear whether and, if so, how the supply chain for large and robust lithium-ion batteries will develop.

On the other hand, NHTSA has also concluded that some technologies can potentially be deployed more widely than estimated in the NPRM. For example, the agency estimates that 6/7/8-speed transmissions, dual clutch or automated manual transmissions, secondary axle disconnect, and aerodynamic improvements can potentially (notwithstanding engineering constraints that, for example, preclude the application of aerodynamic improvements to some performance vehicles) be added at an average rate of 20 percent per year of a given manufacturer's fleet rather than the 14-17 percent average annual phase-in caps used in the NPRM for these technologies. In the agency's judgment, increased phase-in caps are appropriate for these transmission technologies, in part because the agency's review of confidential product plans which indicated a higher than anticipated application rate of these technologies than existed at the time of the NPRM. Additionally, several manufacturers indicated a high likelihood of significant usage of dual clutch transmissions across their fleet of vehicles. The secondary axle disconnect technology was redefined for the final rule to consist of a somewhat basic, existing technology applicable only to 4 wheel-drive vehicles (a smaller population) rather than the NPRM-defined technology (which was applicable to both 4 and all wheel drive vehicles). The agency has also concluded that, because it has identified performance vehicles as such, and has estimated that aerodynamic improvements are not applicable to these vehicles, aerodynamic dynamic improvements can be applied more widely as long as they are applied consistent with vehicle redesign schedules. Furthermore, considering changes in manufacturers' stated expectations regarding prospects for diesel engines, the agency estimates that diesel engines could be added to as much as 4 percent of a manufacturer's light truck fleet each year on average, rather than the 3 percent estimated in the NPRM. These changes in NHTSA's estimates stem from the agency's reevaluation of the status of these technologies, as revealed by manufacturers' plans and confidential statements, as well as other related comments submitted in response to the NPRM.

Regarding comments that manufacturers' public statements reflect the ability to deploy technology more rapidly than reflected in the phase-in caps NHTSA applied in the NPRM, NHTSA notes that it did consider such statements. Combined with other information, these led the agency to conclude that, as mentioned above, some technologies could, particularly in later years, be applied more widely than the agency had previously estimated. However, in their confidential statements to NHTSA, manufacturers are typically more candid about factors—both positive and negative—that affects their ability to deploy new technologies than they are in public statements available to their competitors. Therefore, NHTSA places greater weight on manufacturers' confidential statements, especially when they are consistent with statements made by other manufacturers and/or suppliers. NHTSA also observes that some organizations have exhibited a tendency to take manufacturers' statements out of context, or overlook important caveats included in such statements, which are largely used for marketing purposes.

Table V-8 below outlines the phase-in caps for each discrete technology for MY 2011. These phase-in caps, along with the expanded number and types of vehicle subclasses, address the concerns raised by commenters and represent a substantial improvement in terms of consideration of the factors affecting technology penetration rates over those used in the NPRM. Additional considerations regarding specific phase-in caps, including nonlinear increases in these caps, are presented in the more detailed technology-by-technology analysis summarized below.

For some of the technologies applied in the final rule, primarily the valvetrain and diesel engine technologies, NHTSA has utilized combined phase-ins caps since the technologies are effectively the same from the standpoints of engineering and implementation. The final rule represented diesel engines as two technologies that both result in the conversion of gasoline engine vehicles. The annual phase-in caps for these two technologies, which are both set to a maximum of 3 percent for passenger cars (4 percent for light trucks) have been combined so that the maximum total application of either or both technologies to any manufacturers' passenger car fleet is limited to 3 percent (not 6 percent). For example, if 3 percent of a manufacturers' passenger car fleet has received diesel following combustion restart in a given year, diesel following turbocharging and downsizing will not be applied because the phase-in cap for diesels would have been reached. These combined phase-in caps are discussed below where applicable to each technology.

Table V-8a. Phase in caps from 2006 rule, 2008 NPRM, and current rule

Technology	2006 Rule*	2008 NPRM*	Final Rule MY2011
Low Friction Lubricants	25%	50%	50%
Engine Friction Reduction	17%	20%	20%
VVT - Coupled Cam Phasing (CCP) on SOHC	17%	20%	15%
Discrete Variable Valve Lift (DVVL) on SOHC	17%	20%	15%
Cylinder Deactivation on SOHC	17%	20%	9%
VVT - Intake Cam Phasing (ICP)	17%	20%	15%
VVT - Dual Cam Phasing (DCP)	17%	20%	15%
Discrete Variable Valve Lift (DVVL) on DOHC	17%	20%	15%
Continuously Variable Valve Lift (CVVL)	17%	20%	15%
Cylinder Deactivation on DOHC	17%	20%	9%
Cylinder Deactivation on OHV	17%	20%	9%
VVT - Coupled Cam Phasing (CCP) on OHV	17%	20%	15%
Discrete Variable Valve Lift (DVVL) on OHV	10%	20%	15%
Conversion to DOHC with DCP	n.a	n.a	9%
Stoichiometric Gasoline Direct Injection (GDI)	3%	20%	3%
Combustion Restart	n.a	n.a.	0%
Turbocharging and Downsizing	17%	20%	9%
Exhaust Gas Recirculation (EGR) Boost	n.a	n.a.	0%
Conversion to Diesel following CBRST	3%	3%	3%
Conversion to Diesel following TRBDS	3%	3%	3%

* Increased annually (in a linear manner) at the rate indicated

Table V-8b. Phase in caps from 2006 rule, 2008 NPRM, and current rule

Technology	2006 Rule*	2008 NPRM*	Final Rule MY2011
Electric Power Steering	17%	25%	10%
Improved Accessories	25%	25%	10%
12V Micro-Hybrid	n.a.	n.a.	3%
Higher Voltage/Improved Alternator	17%	25%	10%
Integrated Starter Generator	5%	3%	3%
6-Speed Manual/Improved Internals	n.a.	17%	33%
Improved Auto. Trans. Controls/Externals	n.a.	25%	33%
Continuously Variable Transmission	17%	17%	5%
6/7/8-Speed Auto. Trans with Improved Internals	17%	17%	50%
Dual Clutch or Automated Manual Transmission	17%	17%	20%
Power Split Hybrid	5%	3%	0%
2-Mode Hybrid	5%	3%	0%
Plug-in Hybrid	n.a.	3%	0%
Material Substitution (1%)	17%	17%	5%
Material Substitution (2%)	17%	17%	5%
Material Substitution (5%)	17%	17%	5%
Low Rolling Resistance Tires	25%	25%	20%
Low Drag Brakes	17%	25%	20%
Secondary Axle Disconnect	17%	17%	17%
Aero Drag Reduction	17%	17%	17%

* Increased annually (in a linear manner) at the rate indicated

D. Specific technologies considered for application and NHTSA's estimates of their incremental costs and effectiveness

1. What data sources did NHTSA evaluate?

In developing the technology assumptions in the final rule, NHTSA, working with Ricardo, examined a wide range of data sources and comments. We reexamined the sources we relied on for the NPRM such as the 2002 NAS Report, the 2004 NESCCAF report developed for CARB by AVL and Martec, the 2006 EEA report and the EPA certification data. We also considered more recent and updated sources of information and reports submitted to the NPRM docket, including the (1) Sierra Research report submitted by the Alliance as an attachment to its comments as another set of estimates for fuel economy cost and effectiveness,[146] (2) CARB's response to aspects of that report, which was filed as supplemental comment on October 14, 2008, (3) the 2008 Martec Report,[147] which updated the Martec report on which the 2004 NESCCAF study was based, and the EPA Staff Technical Report,[148] which largely mirrored NHTSA's NPRM estimates.

The agency also evaluated confidential data from a number of vehicle manufacturers and technology component suppliers.[149] We note that vehicle manufacturers updated their product plans in response to NHTSA's May 2008 Request for Comment.[150]

2. Individual technology descriptions and cost/effectiveness estimates

(a) Gasoline Engine Technologies

(i) Overview

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.

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[146] Sierra Research, "Attachment to Comment Regarding the NHTSA Proposal for Average Fuel Economy Standards Passenger Cars and light Trucks Model Years 2011-2015," June 27, 2008. *Available at* Docket No. NHTSA-2008-0089-0179.1.

[147] Martec, "Variable Costs of Fuel Economy Technologies," June 1, 2008. *Available at* Docket No. NHTSA-2008-0089-0169.1.

[148] 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.

[149] The major suppliers that provided NHTSA with fuel economy cost and effectiveness estimates in response to our request for comments included Borg-Warner, Cummins, and Delphi, while Borg-Warner, Bosch, Coring, Cummins, Delphi, and Siemens also provided NHTSA with fuel economy cost and effectiveness estimates during confidential meetings.

[150] Manufacturers that provided NHTSA with fuel economy cost and effectiveness estimates in response to our request for comments include BMW, Chrysler, Daimler, Ford, GM, Honda, Nissan, and Toyota.

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 to 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, as shown in Table V-9 below.

Table V-9. Technology Characterization by Type of Loss Reduced

Technology	Heat Loss Reduction	Exhaust Energy Reduction	Gas Exchange Reduction	Friction Reduction
Low Friction Lubricants				✓
Engine Friction Reduction				✓
VVT - Coupled Cam Phasing (CCP) on SOHC			✓	
Discrete Variable Valve Lift (DVVL) on SOHC			✓	
Cylinder Deactivation on SOHC			✓	
VVT - Intake Cam Phasing (ICP)			✓	
VVT - Dual Cam Phasing (DCP)			✓	
Discrete Variable Valve Lift (DVVL) on DOHC			✓	
Continuously Variable Valve Lift (CVVL)			✓	
Cylinder Deactivation on DOHC			✓	
Cylinder Deactivation on OHV			✓	
VVT - Coupled Cam Phasing (CCP) on OHV			✓	
Discrete Variable Valve Lift (DVVL) on OHV			✓	
Conversion to DOHC with DCP			✓	
Stoichiometric Gasoline Direct Injection (GDI)		✓		
Combustion Restart				✓
Turbocharging and Downsizing			✓	✓
Exhaust Gas Recirculation (EGR) Boost		✓	✓	✓
Conversion to Diesel	✓	✓	✓	

✓ Represents area of primary influence

As Table V-9 shows, 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.

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. The latter is not considered to be at the emerging technology point yet due to the non-availability of lean NO_x aftertreatment, as discussed below. However, the compression ratio may potentially be raised by 1 to 1.5 ratios using stoichiometric direct fuel injection.

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 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.

As illustrated in Table V-9, several different technologies target pumping loss reduction, but it is important to note that 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 revised decision trees, the effectiveness value shown for additional technologies targeting pumping loss depends on the existing technology combination already present on the engine.

(ii) 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. CAFE standards notwithstanding, the trend towards lower friction lubricants is widespread. Within the next several year, most vehicles are likely to use

5W-30 motor oil, and some will use even less viscous oils, such as 5W-20 or possibly even 0W-20, to reduce cold start friction.

The NPRM reflected NHTSA's belief that manufacturer estimates are the most accurate, and it estimated that low friction lubricants could reduce fuel consumption by 0.5 percent for all vehicle types at an incremental cost of $3, which represented the mid-point of manufacturer estimates range, rounded up to the next dollar. For the final rule NHTSA used the $3 cost from the NPRM, updated it to 2007 dollars, and marked it up to a retail price equivalent (RPE) of $5. Several manufacturers commented confidentially that low friction lubricants could reduce fuel consumption by 0 to 1 percent, and the Alliance suggested 0.5 percent relative to the baseline fleet. These comments confirm NHTSA's NPRM effectiveness estimate, so NHTSA has retained it for the final rule.

Low friction lubricants may be applied to any class of vehicles. The phase-in for low friction lubricants is capped at 50 percent for MY 2011. Honda commented that low friction lubricants cannot be applied to engines that have not been developed specifically for them.[151] NHTSA understands that in some cases there could be a need for design changes and durability verification to implement low friction lubricants in existing engines. However, aftermarket low friction lubricant products already exist, and have been approved for use in existing engines.

(iii) Engine Friction Reduction (EFR)

Besides low friction lubricants, manufacturers can also reduce friction and improve fuel economy by improving the design of engine components and subsystems. Examples include improvements in low-tension piston rings, roller cam followers, improved crankshaft design and bearings, material coatings, material substitution, more optimal thermal management, and piston and cylinder surface treatments.

In the NPRM, based on confidential manufacturer data and the NAS, NESCCAF, and EEA reports, NHTSA estimated that friction reduction could incrementally reduce fuel consumption for all vehicles by 1 to 3 percent at a cost of $0 to $21 per cylinder resulting in cost estimates of $0-$84 for a 4-cylinder, $0-$126 for a V-6, and $0-$168 for a V-8. For the final rule, NHTSA assumed there would be some cost associated with reducing engine friction, since at a minimum engineering and validation testing is required, in addition to any new components required such as roller followers or improved bearings. Additionally some revised components, such as improved surface materials/treatments, piston rings, etc., have costs that vary by component size which need to account for the full range of engines under consideration in the rulemaking, from small displacement gasoline to large displacement diesel engines.

Considering the above, NHTSA relied on confidential manufacturer comments in response to the NPRM to determine a lower technology cost bound of $35 for a 4-cylinder engine and an upper cost of $195 for a 6 cylinder engine. These costs were marked up by a 1.5 RPE factor to arrive at per-cylinder costs of $13 to $49 which were used to establish costs based on cylinder count. Costs of $52 to $196 for a 4-cylinder

[151] Docket NHTSA-2008-0089-0191.1.

engine, $78 to $294 for a 6-cylinder engine, and $104 to $392 for an 8-cylinder engine were used in the final rule.

Confidential manufacturer comments submitted in response to the NPRM showed an effectiveness range of 0.3 to 2 percent for engine friction reduction. Besides the comments received another effectiveness estimate, a November 2007 press release from Renault, claimed a gain of 2 percent over the NEDC cycle[152] from engine friction reduction.[153] Based on the available sources, NHTSA established the fuel consumption effectiveness estimate for the final rule as 1 to 2 percent.

Engine friction-reducing technologies are available from model year 2011 and may be applied to all vehicle subclasses. No learning factors were applied to costs as the technology has a loosely defined BOM which may in part consist of materials (surface treatments, raw materials) that are commodity based. As was the case in the NPRM, an average of 20 percent year-over-year phase-in rate starting in 2011 was adopted. As confirmed by manufacturers' comments, NHTSA has maintained the NPRM position that engine friction reduction may only be applied in conjunction with a refresh cycle.

(iv) Variable Valve Timing (VVT)

Variable valve timing (VVT) is a classification 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 positioning the valve at the optimum position needed to sustain horsepower and torque. VVT can also improve thermal 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.

VVT has now become a widely adopted technology: for the 2007 model year, over half of all new cars and light trucks have engines with some method of variable valve timing. Therefore, the degree of further improvement across the fleet is limited by the level of valvetrain technology already implemented on the vehicles. Comments from Ford received in response to the NPRM indicate that many of its new and upgraded engines during the specified time period will launch with or upgrade to advanced forms of VVT, which are discussed below.[154] Information found in the submitted product plans is used

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[152] Due to the advanced nature of many of the technologies discussed in the NPRM, and in an effort to find broad based rationale for the specific benefits of each technology type, reference data has been gathered that specifies fuel consumption benefits as measured on the NEDC test cycle. To make this conversion, data from the International Council on Clean Transportation (ICCT) showed excellent correlation between CAFE test cycle results and NEDC test cycle results. While there was an offset in the linear best fit, the slope was nearly equal to 1; therefore, for this report, any percentage improvement found on the NEDC cycle will be assumed to be equivalent to gains found on the CAFE test cycle.

[153] Renault press release, "Renault Introduces The Ecological, Economical Logan 'Renault Eco²' Concept At The Michelin Organized Challenge Bibendum, November 14, 2007. *Available at* http://www.renault.com/renault_com/en/images/15181%2015181_DP_logan_eco2_Shanghai_14_nov_DEF_GB_2_tcm1120-686305.pdf (last accessed October 27, 2008)

[154] Docket No. NHTSA-2008-0089-0202.1, at 4.

to determine the degree to which VVT technologies have already been applied to particular vehicles to ensure the proper level of VVT technology, if any, is applied. There are three different implementation classifications of variable valve timing: ICP (Intake Cam Phasing), where a cam phaser is used to adjust the timing of the inlet valves only; CCP (Coupled Cam Phasing), where a cam phaser is used to adjust the timing of both the inlet and exhaust valves equally; and DCP (Dual Cam Phasing), where two cam phasers are used to control the inlet and exhaust valve timing independently.

Each of these three implementations of VVT uses a cam phaser to adjust the camshaft angular position relative to the crankshaft position, referred to as "camshaft phasing." This 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. Electrically actuated cam phasers are relatively new, but are now in volume production with Toyota, which suggests that technical issues have been resolved.

Honda commented that VVT is not applicable on existing engine designs that do not already contain these technologies due to durability, noise-vibration-harshness (NVH), thermal, packaging, and other constraints that require engine redesign.

1. Intake Cam Phasing (ICP)

Valvetrains with ICP 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 NPRM, NHTSA and EPA estimated that ICP would cost $59 per cam phaser or $59 for an in-line 4 cylinder engine and $119 for a V-type, for an overall cost estimate of $59 to $119, based on the NAS, NESCCAF, and EEA reports and confidential manufacturer data. NHTSA received several updated cost estimates confidentially from manufacturers for ICP costs in response to the NPRM that varied over a wide range from $35 to $300, and additionally looked to the 2008 Martec report for costing guidance. According to the 2008 Martec report, content assumptions for ICP costing include the addition of a cam phaser and oil control valves at $25 and $10 respectively, per bank, which agreed with confidential manufacturer data received in response to the NPRM. These figures were then adjusted to include an incremental camshaft sensor per bank at $4, and an additional $2 increase to account for an ECU upgrade as shown by confidential data. Using a markup of 1.5 to yield a RPE value, the incremental cost for ICP in the final rule is estimated to be $61 per bank, resulting in a $61 charge for in-line engine configurations and $122 for V-engine configurations.

For fuel economy effectiveness values, NHTSA tentatively concluded in the NPRM that the incremental gain in fuel consumption for ICP would be 1 to 2 percent depending on engine configuration, in agreement with the NESCCAF study. Confidential manufacturer data submitted in response to the NPRM showed a larger effectiveness range of 1.0 to 3.4

percent, although the majority of those estimates fell at the lower end of that range. Based on the comments received, NHTSA retained the NPRM estimates of 1 to 2 percent incremental improvement in fuel consumption due to ICP.

ICP is applicable to all vehicle classes and can be applied at the refresh cycle. For the final rule, NHTSA has combined the phase-in caps for ICP, CCPS, CCPO and DCP and capped the joint penetration allowed at 15 percent in MY 2011 with time-based learning applied.

2. 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.[155] 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 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.[156]

In the NPRM, NHTSA explained that for an OHV engine, the same phaser added for ICP would be used for CCP control, so the cost for CCP should be identical to that for ICP. For an OHV, since only one phaser would be required since only camshaft exists, NHTSA estimated the cost for CCP at $59 regardless of engine configuration, using the logic provided for ICP. For purposes of the final rule, the logic for ICP also carries over to the cost estimates for CCP. Cost assumptions for CCP are the same as ICP resulting in RPE-adjusted costs of $61 for in-line SOHC or OHV engines and $122 for SOHC V-engine configurations, incremental to an engine without VVT.

For fuel economy effectiveness, NHTSA estimated in the NPRM that the incremental gain in fuel consumption for CCP is 1 to 3 percent above that obtained by ICP, in agreement with the NESCCAF report and confidential manufacturer data. Confidential manufacturer data submitted in response to the NPRM also showed an effectiveness range of 1 to 3 percent for CCP, although Ford has publicly reported a 3.3 percent improvement for CCP when applied to its 5.4 liter 3-valve V8 engine (which has high EGR tolerance due to the valve-masking effect with the 3-valve design).[157] Most engines are not as EGR-tolerant and so will not achieve as much effectiveness from CCP as the Ford engine. For purposes of the final rule, NHTSA essentially carried over the NPRM incremental effectiveness of applying the CCP technologies to be 1 to 3 percent.

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[155] Although CCP appears only in the SOHC and OHV branches of the decision tree, it is noted that a single phaser with a secondary chain drive would allow CCP to be applied to DOHC engines. Since this would potentially be adopted on a limited number of DOHC engines NHTSA did not include it in that branch of the decision tree.

[156] It is also noted that coaxial camshaft developments would allow other VVT options to be applied to OHV engines. However, since they would potentially be adopted on a limited number of OHV engines NHTSA did not include them in the decision tree.

[157] Robert Stein, Tachih Chou, and Jeffrey Lyjak, "The Combustion System Of The Ford 5.4 L 3 Valve Engine," Global Powertrain Congress 2003 - Advanced Engine Design & Performance, Sep 2003, Volume 24. *Available at* http://www.gpc-icpem.org/pages/publications.html (last accessed Nov. 8, 2008)

CCP can be applied to any class of vehicles at refresh. For the final rule, NHTSA has combined the phase-in caps for ICP, CCPS, CCPO and DCP and capped the joint penetration at 15 percent in NY 2011. Since these technologies are mature and in high volume, time-based learning factors are applied. CCP can be applied to any class of vehicles.

3. 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 option 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. Additionally, increased internal EGR results in lower engine-out NO_X emissions and improved fuel consumption. This fuel economy improvement depends on the residual tolerance of the combustion system, as noted in the CCP section above. Additional improvements are observed at idle, where low valve overlap can result in improved combustion stability, potentially reducing idle fuel consumption.

In the NPRM, NHTSA estimated costs for DCP by building upon the cost estimates for ICP, where an additional cam phaser is added to control each bank of exhaust valves less the cost of the EGR valve which can be deleted. This resulted in an NPRM cost range of $89 to $209. For purposes of the final rule, cost assumptions for DCP, which included inflation, were determined by essentially doubling the ICP hardware, yielding an incremental cost of $61 per engine cylinder bank, over ICP. This translates to a cost of $61 for in-line engines and $122 for V-engine configurations, incremental to ICP technology.

For fuel economy effectiveness, NHTSA estimated in the NPRM that the incremental gain in fuel consumption for DCP is 1 to 3 percent, in agreement with the NESCCAF report and confidential manufacturer data. Confidential manufacturer data received in response to the NPRM showed an effectiveness range of 0.5 to 3.4 percent for DCP. Publicly available data from BMW[158] and Ford[159] show an effectiveness of 5 percent for DCP over engines without VVT, agreeing with the upper bounds for ICP and DCP combined. For purposes of the final rule, NHTSA concluded that the effectiveness for DCP should be at the upper end of the CCP range due to the additional flexibility gained through independent control of intake and exhaust valve timing, and therefore estimated an incremental fuel consumption reduction of 2 to 3 percent for DCP incremental to the 1 to 2 percent for ICP.

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[158] Meyer, BMW, "Turbo-Charging BMW's Spray-Guided DI Combustion System – Benefits and Challenges," Global Powertrain Congress, September, 2005, vol. 33. *Available at* http://www.gpc-icpem.org/pages/publications.html (last accessed Nov. 8, 2008)

[159] Ulrich Kramer and Patrick Phlips, "Phasing Strategy For An Engine With Twin Variable Cam Timing," SAE Technical Paper 2002-01-1101, 2002. *Available at* http://www.sae.org/technical/papers/2002-01-1101. (last accessed Nov. 9, 2008)

There are no class-specific applications of this technology and DCP can be applied at the refresh cycle. For the final rule, NHTSA has combined the annual average phase-in caps for ICP, CCPS, CCPO and DCP and capped the joint penetration at 15 percent in MY 2011. The DCP technology is assumed to be produced at high volume, thus time-based learning is applied.

(v) Discrete Variable Valve Lift (DVVLS, DVVLD, DVVLO)

DVVL systems allow the selection between two or three separate 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. 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 NPRM, based on the NESCCAF report and confidential manufacturer data, NHTSA estimated the incremental cost for DVVL at $169 to $322 compared to VVT depending on engine size, which included $25 for controls and associated oil supply needs. In response to the NPRM, confidential manufacturer comments noted a cost range of $150 to $600 for DVVL on OHC engines. Sierra Research has noted costs ranging from $518 to $656 for DVVL including dual cam phasers on a mid-size car and $634 to $802 on trucks.[160] For purposes of the final rule, NHTSA has changed the order of the technologies in the decision trees which has changed how the DVVL costs are handled.

For the overhead cam engines, SOHC and DOHC, the costs were derived by taking $30 per cylinder for lost motion devices, adding a $4 incremental cost for a camshaft position sensor upgrade and $10 for an oil control valve on each engine cylinder bank, as indicated by the 2008 Martec report. This assumes that one lost motion device is used to control either a single intake valve on an SOHC engine or a pair of intake valves on a DOHC engine, as was done in the NPRM. NHTSA's independent review concurred with data in the 2008 Martec report because it contained the most complete published description of DVVL costs and it agreed with confidential manufacturer data received in response to the NPRM NHTSA adopted these cost estimates for the final rule, such that incremental costs for DVVLS and DVVLD, including a 1.5 RPE markup, are $201 for an in-line 4-cylinder engine, $306 for V-6 engines, and $396 for V-8 engines. For overhead valve engines, OHV, the costs for V6 and V8 engines do not include the lost motion devices and control hardware since DVVLO follows cylinder deactivation on the OHV decision tree path and employs similar lost motion devices. Rather, the DVVLO cost is for active engine mounts on V6 and V8 OHV engines which was based on $50 variable cost from Martec, adjusted to 2007 dollars and marked up with a 1.5 RPE factor to $76. For in-line 4-cylinder engines cylinder deactivation is not allowed so the cost for DVVLO is the same as for DVVLS and DVVLD at $201.

For fuel economy effectiveness, in the NPRM NHTSA estimated that DVVL could incrementally reduce fuel consumption by 0.5 to 3 percent compared to VVT.

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160 Docket no. NHTSA-2008-0089-0179.1, p 59 and Docket no. NHTSA-2008-0089-0046, p. 52.

Confidential manufacturer comments received in response to the NPRM indicated a 2 percent effectiveness for DVVL, while the Alliance commented that a two-step system with dual cam phasing could reduce fuel consumption by 6.3 percent, with 1.3 percent attributable to DVVL. Publicly-available estimates suggest an improvement over the NEDC test cycle of 8 percent for DCP with 2 stage inlet DVVL applied to a 1.6 liter DOHC 4 cylinder engine in a 1500 kg vehicle.[161] With the DCP system expected to deliver 5 percent effectiveness, this suggests the DVVL system is giving approximately 3 percent. The comments received from manufacturers and publicly available data are in alignment with independent review suggesting a range of 1 to 3 percent for overhead cam engines with VVT. NHTSA has therefore estimated an incremental reduction in fuel consumption for DVVLS and DVVLD of 1 to 3 percent for purposes of the final rule. On OHV engines, DVVLO is applied following both VVT and cylinder deactivation, therefore the fuel consumption effectiveness has been reduced from 1 to 3 percent for OHC engines to 0.5 to 2.6 percent.

This technology may be applied to any class of vehicles with any kind of engine at the redesign cycle. For the final rule, NHTSA has combined the phase-in caps for DVVLS, DVVLD, DVVLO and CVVL and capped the joint penetration allowed at 15 percent in MY 2011 with time-based learning applied. Other technologies, such as continuously variable valve lift (CVVL), described below, will be implemented in place of DVVL in some applications where the fuel economy requirements dictate further optimization of the engine's breathing characteristics to improve efficiency.

(vi) Continuously Variable Valve Lift (CVVL)

In CVVL systems, maximum 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 maximum lift is changed; the relation depends on the geometry of the mechanical system. BMW has the most production experience with CVVL systems and has sold port-injected "Valvetronic" engines since 2001. CVVL allows the airflow into the engine to be regulated by means of inlet valve opening reduction, which improves engine efficiency by reducing pumping losses from throttling the intake system further upstream as with a normally 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. This results 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 inlet valves only.

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[161] Mark Sellnau and Eric Rask, "Two-Step Variable Valve Actuation For Fuel Economy, Emissions, and Performance, Delphi Research Labs, SAE 2003-01-0029. *Available at* http://www.sae.org/technical/papers/2003-01-0029. (last accessed Nov. 9, 2008)

It is generally more difficult to achieve good cylinder-to-cylinder airflow balance at low load with a CVVL valve-throttled engine due to the sensitivity of airflow to small differences in lift caused by manufacturing tolerances. BMW has reported mixture quality issues with CVVL and port fuel injection, requiring a compromise on pumping work reduction to ensure good mixture quality. In addition, a small amount of throttling is necessary with CVVL to maintain the vacuum required for power brake assist, unless a separate vacuum pump is used. BMW calibrations maintain a small amount of inlet manifold depression on their "Valvetronic" engines to allow the brake servo to function, which reduces the efficiency gain from the system somewhat. Tumble air motion generated by the inlet port is not available in the cylinder at low valve lift, which has an effect on combustion characteristics. The high gas velocities at the valve seat generate high turbulence levels, but most of this has decayed by the time of ignition. This phenomenon could potentially lead to sub-optimal combustion characteristics, which would reduce the fuel consumption effectiveness of the technology.

In the NPRM, NHTSA estimated the cost for CVVL of $254 to $508 compared to VVT, with cost estimates varying from $254 for a 4-cylinder engine, $466 for a 6-cylinder engine, and $508 for an 8-cylinder engine, based on confidential manufacturer data and the NESCCAF report, with more weight given to the manufacturer data. As for DVVL, for purposes of the final rule, NHTSA relied primarily on the 2008 Martec report, because it contained the most complete published description of CVVL costs and agreed with confidential manufacturer data received in response to the NPRM. The system consists of 1 stepper motor per bank to control an eccentric shaft and the costs as described by Martec include dual cam phasing are $285 for an in-line 4-cylinder engine, $450 for a V-6 engine, and $550 for a V-8 engine. Applying a 1.5 RPE markup factor to these variable costs, and then deducting $122 for the incremental cost of both ICP and DCP per bank, the incremental RPE cost is $306 for a 4-cylinder engine, $432 for a 6-cylinder engine and $582 for an 8-cylinder engine.

For fuel economy effectiveness, in the NPRM NHTSA estimated that CVVL could incrementally reduce fuel consumption by 1.5 to 4 percent compared to VVT, based on confidential manufacturer data and the NESCCAF report. Confidential manufacturer comments received in response to the NPRM suggested a range of 3 to 7.4 percent incremental fuel consumption savings. NHTSA also found several sources reporting a 5 percent additional fuel consumption effectiveness over the NEDC cycle when applying CVVL to an engine with dual cam phasers.[162] For purposes of the final rule, NHTSA has estimated the reduction in fuel consumption for CVVL at 1.5 to 3.5 percent over an engine with DCP. This estimate is lower that the effectiveness reported by BMW and allows the application of CVVL without the need for the high level of manufacturing complexity inherent in BMW's "Valvetronic" engines.

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[162] *See* Johannes Liebl, Manfred Kluting, Jurgen Poggel, and Stephen Missy, BMW, "The New BMW 4-Cylinder Engine with Valvetronic Part 2: Thermodynamics and Functional Features," MTZ Worldwide, July/Aug 2001, pp 26-29. *See also* Meyer, BMW, "Turbo-Charging BMW's Spray-Guided DI Combustion System – Benefits and Challenges," Global Powertrain Congress, Sept. 2005, vol. 33. *Available at* http://www.gpc-icpem.org/pages/publications.html (last accessed Nov. 8, 2008). *See also* Rainer Wurms, Philipp Lobbert, Stefan Dengler, Ralf Budack, and Axel Eiser, Audi, "How Much VVT Makes Sense?" Haus der Technik Conference on Variable Valve Control, Essen, Feb. 2007.

There are no class specific applications of this technology, although it appears in only the DOHC portion of the decision tree. Due to the changes required to implement DVVL on an engine the Volpe model allows it to be applied at redesign model years only with time-based learning applied. For the final rule, NHTSA has combined the phase-in caps for DVVLS, DVVLD, DVVLO and CVVL and capped the joint penetration allowed at 20 percent per year on average (15 percent in year one). There is no technical reason this technology could not be applied to all DOHC engines, but due to engineering resource limitations it is unlikely that CVVL will be applied to all engines, and that other technologies such as DVVL will be used in some instances.

(vii) Cylinder Deactivation (DEACS, DEACD, DEACO)

In conventional spark-ignited engines, combustion occurs in all cylinders of the engine (*i.e.*, the engine is "firing on all cylinders"), and throttling the airflow controls the engine output, or load. This is an inefficient method of operating the engine at low loads as pumping losses result from throttling. Cylinder deactivation (DEAC) can improve engine efficiency by disabling or deactivating half of the cylinders when the load is less than half of the engine's total torque capability, allowing the active cylinders to operate at roughly twice the load level, and thereby incur roughly half the pumping losses.

Simplistically, cylinder deactivation control strategy relies on setting maximum and minimum manifold absolute pressures (which are directly proportional to load) within which it can deactivate the cylinders. The engine operating range over which cylinder deactivation may be enabled is restricted by other factors as well, with noise, vibration, and harshness (NVH) being the primary concern; these restrictions all reduce the fuel economy effectiveness achievable with cylinder deactivation. In general, DEAC has very high sensitivity of efficiency gain relative to vehicle application, according to comments from Ford, Chrysler, the Alliance, and in confidential comments submitted in response to the NPRM.

Manufacturers have stated that use of DEAC on 4 cylinder engines would cause unacceptable NVH; therefore NHTSA has not applied cylinder deactivation to 4-cylinder engines. In addition, to address NVH issues for V6 and V8 engines, active engine mounts are included in the content list. Noise quality from both intake and exhaust systems has been problematic on some vehicle applications, and in some cases, has resulted in active exhaust systems solutions with an ECU-controlled valve.

The NPRM reported an incremental cost range for DEAC at \$203 to \$229, citing manufacturer data as the most credible, with the bill of materials including lost motion devices for each cylinder. The 2008 Martec report estimated the additional hardware necessary for cylinder deactivation ranging between \$50 for the addition of two active engine mounts (\$75 RPE using 1.5 RPE factor) where DVVL already exists. This value has been adopted by NHTSA in the final rule so DEACS and DEACD costs are \$75. For OHV engines NHTSA estimates the costs for DEACO as being \$306 for V6 engines and \$400 for V8 engines that are not already equipped with DVVL using assumptions for lost motion devices plus incremental costs for oil control valves and camshaft position sensors as noted in the DVVL section.

For fuel economy effectiveness, in the NPRM NHTSA estimated that cylinder deactivation could reduce fuel consumption by 4.5 to 6 percent. As noted, DEAC has very high sensitivity of efficiency gain relative to vehicle application. Chrysler, for example, stated that the effectivenesss could range from 3 to 10 percent on the same engine depending on the specific vehicle application.[163] Confidential manufacturer comments received in response to the NPRM reported a range of 3 to 7.5 percent. For the final rule, the incremental fuel consumption effectiveness varies depending on which branch of the decision tree it is on: for DOHC engines which are already equipped with DCP and DVVLD there is little benefit that can be achieved since the pumping work has already been minimized and internal EGR rates are maximized, so the effectiveness ranges from 0 to 0.5 percent for DEACD; for SOHC engines which have CCP and DVVLS applied, NHTSA estimates a 2.5 to 3 percent effectiveness for DEACS; and for OHV engines, which do not have VVT or VVL technologies, the effectiveness for DEACO ranges from 3.9 to 5.5 percent.

This technology may be applied only to V-6 and V-8 engines, as discussed above, and so does not apply to vehicle classes with I-4 engines. DEAC can be applied during a redesign or refresh model year with time-based learning. NHTSA proposed to raise the phase-in cap for this technology to 20 percent per year in the NPRM. For the final rule, NHTSA has combined the phase-in caps for DEACS, DEACD and DEACO and capped the joint average annual penetration allowed at 9 percent in MY 2011.

(viii) Conversion to Double Overhead Camshaft Engine with Dual Cam Phasing (CDOHC)

This technology was named “Multi-valve Overhead Camshaft Engine” in the NPRM. Engines with overhead cams (OHC) and more than two valves per cylinder achieve increased airflow at high engine speeds and reductions of the valvetrain’s moving mass and enable central positioning of the spark plug. Such engines typically develop higher power at high engine speeds. In the NPRM, the model was generally not allowed to apply multivalve OHC technology to OHV engine, except where continuous variable valve timing and lift (CVVL) is applied to OHV engine. In that case, the model assumed conversion to a DOHC valvetrain, because a DOHC valvetrain is a prerequisite for the application of any advanced engine technology over and above CVVL. Since applying CVVL to an OHV engine is the last improvement that could be made, it was assumed that manufacturers would redesign that engine as a DOHC and include CVVL as part of that redesign.

However, it appears likely that vehicles will still use overhead valve (OHV) engine with pushrods and one intake and one exhaust valve per cylinder into the next decade. For the final rule, NHTSA assumed that conversion of an OHV engine to a DOHC engine would more likely be accompanied by dual cam phasing (DCP) than by CVVL, since DCP application rates are higher than CVVL rates.

[163] Docket No. NHTSA-2008-0089-0215.1.

For V8 engines, the incremental cost to redesign an OHV engine as a DOHC with DCP was estimated as $746 which includes $415 for the engine conversion to DOHC per the 2008 Martec report and a 1.5RPE factor, plus $122 for an incremental cam phasing system (reflecting the doubling of cam shafts). For a V6 engine we estimated 75 percent of the V8 engine cost to convert to DOHC plus the same incremental coupled cam phasing cost to arrive at $590. For inline 4-cylinder engines, 50 percent of the V8 engine conversion costs were assumed and one additional cam phasing system yielding an incremental cost including a 1.5 RPE factor of $373.

For fuel economy effectiveness, NHTSA estimated in the NPRM that the incremental gain in fuel consumption for conversion of an OHV engine with cylinder deactivation and CCP to a DOHC engine with CVVL at 1 to 4 percent, in agreement with the NESCCAF report and confidential manufacturer data. The fuel consumption benefit for converting an OHV engine to a DOHC engine with DCP is due largely to friction reduction according to a confidential manufacturer comment. For the final rule the upper bound stated in the NPRM was reduced because DCP will give less improvement than CVVL compared to an engine that already has cylinder deactivation and CCP applied. NHTSA estimates the incremental fuel consumption effectiveness at 1 to 2.6 percent independent of the number of engine cylinders.

There are no class-specific applications of this technology. In the NPRM, NHTSA proposed raising the phase-in cap to 20 percent per year, but has concluded for the final rule that a 9 percent phase-in cap for MY 2011 is more consistent with manufacturers' comments. No comments were received regarding phase-in rates of converting OHV engines to DOHC. The conversion from OHV to DOHC engine architecture with DCP is a major engine redesign that can be applied at redesign model years only with time-based learning applied.

(ix) Stoichiometric Gasoline Direct Injection (SGDI)

In gasoline direct injection (GDI) engines, fuel is injected into the cylinder rather than into the inlet manifold or inlet port. GDI allows for the compression ratio of the engine to be increased by up to 1.5 units higher than a port-injected engine at the same fuel octane level. As a result of the higher compression ratio, the thermodynamic efficiency is improved, which is the primary reason for the fuel economy effectiveness with stoichiometric DI systems. The compression ratio increase comes about as a result of the in-cylinder air charge cooling that occurs as the fuel, which is sprayed directly into the combustion chamber, evaporates.

Volumetric efficiency in naturally-aspirated GDI engines can also be improved by up to 2 percent, due to charge cooling, which improves the full load torque. The improved full load torque capability of GDI engines can have a secondary effect on fuel economy by enabling engine downsizing, thereby reducing fuel consumption.

Two operating strategies can be used in gasoline DI engines, characterized by the mixture preparation strategy. One strategy is to use homogenous charge where fuel is injected during the intake stroke with a single injection. The aim is to produce a homogeneous air-fuel-residual mixture by the time of ignition. In this mode, a stoichiometric air/fuel ratio can be used and the exhaust aftertreatment system can be a relatively low cost, conventional three-way catalyst. Another strategy is to use stratified charge where fuel is injected late in the compression stroke with single or multiple injections. The aim here is to produce an overall lean, stratified mixture, with a rich area in the region of the spark plug to enable stable ignition. Multiple injections can be used per cycle to control the degree of stratification. Use of lean mixtures significantly improves efficiency by reducing pumping work, but requires a relatively high cost lean NO_x trap in the exhaust aftertreatment system.

For purposes of this rulemaking, only homogeneous charge stoichiometric DI systems were considered, due to the anticipated unavailability of low sulfur gasoline during the time period considered. This decision was supported by comments from Mercedes, which sells lean burn DI engines in other world markets, stating that lean burn DI engines cannot function in the absence of ultra-low sulfur gasoline. Lean NO_x trap technologies require ultra-low sulfur gasoline to function at high conversion efficiency over the entire life cycle of a vehicle.

Gasoline DI systems effectiveness from the increased efficiency of the thermodynamic cycle. The fuel consumption effectiveness from DI technology is therefore cumulative to technologies that target pumping losses, such as the VVT and VVLT technologies. The Sierra Research report stated that Sierra Research could not determine from the NPRM decision trees if VVLT technologies were retained when SGDI was applied. To clarify, as the model progresses through the decision trees, technologies preceding SGDI are retained in the cumulative effectiveness and cost.

In the NPRM, NHTSA estimated the incremental fuel consumption effectiveness for naturally aspirated SGDI[164] to be 1 to 2 percent. The Alliance commented that it estimated 3 percent gains in fuel efficiency, as well as a 7 percent improvement in torque, which can be used to mildly downsize the engine and give up to a 5.8 percent increase in efficiency. Other published literature reports a 3 percent effectiveness for SGDI,[165] and another source reports a 5 percent improvement on the NEDC drive cycle.[166] Confidential manufacturer data submitted in response to the NPRM reported an efficiency effectiveness range of 1 to 2 percent. For the final rule NHTSA has estimated, following independent review of all the sources referenced above, the incremental gain in fuel consumption for SGDI to be approximately 2 to 3 percent.

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164 SGDI was referred to as GDI or SIDI in the NPRM.

165 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. *Available at* http://www.erc.wisc.edu/symposiums/2005_Symposium/June%208%20PM/Whitaker_Ricardo.pdf (last accessed Nov. 9, 2008).

166 Stefan Trampert, FEV Motorentechnik GmbH, "Engine and Transmission Development Trends - Rising Fuel Cost Pushes Technology," Symposium on International Automotive Technology, Pune, India, January 2007.

Content assumptions for cost estimating of SGDI include no major changes to engine architecture compared to a port fuel injection engine, although cylinder head casting changes are required to incorporate the fuel injection system and the piston must change as well to suit the revised combustion chamber geometry. The fuel injection system utilizes an electrically-driven low pressure fuel pump to feed a high pressure mechanical pump, supplying fuel at pressures up to 200 Bar. A common fuel rail supplies the injectors, which produce a highly atomized spray with a Sauter Mean Diameter (SMD) of 15-20 microns, which compares to approximately 50 microns for a port injector.

In the NPRM, NHTSA estimated the following incremental cost ranges for applying SGDI: $122 to $420 for an inline 4-cylinder engine, $204 to $525 for a V6 engine, and $228 to $525 for a V8 engine. The Alliance commented that NHTSA had not accounted for the costs required to address NVH concerns associated with the implementation of SGDI. For purposes of the final rule, all costs have been based upon side mount DI technology as these costs were determined in the 2008 Martec Report to be lower than center mount DI systems. An applied RPE factor of 1.5 was used in all cases, and a NVH package was added to all engines in response to Alliance comments, providing incremental costs that ranged from $293 to $440 for an I4 engine, to $384 to $558 for a V6 engine and $512 to $744 for a V8 engine.

Homogeneous, stoichiometric DI systems are regarded as mature technology with minimal technical risk and are expected to be increasingly incorporated into manufacturers' product lineups. Time-based learning has been applied to this technology due to the fact that over 1.5 million vehicles containing this technology are now produced annually. Due to the changes to the cylinder head and combustion system and the control system development required to adopt SGDI technology, which are fairly extensive, SGDI can be applied only at redesign model years. There are no limitations on applying SGDI to any vehicle class. The phase-in cap for SGDI is applied at a 3 percent rate for MY 2011 in order to account for the lead time required to incorporate SGDI engines.

(x) Combustion Restart (CBRST)

Combustion restart allows "start-stop" functionality of DI engines through the implementation of an upgraded starter with bi-directional rotation to allow precise crankshaft positioning prior to subsequent fuel injection and spark ignition, allowing engine restart. This method of implementing engine stop/start functionality allows not only the fuel savings from not idling the engine, but also reduces fuel consumption as the engine speeds up to its operational speed. A Direct Injection (DI) fuel system is required for implementation of this technology.

NHTSA has determined, upon independent review, combustion restart to be a high technical risk due to the following unresolved issues. First, very high or very low ambient air temperatures may limit the ability to start the engine in the described manner. Although the starter motor can provide fail-safe starting capability in these temperature limited areas, strategies must be developed to manage the transitions. Additionally, a fail-safe start strategy that recognizes failed attempts and responds quickly enough has yet to be demonstrated. The risk of missed start events is currently relatively high, which is unacceptable from a production implementation perspective. As a result, availability of this technology was assessed as beyond the emerging technology time frame for MY 2011.

(xi) Turbocharging and Downsizing (TRBDS)

Forced induction in the form of turbocharging and supercharging has been used on internal combustion engines for many years. Their traditional role has been to provide enhanced performance for high-end or sports car applications. However, turbocharging and downsizing can also be used to improve fuel economy. There is a natural friction reduction with a boosted downsized engine, because engine friction torque is primarily a function of engine displacement. When comparing FMEP (Friction Mean Effective Pressure – friction torque normalized by displacement) there is very little difference between the full size naturally-aspirated engine and the boosted downsized engine despite the higher cylinder pressure associated with higher BMEP. Turbocharging and downsizing can also reduce pumping losses (PMEP), because a turbocharged downsized engine runs at higher BMEP (Brake Mean Effective Pressure) levels, and therefore higher manifold pressures, than a naturally aspirated engine. The upper limit of BMEP level that can be expected from a naturally aspirated engine is approximately 13.5 Bar, whereas a turbocharged engine can produce BMEP levels in excess of 20 Bar. Engines that are not downsized and boosted use a throttle to regulate load, but this causes pumping losses as discussed previously. Thus, by using a small displacement engine with a turbocharger, the smaller engine works harder (higher cylinder load), which results in lower pumping loss since the throttle must be further open to produce the same road power output.

Due to the incremental nature of the decision tree, engines having turbocharging and downsizing applied are assumed to have SGDI already applied. In boosted engines, SGDI allows improved scavenging of the cylinder, which reduces the internal exhaust gas residual level and the charge temperature. This in turn allows a higher compression ratio to be used for a given fuel octane rating and can therefore improve the fuel consumption of boosted SGDI engines.

In most cases, a boosted downsized engine can replace a conventional naturally aspirated engine and achieve equivalent or greater (albeit at the expense of fuel economy) power and torque. However, there are some challenges associated with acceptance of a down sized boosted engine, including:

- Achievement of "seamless" power delivery compared to the naturally aspirated engine (no perceptible turbo lag);
- A complication in emissions regulatory compliance, because the addition of a turbocharger causes additional difficulty with catalyst light off due to the thermal inertia of the turbo itself;
- Potential issue with customer acceptance of smaller-displacement engines, given a common perception that only larger-displacement engines can be high-powered; and
- Additional base engine cost and vehicle integration costs.

Manufacturers' structural changes to the base engine are generally focused on increasing the structure's capacity to tolerate higher cylinder pressures. NHTSA believes that it is reasonable to expect that the maximum cylinder pressure would increase by 25 to 30 percent over those typical of a naturally aspirated engine. Another consideration is that higher pressures lead to higher thermal loads.

One potential disadvantage of downsized and boosted engines is cost. Turbocharging systems can be expensive and are best combined with direct injection and other engine technologies. The Alliance expressed a related concern that the fuel economy effectiveness was based on the use of premium grade fuel in direct injection turbocharged engines, and argued that as the baseline vehicles were not fueled with premium gasoline, this gave the direct injection turbocharged engines an unrealistic advantage.[167] However, CARB stated in its comments that premium fuel is not necessary for use with turbocharged downsized engines and that substantial effectiveness are still available with regular fuel.[168] In fact, most turbocharged direct injection engines will have a compression ratio and calibration designed to give best performance on premium fuel, although they are safe to operate on regular fuel. On regular fuel, the knock sensor output is used to allow the ECU to keep the engine safe by controlling boost and ignition timing. Maximum torque is reduced on the lower octane fuel due to the ECU intervention strategy, but at part load, where knock is not an issue, the fuel economy will not be affected adversely relative to the estimated effectiveness. Additionally, the driver retains the choice of obtaining more performance by paying more for premium fuel and will still obtain stated fuel consumption effectiveness.

Nevertheless, the case for using downsized boosted engines has strengthened with the wider introduction of direct injection gasoline engines. Downsized boosted engines with stoichiometric direct injection present minimal technical risk, although there have been only limited demonstrations of this technology achieving SULEV emission levels.

In the NPRM, NHTSA estimated that downsized and turbocharged engines could incrementally reduce fuel consumption from 5 to 7.5 percent. CARB commented that Sierra Research in its presentation to the NAS committee on January 24, 2008, suggested there is no carbon dioxide reduction potential for turbocharging and downsizing, but argued that this is not supported by other vehicle simulation efforts nor by manufacturer plans to release systems such as the Ford EcoBoost.[169] The Alliance and Sierra Research, in contrast, commented that turbocharged and downsized engines do not improve fuel economy unless they are also equipped with DI fuel systems and using premium fuel.[170] NHTSA believes that turbocharging and downsizing, when combined with SGDI, offers benefits without the use of premium fuel as noted above. 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 benefit of 8 to 13 percent compared to current-production naturally-

[167] Docket No. NHTSA-2008-0089-0179.1.
[168] Docket No. NHTSA-2008-0089-0173.
[169] Docket no. NHTSA-2008-0089-0173.4.
[170] Docket no. NHTSA-2008-0089-0046, Docket no. NHTSA-2008-0089-0179.1.

aspirated engines without friction reduction or other fuel economy technologies: a joint technical paper by Bosch and Ricardo suggesting an EPA fuel economy gain of 8 to 10 percent for downsizing from a 5.7 liter port injection V8 to a 3.6 liter V6 with direct injection;[171] a Renault report suggesting 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 with direct injection;[172] and a Robert Bosch paper suggesting a 13 percent NEDC gain for downsizing to a turbocharged DI engine.[173] These reported fuel economy benefits show a wide range in large part due to the degree of vehicle attribute matching (such as acceleration performance) that was achieved.

For purposes of the final rule, NHTSA estimated a net fuel consumption reduction of approximately 14 percent for a turbocharged downsized DOHC engine with direct injection and DCP over a baseline fixed-valve engine that does not incorporate friction reducing technologies. This equates to an incremental fuel consumption reduction of 2.1 to 5.2 percent for TRBDS, which is incremental to an engine with SGDI and previously applied technologies (*e.g.*, VVT and VVL) as defined by the decision tree. This wide range is dependent upon the decision tree path that is followed or the configuration of the engine prior to conversion to TRBDS. The incremental fuel consumption benefit for TRBDS is estimated to range from 2.1 to 2.2 percent for V6 and V8 engines and from 4.5 to 5.2 percent for inline 4-cylinder engines. As explained, the incremental improvement from TRBDS must be added to the previous technology point on the decision tree. In the case of SOHC and OHV engines, for example, moving to the TRBDS technology also assumes implementation of DOHC engine architecture in addition to DCP and SGDI.

In the NPRM, NHTSA estimated that the cost for a boosted/downsized engine system would be $690 for small cars, $810 for large trucks, and $120 for all other vehicle classes, based on the NAS report, the EEA report, and confidential manufacturer data, which assumed downsizing allowed the removal to two cylinders in most cases, except for small cars and large trucks. CARB questioned Martec's cost estimates for turbocharging and downsizing, specifically the credit for downsizing a V6 engine to an in-line 4 cylinder dropped from their estimate used in the NESCCAF report of $700 to $310 and the use of more expensive hardware than some manufacturers use. In response, NHTSA's independent review of the cost to downsize a V6 DOHC engine to a I4 DOHC engine closely aligned with the 2008 Martec credit of $310, while the report for NESCCAF was not specific with regard to the assumptions used to construct that estimate. Additionally, confidential manufacturer data submitted in response to the NPRM provided a range for TRBDS with SGDI of $600 to $1,400 variable cost or $900 to $2100 RPE assuming a 1.5 markup factor. When comparing the confidential

[171] 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 Nov. 9, 2008)
[172] 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.
[173] 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.

manufacturer cost range and the incremental RPE cost estimates for the final rule, it is important to realize the incremental cost for TRBDS does not include SGDI since it is considered a separate technology.[174]

Some of the costs included in turbocharging and downsizing come from structural changes due to the higher cylinder pressures and increased cylinder temperatures, which also drive additional cooling requirements (*e.g.* water-cooled charge air cooler, circulation pump, and thermostats) and require improved exhaust valve materials. High austenitic stainless steel exhaust manifolds and upgraded main bearings are some of the other hardware upgrades required. For purposes of the final rule, NHTSA used cost data from the 2008 Martec report, but constructed a bill of materials consistent with the incremental TRBDS technology as shown in the decision trees and based on confidential manufacturer data. For the vehicle subclasses which have a baseline gasoline V8 engine, two turbochargers rated for 1050°C at $250 each were added, $270 was deducted for downsizing to a V6 from a V8 engine, $217 was added for engine upgrades to handle higher operating pressures and temperatures at, and a water-cooled charge air cooler was added at $280. The baseline SOHC engine was converted to a DOHC engine with 4 valves per cylinder at a variable incremental cost of $92. The total variable costs summed to $819 and a 1.5 RPE factor was applied to arrive at $1,229 incremental cost to turbocharging and downsizing.

For the vehicle subclasses which have a baseline gasoline V6 engine, a twin-scroll turbocharger rated for 1050°C was added at a cost of $350, $310 was deducted for downsizing to an I4 from a V6 engine, $160 was added for engine upgrades to handle higher operating pressures and temperatures, and a water-cooled charge air cooler was added at $259. The baseline SOHC engine was converted to a DOHC engine with 4 valves per cylinder at a variable incremental cost of $87. The total variable costs summed to $548 and a 1.5 RPE factor was applied to arrive at $822 incremental cost to turbocharging and downsizing.

For the vehicle subclasses which have a baseline gasoline I4 engine, a twin-scroll turbocharger rated for 1050°C was added at a cost of $350, $160 was added for engine upgrades to handle higher operating pressures and temperatures, and a water-cooled charge air cooler was added at $259. The baseline SOHC engine was converted to a DOHC engine with 4 valves per cylinder at a variable incremental cost of $46. The total variable costs summed to $815 and a 1.5 RPE factor was applied to arrive at $1,223 incremental cost for turbocharging and downsizing.

In summary, for the final rule NHTSA estimated TRBDS to have an incremental RPE cost of $1,223 for vehicle classes with a baseline in-line 4-cylinder engine downsized to a

[174] NHTSA also examined the Jetta TDI as an example of a current vehicle model that comes in both diesel and gasoline-engine form, but in attempting to do an apples-to-apples comparison with the non-turbocharged/downsized version , the SE, found indications that VW appears to be keeping the cost of the TDI down by removing other content (*e.g.*, the SE has a sunroof, which normally costs around $1,000, while the TDI does not). Thus, NHTSA did not find VW's price differential for the two versions of the Jetta to be convincing evidence of the actual cost of turbocharging and downsizing an engine.

smaller I-4 engine which are: Subcompact, Performance Subcompact, Compact and Midsize Car, and Small Truck. For vehicle classes with a baseline V6 engine that was downsized to an I4 engine the RPE cost is estimated at $822; these classes are the Performance Compact, Performance Midsize and Large Car, Minivan and Midsize Truck. The two vehicle classes with baseline V8 engines, Performance Large Car and Large Truck, were downsized to V6 turbocharged engines at an incremental RPE cost of $1,229.

Time-based learning has been applied to TRBDS because submitted product plan data indicated turbocharging and downsizing would already be at high volume in 2011. Due to the fact that a turbocharged and downsized engine is entirely different than the baseline engine it can be applied only at redesign model years. The phase-in cap for TRBDS is applied at a 9 percent rate for MY 2011 in order to account for the lead time required to incorporate TRBDS engines.

(xii) Cooled Exhaust Gas Recirculation Boost (EGRB)

EGR Boost is a combustion concept that involves utilizing EGR as a charge dilutant for controlling combustion temperatures. Fuel economy is therefore increased by operating the engine at or near the stoichiometric air/fuel ratio over the entire speed and load range and using higher exhaust gas residual levels at part load conditions. Further fuel economy increases can be achieved by increased compression ratio enabled by reduced knock sensitivity, which enables higher thermal efficiency from more advanced spark timing. Currently available turbo, charge air cooler, and EGR cooler technologies are sufficient to demonstrate the feasibility of this concept.

However, this remains a technology with a number of issues that still need to be addressed and for which there is no production experience. EGR system fouling characteristics could be potentially worse than diesel EGR system fouling, due to the higher HC levels found in gasoline exhaust. Turbocharger compressor contamination may also be an issue for low pressure EGR systems. Additionally, transient controls of boost pressure, EGR rate, cam phasers and intake charge temperature to exploit the cooled EGR combustion concept fully will require development beyond what has already been accomplished by the automotive industry. These are all “implementation readiness” issues that must be resolved prior to putting EGR Boost into volume production.

Because of these issues NHTSA did not consider EGR Boost in the NPRM, and consequently had no tentative conclusions with regard to its cost or fuel economy effectiveness. For purposes of the final rule, NHTSA found no evidence from commenters or elsewhere that these implementation readiness issues could be resolved prior to MY 2011. Therefore, in the final rule, the phase-in cap for MY 2011 is zero.

(b) Diesel Engine Technologies

Diesel engines, which currently make up about 0.27 percent of engines in the MY 2008 U.S. fleet, 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. The diesel combustion cycle operates at a higher compression ratio, with a very lean air/fuel mixture, and turbocharged light-duty diesels typically achieve much higher torque levels at lower engine speeds than equivalent-displacement naturally-aspirated gasoline engines. Additionally, diesel fuel has higher energy content per gallon.[175]

However, diesel engines, including those on the many diesel vehicles sold in Europe, have emissions characteristics that present challenges to meeting federal Tier 2 emissions standards. It is a significant systems-engineering challenge to maintain the fuel consumption advantage of the diesel engine while meeting U.S. emissions regulations, since fuel consumption is negatively impacted by emissions reduction strategies. Emission compliance strategies for diesel vehicles sold in the U.S. are expected to include a combination of combustion improvements and aftertreatment. These emission control strategies are currently widely used in Europe, but will have to be modified due to the fact that U.S. emission standards, especially for NO_x, are much tighter than corresponding European standards. To achieve U.S. Tier 2 emissions limits, roughly 45 to 65 percent more NO_x reduction is required compared to the Euro VI standards. Additionally, as discussed below, there may be a fuel consumption penalty associated with diesel aftertreatment since extra fuel is needed for the aftertreatment, subsequently this extra fuel is not used in the combustion process of the engine that provides torque to propel the vehicle.

Nevertheless, emissions control technologies do exist, and will enable diesel engines to make considerable headway in the U.S. fleet in coming years. Several key advances in diesel technology have made it possible to reduce emissions coming from the engine prior to aftertreatment. These technologies include improved fuel systems (higher pressures and more responsive injectors), advanced controls and sensors to optimize combustion and emissions performance, higher EGR levels and EGR cooling to reduce NO_x, lower compression ratios, and advanced turbocharging systems.

The fuel systems on advanced diesel engines are anticipated to be of a High-Pressure Common Rail (HPCR) type with piezoelectric injectors that operate at pressures up to 1800 Bar or greater and provide fast response to allow multiple injections per cycle. The air systems will include a variable geometry turbocharger for 4-cylinder inline engines with charge-air cooling and high-pressure and low-pressure EGR loops with EGR coolers. For V-6 or V-8 engines the air systems will employ series sequential turbo-charging with one variable geometry turbocharger and one fixed geometry turbocharger.

As suggested above, the traditional 3-way catalyst aftertreatment found on gasoline-powered vehicles is ineffective due to the lean-burn combustion of a diesel. All diesels will require a diesel particulate filter (DPF), a diesel oxidation catalyst (DOC), and a 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) or selective catalytic reduction (SCR), which are outlined below.

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[175] Burning one gallon of diesel fuel produces about 11 percent more carbon dioxide than gasoline due to the higher density and carbon to hydrogen ratio.

(i) Diesel Engine with Lean NO_x Trap (LNT) Catalyst After-Treatment

A lean NO_x trap operates, in principle, by storing NO_x (NO and NO_2) when the engine is running in its normal (lean) state. 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 are sensitive to sulfur deposits that can reduce catalytic performance, but periodically undergo a desulfurization engine-operating mode to clean it of sulfur buildup.

The fuel consumption penalty associated with aftertreatment systems, including both DPF and LNT, is taken into account in the reported values. In the case of the DPF, extra fuel is needed to raise the temperature of the DPF above approximately 550°C to enable active regeneration. A similar process is needed to regenerate the LNT, but instead of being used to remove particulates and raise the temperature, the excess fuel is used to provide a fuel-rich condition at the LNT to convert the trapped NO_x on the LNT to nitrogen gas. The estimated fuel consumption penalty on the CAFE test cycle associated with the LNT aftertreatment system is 5 percent on the EPA city cycle and 3 percent on the highway cycle, as described in the report to the EPA.[176]

In order to maintain equivalent performance to comparable gasoline-engine vehicles, an inline 4-cylinder (I-4) diesel engine with displacement varying around 2 liters to meet vehicle performance requirements was assumed for Subcompact, Performance Subcompact, Compact, and Midsize Passenger Car and Small Truck vehicle subclasses, and it was also assumed that these vehicles would utilize LNT aftertreatment systems.

In the NPRM, NHTSA estimated that LNT-based diesels could incrementally reduce fuel consumption by 8 to 15 percent at an incremental RPE cost of $1,500 to $1,600 compared to a direct injected turbocharged and downsized spark-ignition engine, in agreement with confidential manufacturer data. These costs were based on a "bottom up" cost analysis that was performed with EPA, which then subtracted the costs of all previous steps on the decision tree prior to diesel engines.

Comments submitted in response to the NPRM including both manufacturers' confidential data and non-confidential data sources for diesel engines was in the range of 16.7 percent to 26.7[177] percent fuel consumption benefit over a baseline gasoline engine at a variable cost of $2,000 to $11,200. Confidentially submitted diesel cost and effectiveness estimates generally did not differentiate between car and truck applications, engine size and aftertreatement systems leading to large ranges for both cost and

[176] Ricardo, "A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies, Revised Final Report," at 62. *Available at* http://www.epa.gov/otaq/technology/420r08004a.pdf (last accessed Oct. 4, 2008).

[177] The 26.7 percent fuel consumption reduction is a maximum estimate cited in a June 2008 Sierra Research report (Docket No. NHTSA-2008-089-0179.1) for a CAFE estimate in a midsize car, whereas an April 2008 Sierra report (Docket No. NHTSA-2008-089-0046) cites a maximum estimate of 22.4 percent for the same vehicle class; NHTSA was unable to discern why the estimates differed.

effectiveness estimates. Additionally, most of the costs appeared to be stated as variable costs not RPE but this was not always completely discernible.

For purposes of the final rule, NHTSA estimated the net fuel consumption benefit for an I-4 diesel engine with LNT aftertreatment to be approximately 20 to 26 percent improvement over a baseline gasoline engine. This equates to a 5.3 to 7.7 percent improvement for DSLT, which is incremental to a turbocharged downsized gasoline engine (TRBDS) with EGRB, and a 15.0 to 15.3 percent incremental improvement for DSLC, which is incremental to a gasoline engine with combustion restart (CBRST.) The 2008 Martec report was relied upon for cost estimates and the diesel cost was adjusted by removing the downsizing credit and applying a 1.5 RPE marked up factor to arrive at a cost of $4007 compared to a baseline gasoline engine. This results in an incremental RPE cost of $1,567 to $1,858 for DSLT and $2,963 to $3,254 for DSLC. NHTSA's independent review concurred with all the costs in this bill-of-material-based cost analysis.

A large part of the explanation for the cost increase since the NPRM is the dramatic increase in commodity costs for the aftertreatment systems, namely the platinum group metals. The updated cost estimates of Martec 2008 and others reflect the rise of global costs for raw materials since Martec 2004 and other prior referenced cost estimates were conducted. As described in Martec 2008, engine technologies employing high temperature steels or catalysts with considerable platinum group metals usage have experienced tremendous inflation of raw material prices. These updated estimates account for current spot prices of platinum and rhodium which have demonstrated cost inflation amounting to between 300 and 750 percent of global prices.[178]

(ii) Diesel Engine with Selective Catalytic Reduction (SCR) After-Treatment

An SCR aftertreatment system uses a reductant (typically, ammonia derived from urea) that is continuously 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 into the exhaust stream). While a rich engine-operating mode is not required for NO_x reduction, the urea is typically injected at a rate of 3 to 4 percent of the fuel consumed. Manufacturers designing SCR systems intend to align urea tank refills with standard maintenance practices such as oil changes.

The fuel consumption penalty associated with the SCR aftertreatment system is taken into account in the values reported here. Similar to the LNT system, extra fuel is needed to warm up the SCR system to an effective operating temperature. The estimated fuel consumption penalty on the CAFE test cycle associated with the SCR aftertreatment system is 5 percent on the EPA city cycle and none on the highway cycle, as described in

[178] Martec, "Variable Costs of Fuel Economy Technologies," June 1, 2008, at 13-20. Docket No. NHTSA-2008-0089-0169.1.

the report to the EPA.[179] A recent report, however, suggests a fuel economy benefit associated with the use of a SCR system, based on the supposition that the engine calibration is shifted towards improved fuel consumption and more of the NO_x reduction is being handled by the SCR system.[180] Nevertheless, since this benefit is not yet proven for high-volume production, it has not been applied for purposes of the final rule.

In order to maintain equivalent performance to comparable gasoline-engine vehicles, a V-6 diesel engine, with displacement varying around 3 liters was assumed for Performance Compact, Performance Midsize, Large Passenger Car, Minivan, and Midsize Truck. A V-8 diesel engine, with displacement varying around 4.5 liters to meet vehicle performance requirements, was assumed for Large Truck and Performance Large Car vehicle classes. It was also assumed that these classes with V-6 and V-8 diesel engines utilize SCR aftertreatment systems instead of LNT.

In the NPRM, NHTSA estimated incremental fuel consumption reduction for diesel engines with an SCR system to range from 11 to 20 percent at an incremental RPE cost of $2,051 to $2,411 compared to a direct injected turbocharged and downsized spark-ignition engine. These costs were based on a "bottom up" cost analysis that was performed with EPA, which then subtracted the costs of all previous steps on the decision tree prior to diesel engines.

As explained above for LNT, confidential manufacturer and non-confidential comment data submitted in response to the NPRM for diesel engines was in the range of 16.7 percent to 26.7 percent fuel consumption benefit over a baseline gasoline engine at variable cost of $2,000 to $11,200 with no detail about the aftertreatment, engine size or application. Additionally, Ricardo's vehicle simulation work for EPA found an incremental *fuel economy* benefit of 19 percent for a 4.8L diesel in a Large Truck.[181] However, when the baseline 4-speed automatic transmission shift and torque converter lockup scheduling was optimized for the diesel engine, an additional 5 percent fuel economy benefit was obtained to yield an incremental benefit for a diesel of 24 percent. As noted in the report on page 84, however, this does not represent an optimized result, as only the final packages complete with all technologies were optimized. Nevertheless, this is a reasonable estimate for diesel engine fuel economy benefit over a baseline gasoline engine with coordinated cam phasing (CCP). This estimate did not have the aftertreatment penalty, however, so applying the 5 percent penalty associated with diesel oxidation catalyst, diesel particulate filter, and SCR aftertreatment brings the fuel

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[179] Ricardo, "A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies, Revised Final Report," at 62. *Available at* http://www.epa.gov/otaq/technology/420r08004a.pdf (last accessed Oct. 4, 2008).

[180] Timothy V. Johnson, "Diesel Emission Control in Review," Society of Automotive Engineers Technical Series, 2008-01-0069, 2008. Available at http://www.sae.org/technical/papers/2008-01-0069 (last accessed Nov. 9, 2008).

[181] Ricardo, "A Study of Potential Effectiveness of Carbon Dioxide Reducing Vehicle Technologies, Revised Final Report," Table 7-9 shows incremental fuel economy and CO2 benfits for Truck with technology package 11, p. 87. *Available at* http://www.epa.gov/otaq/technology/420r08004a.pdf (last accessed Oct. 4, 2008).

economy benefit for diesel engine with aftertreatment down to 19 percent, which is equal to a 16 percent *fuel consumption* benefit.

For purposes of the final rule, NHTSA estimated the net fuel consumption benefit for a V-6 diesel engine with SCR aftertreatment to be approximately 20 to 26 percent improvement over a baseline gasoline engine. This equates to a 4.0 to 7.7 percent improvement for DSLT, which is incremental to a turbocharged downsized gasoline engine (TRBDS) with EGRB, and a 9.9 to 13.1 percent incremental improvement for DSLC, which is incremental to a gasoline engine with combustion restart (CBRST.) The 2008 Martec report was relied upon for cost estimates and the diesel cost was adjusted by removing the downsizing credit and applying a 1.5 RPE marked up factor to arrive at a cost of $5,603 compared to a baseline gasoline engine. This results in an incremental RPE cost of $3,110 to $3,495 for DSLT and $4,105 to $4,490 for DSLC. NHTSA's independent review concurred with all the costs in this bill-of-material-based cost analysis for V-6 engines.

NHTSA estimated the net fuel consumption benefit for a V-8 diesel engine with SCR aftertreatment to be approximately 19 to 25 percent improvement over a baseline gasoline engine. This equates to a 4.0 to 6.5 percent improvement for DSLT, which is incremental to a turbocharged downsized gasoline engine (TRBDS) with EGRB, and a 10.0 to 12.0 percent incremental improvement for DSLC, which is incremental to CBRST. The 2008 Martec report was relied upon for cost estimates and the diesel cost was adjusted by removing the downsizing credit and applying a 1.5 RPE marked up factor to arrive at a cost of $7,002 compared to a baseline gasoline engine. This results in an incremental RPE cost of $3,723 to $4,215 for DSLT and $5,125 to $5,617 for DSLC. NHTSA's independent review concurred with all the costs in this bill-of-material-based cost analysis for V-8 engines.

The diesel engine with SCR has an incremental cost that is significantly higher for the final rule than the NPRM. NHTSA believes the increase is explained by the improved accuracy of the final rule analysis which relied on the updated cost estimates from the 2008 Martec Report as described previously[182]. In addition, comments from the Alliance suggested that the incremental diesel cost for a midsize car was $6,198 and $7,581[183] for a pickup truck.

The economic breakeven point for diesel engine aftertreatment options is based on public information[184] and on recent discussions that NHTSA and EPA have had with auto

[182] Martec, "Variable Costs of Fuel Economy Technologies," June 1, 2008, at 13-20. Docket No. NHTSA-2008-0089-0169.1.

[183] These cost estimates are taken from the April 2008 Sierra Research report (Docket No. NHTSA-2008-089-0046). A June 2008 Sierra Research report (Docket No. NHTSA-2008-089-0179.1) contained lower estimates of $5,947 and $7,271 for the same vehicles; NHTSA was unable to discern the reason for the difference.

[184] Timothy V. Johnson, "Diesel Emission Control in Review," Diesel Engine-Efficiency and Emissions Research (DEER) Conference, Detroit, MI, August 20-24, 2006. *Available at* http://www1.eere.energy.gov/vehiclesandfuels/pdfs/deer_2006/session2/2006_deer_johnson.pdf (last accessed Nov. 9, 2008). *See also* Tim Johnson, "Diesel Engine Emissions and Their Control," Platinum

manufacturers and aftertreatment device manufacturers. NHTSA explained in the NPRM that it had received strong indications that LNT systems would probably be used on smaller vehicles while the SCR systems would be used on larger vehicles and trucks. The economic break-even point between LNT and SCR is dependent on the quantity of catalyst used, the market price for the metals in those catalysts, and the cost of the urea injection system. The NPRM estimated that the breakeven point would occur around 3 liters engine displacement, based on discussions with auto manufacturers and aftertreatment device manufacturers. Thus, NHTSA tentatively concluded that it would be cheaper to manufacturer diesel engines smaller than 3 liters with an LNT system, and that conversely, it would be cheaper to manufacturer diesel engines larger than 3.0 liters with a SCR system. No comments were submitted to NHTSA regarding the breakeven point between a LNT and SCR system. However, according to one source of recently published data the breakeven point occurs between 2.0 to 2.5L.[185] Considering that continuing developments are being made in this area and the wide range of precious metal content required, NHTSA believes that an economic breakeven point of 2 to 3 liters is reasonable and that other factors will strongly influence which system is chosen by any given vehicle manufacturer.

Cummins commented that LNT systems should be considered for more than just the compact and subcompact vehicles, and stated that a number of large vehicles and trucks currently use LNT. Cummins argued that a LNT after-treatment system can be a cost-effective technology on both small and larger engines. For the final rule, NHTSA assumed the use of a LNT after-treatment system for three additional vehicle subclasses compared to the NPRM. However, following the rationale explained in the preceding paragraph, the SCR type after-treatment system is assumed for larger vehicle subclasses. As is the case with all technologies in the analysis, technology application assumptions are based on the general understanding of what a manufacturer could do in response to meeting emissions compliance but other manufacturer specific factors will dictate the actual technology applications.

In the NPRM, NHTSA assumed a 3 percent phase in rate per year for diesel technologies. For the final rule, passenger cars, as defined by the technology class, retained the 3 percent combined (for DSLT and DSLC) phase-in cap. However, diesel technologies for truck technology classes were allowed to be applied at a 4 percent combined (for DSLT and DSLC) phase-in cap to account for the higher application rates observed in the submitted product plans and diesel's favorable characteristics in truck applications. Volume-based learning was assumed for the NPRM, however, confidential product plans indicated that this technology would be in high-volume in the 2011 time frame, thus time-based learning was assumed for the final rule. For the final rule, diesel technologies can only be applied at redesign, which is consistent with the NPRM.

(c) Transmission Technologies

Metals Review, 52, at 23-37 (2008). *Available at* http://www.platinummetalsreview.com/dynamic/article/view/52-1-23-37 (last accessed Nov. 9, 2008)

[185] *Id*.

NHTSA has also reconsidered the way it applies transmission technologies in the Volpe model to obtain increased fuel savings. The revised decision tree for transmission technologies reflects the fact that baseline vehicles now include either 4- or 5-speed automatic transmissions, given that many manufacturers are already employing 5-speed automatic transmissions or are going directly to 6-speed automatics.[186] The decision tree in the final rule also combines "aggressive shift logic" and "early torque converter lockup," although the NPRM considered them separately, because NHTSA concluded upon further review that the two technologies could be optimized simultaneously due to the fact that adding both of them primarily required only minor modifications to the transmission or calibration software. Cost and effectiveness numbers have also been thoroughly reexamined, as have learning rates and phase-in caps, based on comments received. The section below describes each of the transmission technologies considered.

(i) Improved Transmission Controls and Externals (IATC)

During operation, an automatic transmission's controller manages the operation of the transmission by scheduling the upshift or downshift, and 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 as noted in the gas engine section. Early torque converter lockup[187] in conjunction with ASL can further improve fuel economy by locking the torque converter sooner, thus reducing inherent torque converter slippage or losses. As discussed above, the NPRM separated these two technologies, but they are combined for purposes of the final rule since the calibration software can be optimized for both functions simultaneously.

Calibrating the transmission shift schedule to improve fuel consumption reduces the average engine speed and increases the average engine load, which can lead to a perceptible increase in engine harshness. The degree to which the engine harshness can be increased 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. The Alliance agreed in its comments that ASL can be used effectively to reduce throttling losses, but at the expense of noise-vibration-harshness (NVH) and drivability concerns. The Alliance also commented that losses in the torque converter typically make automatic transmissions less efficient than manual transmissions, and suggested that efficiency can be improved by mechanically "locking up" the torque converter earlier or

[186] Confidential product plans indicate that future products manufactured within the rulemaking period may not go from 4- or 5-speed transmission, but will instead introduce 6- or 7-speed automatic transmissions as replacements.

[187] 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. Internal transmission hardware changes associated with this technology are addressed in 6/7/8-Speed Automatic Transmission with Improved Internals section.

replacing the torque converter with a friction clutch of the type used on a manual transmission. Simply replacing a torque converter with a friction clutch, however, ignores the torque multiplication that torque converters provide at vehicle launch.

In the NPRM, NHTSA estimated that aggressive shift logic could incrementally reduce fuel consumption by 1 to 2 percent at an incremental cost of $38 and early torque converter lockup could incrementally reduce fuel consumption by 0.5 percent at a $30 cost for the calibration effort. Confidential manufacturer comments suggested that less aggressive shift logic must be employed on vehicles with low acceleration reserve, but that a 1-3 percent improvement in fuel economy was attainable on vehicles with adequate acceleration reserve.

For the final rule, NHTSA combined aggressive shift logic and early torque converter lockup into the IATC technology with an effectiveness estimate of 1.5 to 2.5 percent in agreement with most confidential manufacturer estimates. As aggressive shift logic and early torque converter lockup are both achievable with a similar calibration effort, the incremental cost for improved automatic transmission controls used the higher value of $38, converted this value to 2007 dollars, and applied a 1.5 RPE markup factor to arrive at an incremental cost estimate of $59 for the final rule.

The IATC technology is considered to be available at the start of the 2011 model year, and as was the case in the NPRM, NHTSA considers that it can be applied during a refresh model year since NVH concerns must be addressed. The technology is applicable to all vehicle subclasses and NHTSA determined IATC type technologies will be high volume within the 2011 time frame so time-based learning is assumed, with a phase-in cap for MY 2011 of 33 percent.

(ii) Automatic 6-, 7- and 8-Speed Transmissions (NAUTO)

Having more “speeds” on a transmission (*i.e.*, having more gear ratios on the transmission) gives three effects in terms of vehicle performance and fuel economy. First, more gear ratios allow deeper 1st and 2nd gear ratios for improved launch performance, or increased acceleration. Second, a wider ratio spread also offers the ability to reduce the steps between gear ratios, which allows the engine to operate closer to optimum speed and load efficiency region. And third, a reduction in gear ratio step size improves internal transmission losses by reducing the sliding speeds across the clutches, thus reducing the viscous drag loss generated between two surfaces rotating at different speeds. Bearing spin losses are also reduced as the differential speed across the two bearing surfaces is reduced. This allows the engine to operate at a reduced load level to improve fuel economy.

Although the additional gear ratios improve shift feel, they also introduce more frequent shifting between gears, which can be perceived by consumers as bothersome. Additionally, package space limitations prevent 7- and 8-speed automatics from being applicable to front wheel drive vehicles.

Comparison between NPRM and final rule cost and effectiveness estimates are somewhat complicated by the revisions in the decision trees and technology assumptions. In the NPRM, NHTSA estimated that 6-, 7- and 8-speed transmissions could incrementally reduce fuel consumption by 0.5 to 2.5 percent at an incremental cost of $76 to $187, relative to a 5-speed automatic transmission, a technology not used in the final rule decision tree, and the incremental cost for a 4-speed to a 5-speed automatic transmission (again no longer considered in the final rule) was estimated to be $76 to $167.

In response to NHTSA's request for information, 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. The 2008 Martec report estimated a cost of $323 (RPE adjusted) for converting a 4-speed to a 6-speed transmission and a cost of $638 (RPE adjusted) for converting a 4-speed to an 8-speed transmission. GM has publicly claimed a fuel economy improvement of up to 4 percent for its new 6-speed automatic transmissions.[188] 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.[189]

For the final rule, NHTSA estimated 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 subclasses. The 2008 Martec report, which quoted high volume, fully learned costs, was relied on to develop the final rule cost estimates. Subcompact, Compact, Midsize, Large Car and Minivan subclasses, which are typically considered normal performance passenger cars, are assumed to utilize a 6-speed automatic transmission only (as opposed to 7 or 8 speeds) resulting in an incremental RPE cost of $323 from Martec 2008. For Performance Subcompact, Performance Compact, Performance Midsize, Performance Large car and Small, Midsize and Large truck, where performance and or payload/towing may be a larger factor, NHTSA assumed that 6-, 7- or 8-speed transmissions are applicable thus the incremental RPE cost range of $323-$638 was established which used the Martec 2008 six speed cost and 8-speed costs for the estimates.

This technology will be available from the start of the rulemaking period. Confidential manufacturer data indicates the widespread use of 6-speed or greater automatic transmissions and introductions into the fleet occur primarily at vehicle redesign cycles. This prompted NHTSA to set the phase-in rate at 50 percent for MY 2011, but also to consider that the technology can only be applied at a redesign cycle, as opposed to the refresh cycle application of the NPRM. The technology is determined to be at high

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[188] 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 at http://www.gm.com/experience/fuel_economy/news/2007/adv_engines/2008-powertrain-lineup-082707.jsp* (last accessed Sept. 18, 2008).

[189] Page 17, "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.

volume in the 2011 timeframe, and since these are mature and stable technologies, time-based learning factors are applied.

(iii) Dual Clutch Transmissions / Automated Manual Transmissions (DCTAM)
An automated manual transmission (AMT) is similar in architecture to a conventional manual transmission, but shifting and launch functions are performed through hydraulic or electric actuation. There are two basic types of AMTs, single-clutch and dual-clutch transmission (DCT), both of which were considered in the NPRM. Upon further consideration and in response to manufacturer comments to only include dual-clutch AMTs, single-clutch AMTs are not applied in the analysis for the final rule.

Single clutch transmissions exhibit a torque interruption when changing gears because the clutch has to be disengaged. In a conventional manual transmission vehicle, the driver has initiated the gear change, and so expects to feel the resulting torque interruption. With an AMT, in contrast, a control system initiates the shift, which is unexpected and can be disconcerting to the driver. Comments from Ford in response to the NPRM indicated that the acceptability of this torque interruption among U.S. drivers is poor, although Ford also commented that DCTs do not have the risk of customer acceptance that AMTs do. BorgWarner, a DCT supplier, echoed these comments. DCTs do not display the torque interrupt characteristic due to their use of two clutch mechanisms which allow for uninterrupted power transmission. To assist with launch of a DCT equipped vehicle, the first gear ratio can be deepened to gain back some of the performance advantage an automatic transmission possesses due to the torque converter's torque multiplication factor.

There are two types of DCT systems, wet clutch and dry clutch, which are used for different types of vehicles. Wet clutch DCTs offer a higher torque capacity that comes from the use of a hydraulic system that cools the clutches, but that are less efficient than the dry clutch type due to the losses associated with hydraulic pumping. Additionally, wet DCTs have a higher cost due to the additional hydraulic hardware required. Wet clutch DCT systems have been available in the U.S. market on imported products since 2005, and Chrysler has publicly stated that it will have a DCT transmission in its 2010 model year vehicle line-up.[190]

Consistent with manufacturers' confidential comments and based on its own analysis, NHTSA determined that dry clutch DCTs are applicable to smaller front wheel drive cars, due to their lower vehicle weight and torque production, and wet clutch DCTs are more applicable to higher torque applications with higher power requirements. Therefore lower cost, higher efficiency dry clutch DCTs are specified for the Subcompact and Compact Car vehicle classes, while all other classes required wet clutch DCTs.

In the NPRM, NHTSA estimated that the incremental cost for DCTs was $141, independent of vehicle class, which was the midpoint of the NESCCAF estimates and within the range provided confidential manufacturer data. CARB commented that

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[190] Chrysler blog, "Dual-Clutch Transmissions Explained" (released October 3, 2007) available at http://blog.chryslerllc.com/blog.do?p=entry&id=113, last accessed September 18, 2008.

NHTSA had incorrectly cited the cost of AMTs from the NESCCAF study in the NPRM, stating that AMTs had been determined to be cost neutral (zero cost) relative to baseline transmission, as opposed to a $0-$240 cost justification. Confidential manufacturer data suggest additional DCT costs from $80 to $740, with dry clutch DCT costs being approximately $100 less due to reduced hydraulic system content. The 2008 Martec study also reported variable costs for AMTs.

In the NPRM, NHTSA cited the NESCCAF study as projecting that AMTs could incrementally reduce fuel consumption by 5 to 8 percent and confidential manufacturer data projected that AMTs could incrementally reduce fuel consumption by 2 to 5 percent. On the basis of these estimates, NHTSA concluded in the NPRM that AMTs could incrementally reduce fuel consumption by 4.5 to 7.5 percent. Confidential manufacturer data received in response to the NPRM suggest a benefit of 2 to 12 percent for DCTs over a 6-speed planetary automatic, and one confidential manufacturer estimates a benefit of 1 to 2 percent for a dry clutch DCT over a wet clutch DCT. The 2008 EPA Staff Technical Report also indicates a benefit of 9.5 to 14.5 percent for a DCT (wet or dry was not specified) over a 4-speed planetary automatic transmission.

For the final rule, 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 vehicle subclasses except Subcompact and Compact Car. This results in an incremental effectiveness estimate of 2.7 to 4.1 percent over the NAUTO technology. For Subcompact and Compact Cars, 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 NAUTO technology.

The 2008 Martec report was utilized to develop the cost estimates for the final rule; it estimated an RPE cost of $450 for a dry clutch DCT, and $600 for a wet clutch DCT, both relative to a baseline 4/5-speed. In the transmission decision tree for the final rule, this yielded a dry clutch DCT incremental cost estimate of $68 for the Subcompact and Compact Cars relative to the NAUTO technology. For Midsize, Large Car and Minivan classes the wet clutch DCT incremental cost over NAUTO is $218, which reflects the lower, 6-speed only cost of the NAUTO technology applied to these vehicles. The average incremental cost for wet DCT for the four Performance classes and the Small, Midsize and Larger truck is $61, which is lower than the other vehicle subclasses due to the higher cost NAUTO technology (up to 8-speeds) that the DCTAM technology supersedes.

NHTSA relied upon confidential manufacturer product plans showing DCT production will be readily available and at high volume by 2011. Therefore volume-based learning is not applicable, and since this is a mature and stable technology, time-based learning is applied. As production facility conversion or construction may be required to facilitate required capacity, NHTSA limited the production phase-in caps in MY 2011 to 20 percent. As with other transmission technologies, application was allowed at redesign only due to the vehicle changes required to adapt a new type transmission.

(iv) Continuously Variable Transmission (CVT)

A continuously variable transmission (CVT) is unique in that it does not use gears to provide ratios for operation. Most CVTs use either a belt or chain on a system of two pulleys (the less common toroidal CVTs replace belts and pulleys with discs and rollers) that progressively vary the ratio, thus permitting an infinite number of effective gear ratios between a maximum and minimum value, and often a wider range of ratios than conventional automatic transmissions. This enables even finer optimization of the transmission ratio under different operating conditions and, therefore, some reduction of engine pumping and friction losses. In theory, the CVT has the ability to be the most fuel-efficient kind of transmission due to the infinite ability to optimize the ratio and operate the engine at its most efficient point. However, this effectiveness is reduced by the significant internal losses from high-pressure, high-flow-rate hydraulic pump, churning, friction loss, and bearing losses required to generate the high forces needed for traction.[191]

Some U.S. car manufacturers have abandoned CVT applications because they failed to deliver fuel economy improvements over automatic transmissions. GM abandoned the use of CVT before 2006.[192] Ford offered a CVT in the Five Hundred and Freestyle from MYs 2005-2007 and discontinued it thereafter. However, Chrysler offers CVTs in the Dodge Caliber, the Jeep Compass, and the Jeep Patriot. Nissan was using CVTs in many vehicles, but appears to be restricting the use of this technology to passenger cars only.

In the NPRM, NHTSA estimated a CVT effectiveness of approximately 6 percent over a 4-speed automatic, which was above the NESCCAF value but in the range of NAS. For costs, NHTSA concluded in the NPRM that the adjusted costs presented in the 2002 NESCCAF study represent the best available estimates, and thus estimated that CVTs could incrementally reduce fuel consumption by 3.5 percent when compared to a conventional 5-speed automatic transmission (which cost an incremental $76 - $167), a technology which is considered a baseline transmission option on the final rule decision tree, at an incremental cost of $100 to $139. After reviewing confidential manufacturer data and the Martec report, for the final rule NHTSA is now estimating the incremental cost of CVTs to be $300 for all vehicle subclasses, except for large performance cars, midsize light trucks and large light trucks for which the technology is incompatible.

Confidential manufacturer data in response to the NPRM suggested that the incremental effectiveness estimate from CVTs may be 2 to 8 percent over 4-speed planetary transmissions in simulation (however one commenter reported a zero percent improvement in dynamometer testing) at a cost of $140 to $800. Considering the NPRM conclusion and confidential data together with independent review, NHTSA has

[191] "Transmission and Driveline – Major contributors to FUEL efficiency, safety, fun to drive and brand differentiation", Car Training Institute Symposium, May 6-7, 2008- Plenary Speech, Robert Lee, Vice President, Mircea Gradu, Director Transmission and Driveline, Chrysler LLC, USA. Available from the Car Training Institute, for contact information *see* http://www.car-training-institute.com/cti_en/html/kontakt.html (last accessed Nov. 9, 2008).

[192] *See* http://car-reviews.automobile.com/news/general-motors-to-kill-continually-variable-transmission/166/ (last accessed Oct. 23, 2008).

estimated the fuel consumption effectiveness for CVTs at 2.2 to 4.5 percent over a 4/5-speed automatic transmission, which translates into a 0.7 to 2.0 incremental effectiveness improvement over the IATC technology. NHTSA estimated the CVT incremental cost to be $300 for the final rule, noting that the NPRM costs were incremental to a 5-speed technology that is no longer represented in the decision tree, hence the higher final rule cost.[193]

CVTs are currently available, but due to their limited torque-carrying capability, they are not applied to Performance Large cars and Midsize and Large trucks. There is limited production capability for CVTs, so the phase-in cap for MY 2011 is limited to 5 percent to account for new plants and tooling to be prepared. CVTs can be introduced at product redesign intervals only based on confidential manufacturer data and consistent with the NPRM approach (since it requires vehicle attribute prove-out, test and certification prior to introduction). Confidential manufacturer data indicates that CVTs will be at high volumes by 2011, and this is a mature and stable technology, therefore NHTSA applied time-based learning factors.

(v) 6-Speed Manual Transmissions (6MAN)

Manual transmissions are entirely dependent upon driver input to change gear ratio: the driver selects when to perform the shift and which gear ratio 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 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.

NHTSA recognizes that while the manual transmission is very efficient, its effect on fuel consumption relies heavily upon driver input. In driving environments where little shifting is required, the manual transmission is the most efficient because it has the lowest internal losses of all transmissions. However, the manual transmission may have lower fuel efficiency on a drive cycle when drivers shift at non-optimum points.

In the NPRM, NHTSA estimated that a 6-speed manual transmission could incrementally reduce fuel consumption by 0.5 percent when compared to a 5-speed manual transmission, at an incremental cost of $107. Confidential manufacturer data received in

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[193] Since the decision trees are configured differently, the net cost to CVT in the NPRM included 5-speed automatic transmission technology costs that are not applied in the final rule.

response to the NPRM suggests that manual transmissions could incrementally reduce fuel consumption by 0 to 1 percent over a base 5-speed manual transmission at an incremental cost of $40 to $900. Most confidential comments suggested that the incremental cost was within the lower quartile of the full range, thus $225 (the lower quartile upper-bound) was multiplied by the 1.5 RPE markup factor for a total of $338. Therefore, the final rule states that the incremental fuel consumption effectiveness for a 6-speed manual transmission over a 5-speed manual transmission is 0.5 percent at a RPE cost of $338.

This technology is applicable to all vehicle classes considered and can be introduced at product redesign intervals, consistent with the NPRM and other final rule transmission technologies. Six-speed manuals are already in production at stable and mature high volumes so time-based learning is applied with a 33 percent phase-in rate for MY 2011.

(d) Hybrid and Electrification/Accessory Technologies

(i) Overview

A hybrid describes a vehicle that combines two or more sources of energy, where one is a consumable energy source (like gasoline) and one is rechargeable (during operation, or by another energy source). Hybrids reduce fuel consumption through three major mechanisms: (1) by turning off the engine when it is not needed, such as when the vehicle is coasting or when stopped; (2) by recapturing lost braking energy and storing it for later use; and by (3) optimizing the operation of the internal combustion engine to operate at or near its most efficient point more of the time. A fourth mechanism to reduce fuel consumption, available only to plug-in hybrids, is by substituting the fuel energy with energy from another source, such as the electric grid.

Engine start/stop is the most basic of hybrid functions, and as the name suggests, the engine is shut off when the vehicle is not moving or when it is coasting, and restarted when needed. This saves the fuel that would normally be utilized to spin the engine when it is not needed. Regenerative braking is another hybrid function which allows some of the vehicle's kinetic energy to be recovered and later reused, as opposed to being wasted as heat in the brakes. The reused energy displaces some of the fuel that would normally be used to drive the vehicle, and thus results in reduced fuel consumption. Operating the engine at its most efficient operating region more of the time is made possible by adding electric motor power to the engine's power so that the engine has a degree of independence from the power required to drive the vehicle. Fuel consumption is reduced by more efficient engine operation, the degree of which depends heavily on the amount of power the electric motor can provide. Hybrid vehicles with large electric motors and battery packs can take this to an extreme and drive the wheels with electric power only and the engine consuming no fuel. Plug-in hybrid vehicles can substitute fuel energy with electrical energy, further reducing the fuel consumption.[194]

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[194] Substituting fuel energy with electrical energy may not actually save total overall energy used, when considering the inefficiencies of creating the electricity at a power plant and storing it in a battery pack, but it does enable use of other primary energy sources, and reduces the vehicle's fuel consumption. Plug-in hybrids are also receiving increasing attention because of their ability to use "clean energy" from the electric grid, such as that solar or wind, which can reduce the overall greenhouse gas output.

Hybrid vehicles utilize some combination of the above mechanisms to reduce fuel consumption. The effectiveness of a hybrid, and generally the complexity and cost, depends on the utilization of the above mechanisms and how aggressively they are pursued.

In addition to the purely hybrid technologies, which decrease the proportion of propulsion energy coming from the fuel by increasing the proportion of that energy coming from electricity, there are other steps that can be taken to improve the efficiency of auxiliary functions (*e.g.*, power-assisted steering or air-conditioning) which also reduce fuel consumption. These steps, together with the hybrid technologies, are collectively referred to as "vehicle electrification" because they generally use electricity instead of engine power. Three "electrification" technologies are considered in this analysis along with the hybrid technologies: electrical power steering (EPS), improved accessories (IACC), and high voltage or improved efficiency alternator (HVIA).

(ii) Hybrid System Sizing and Cost Estimating Methodology

Estimates of cost and effectiveness for hybrid and related electrical technologies have been adjusted from those described in the NPRM to address commenters' concerns that NHTSA considered technologies not likely to be adopted by automakers (*e.g.*, 42V electrical systems) or did not scale the costs for likely technologies across the range of vehicle subclasses considered. To address these concerns, the portfolio of vehicle electrification technologies has been refined based on commenter data as described below in the individual hybrid technologies sections. Ricardo and NHTSA have also developed a "ground-up" hybrid technology cost estimating methodology and, where possible, validated it to confidential manufacturer data. The hybrid technology cost method accounts for variation in component sizing across both the hybrid type and the vehicle platform. The method utilizes four pieces of data: (1) key component sizes for a midsize car by hybrid system type; (2) normalized costs for each key component; (3) component scaling factors that are applied to each vehicle subclass by hybrid system type; and (4) vehicle characteristics for the subclasses which are used as the basis for the scaling factors.

Component sizes were estimated for a midsize car using publicly available vehicle specification data and commenter data for each type of hybrid system as shown in Table V-10.

Table V-10. Component Sizes by Hybrid Type for a Midsize Car

Component	Hybrid Type				
	MHEV	ISG	PSHEV	2MHEV	PHEV
Primary Motor power, continuous (kW)	3	11	45	45	45
Secondary Motor power, continuous (kW)	na	na	30	45	30
Primary Inverter power, continuous (kW)	3	11	45	45	45
Secondary Inverter power, continuous (kW)	na	na	30	45	30
Controls complexity (relative to strong hybrid)	25%	50%	100%	100%	100%
NiMH Battery Pack capacity (kW-hr)	na	1	2	2	na
Li-Ion Battery Pack capacity (kW-hr)	na	na	na	na	15
DC/DC Converter power (kW)	0.7	3	3	3	3
High Voltage Wiring (relative to strong hybrid)	na	50%	100%	100%	100%
Supplemental heating	Yes	Yes	Yes	Yes	Yes
Mechanical Transmission (relative to baseline vehicle)	100%	100%	50%	100%	25%
Electric AC	No	No	Yes	Yes	Yes
Blended Brakes	No	No	Yes	Yes	Yes
Charger power, continuous (kW)	na	na	na	na	3

In developing Table V-10, NHTSA made several assumptions:

1) Hybrid controls hardware varies with the level of functionality offered by the hybrid technology. Assumed hybrid controls complexity for a 12V micro hybrid (MHEV) was 25 percent of a strong hybrid controls system and the complexity for an Integrated Starter Generator (ISG) was 50 percent. These ratios were estimates based on the directional need for increased functionality as system complexity increases.
2) In the time frame considered, Li-ion battery packs will have limited market penetration, with a majority of hybrid vehicles using NiMH batteries. One estimate from Anderman indicates that Li-ion market penetration will achieve 35 percent by 2015.[195] For the purposes of this analysis, it was assumed that mild and strong hybrids will use NiMH batteries and plug-in hybrids will use Li-ion batteries.
3) The plug-in hybrid battery pack was sized for a mid-sized car by assuming: the vehicle has a 20 mile all electric range and consumes an average of 300 W-hr per mile; the battery pack can be discharged down to 50 percent depth of discharge; and the capacity of a new battery pack is 20 percent greater than at end of life (*i.e.*, range on a new battery pack is 24 miles).
4) All hybrid systems included a DC/DC converter which was sized to accommodate vehicle electrical loads appropriate for increased vehicle electrification in the time frame considered.
5) High voltage wiring scaled with hybrid vehicle functionality and could be represented as a fraction of strong hybrid wiring. These ratios were estimates based on the directional need for increased functionality as system complexity increases.
6) All hybrid systems included a supplemental heater to provide vehicle heating when the engine is stopped, however, only stronger hybrids included electric air conditioning to enable engine stop/start when vehicle air conditioning was requested by the operator.

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[195] Anderman, Advanced Automotive Battery Conference, May 2008. Proceedings available for purchase at http://www.advancedautobat.com/Proceedings/index.html (last accessed October 17, 2008).

In the hybrid technology cost methodology developed for cost-scaling purposes, several strong hybrid systems replaced a conventional transmission with a hybrid-specific transmission, resulting in a cost offset for the removal of a portion of the clutches and gear sets within the transmission. The transmission cost in Table V-11 below expresses hybrid transmission costs as a percentage of traditional automatic transmission cost, as described in the 2008 Martec Report, at $850. The method assumed that the mechanical aspect of a power-split transmission with a reduced number of gear sets and clutches resulted in a cost savings of 50 percent of a conventional transmission with torque converter. For a 2-mode hybrid, the mechanical aspects of the transmission are similar in complexity to a conventional transmission with a torque converter, thus no mechanical cost savings was appropriate. The plug-in hybrid assumed a highly simplified transmission for electric motor drive, thus 25 percent of the base vehicle transmission cost was applied.

Estimates for the cost basis of each key component are shown in Table V-11 below along with the sources of those estimates. The cost basis estimates assume fully learned, high-volume (greater than 1.2 million units per annum) production. The costs shown are variable costs that are not RPE adjusted.

Table V-11. Component Cost Basis at High Volumes and Data Sources

Component	Cost Basis	Data Source
Primary Motor ($/kW)	$ 15	Martec 2008
Secondary Motor ($/kW)	$ 15	
Primary Inverter ($/kW)	$ 10	Confidential business information
Secondary Inverter ($/kW)	$ 10	
Controls	$ 100	
NiMH Battery Pack ($/kW-hr.)	$ 50	Attorneys General/Anderman comments (NHTSA-2008-089-0199.5)
Li-Ion Battery Pack ($/kW-hr.)	$ 600	Anderman, AABC 2008 ($900/kW-hr @ 2000 units/yr learned and rounded)
DC/DC Converter	$ 100	Confidential business information
High Voltage Wiring	$ 250	Martec 2008
Supplemental heating	$ 84	
Mechanical Transmission	$ 850	Martec 2008 (to 4-spd. Auto.)
Electric AC	$ 450	Confidential business information
Blended Brakes	$ 400	Martec 2008
Charger	$ 100	Confidential business information
Automatic Transmission pump	$ 75	Martec 2008

Component scaling factors were determined based on vehicle characteristics for each type of hybrid system as shown in Table V-12 below.

Table V-12. Component Scaling Factors applied to Vehicle Class for each Hybrid System Type

Component	Hybrid Type				
	MHEV	ISG	PSHEV	2MHEV	PHEV
Primary Motor	Engine displacement	Curb weight	Curb weight[1]		Engine power
Secondary Motor	na	na	Engine displacement		Vehicle mass[2]
Primary Inverter	Primary motor power				
Secondary Inverter	na	na	Secondary motor power		
Controls	Complexity				
NiMH Battery Pack	na	Vehicle mass			na
Li-Ion Battery Pack	na	na	na	na	Vehicle mass
DC/DC Converter	Vehicle mass[3]				
High Voltage Wiring	na	Vehicle footprint			
Supplemental heating	Vehicle footprint				
Mechanical Transmission	Same for all vehicle classes				
Electric AC	na	na	Vehicle footprint		
Blended Brakes	na	na	Same for all vehicle classes		
Charger	na	na	na	na	Same for all vehicle classes

(1) For all vehicle classes except for performance classes which use Engine Torque

(2) Vehicle mass used as surrogate for vehicle road load

(3) Vehicle mass used as surrogate for vehicle electrical load

NHTSA's CAFE database was used to define the average vehicle characteristics for each vehicle subclass as shown in Table V-13 below, and these attributes were used as the basis of the scaling factors.

Table V-13. Key Vehicle Characteristics For Each Vehicle Class

Vehicle Subclass	Curb Weight (lbs)	Footprint (ft2)	Engine Disp. (L)	Power (hp)	Torque (ft-lb)
Subcompact Car	2795	41	1.9	134	133
Compact Car	3359	44	2.2	166	167
Midsize Car	3725	47	2.9	205	206
Large Car	4110	50	3.4	258	248
Performance Subcompact Car	3054	40	2.7	260	260
Performance Compact Car	3516	44	3.0	269	260
Performance Midsize Car	3822	47	3.9	337	318
Performance Large Car	4189	51	4.8	394	388
Minivan	4090	50	3.3	247	242
Small Truck	3413	45	2.6	178	185
Medium Truck	4260	50	3.6	250	256
Large Truck	5366	63	5.0	323	352

Table V-14 shows the costs for the different types of hybrid systems on a midsize vehicle. The individual component costs were scaled from the normalized costs shown in Table V-11 according to the component size shown in Table V-10 and adjusted to a low volume cost by backing out volume-based learning reductions.[196] These component costs were summed to get the total low volume cost for each hybrid type, and a 1.5 RPE adjustment was applied. The ISG technology replaces the MHEV technology on the Electrification/Accessory technology decision tree, therefore the MHEV technology costs must be subtracted to reflect true costs ($2,898 - $707 = $2,191 in this example).

Wherever possible, the results of the hybrid technology cost method were compared with values as previously described in the NPRM and the results generally matched prior estimates. Additionally, the results from the hybrid technology cost method were validated with public literature and confidential manufactures test data as allowed. Elements of the 2008 Martec report identified cost data and a detailed bill of materials for several comparable hybrid technologies (Micro-hybrid systems and Full Hybrid systems), and the hybrid technology cost model agreed well with this data. The scalable bill of material based methodology described above was determined to offer the best solution for estimating component sizes and costs across a range of hybrid systems and vehicle platforms and the validation of these cost outputs with other data sources suggests that this approach is a reasonable approach.

[196] High volume costs are multiplied by a factor of 1.56, which represents two cycles of 20 percent reverse learning, to determine the appropriate low volume, or unlearned costs.

Table V-14. Hybrid System - Midsize Vehicle Low Volume Costs

Component	Hybrid Type Low Volume (Unlearned) Costs				
	MHEV	**ISG***	**PSHEV**	**2MHEV**	**PHEV**
Primary Motor [Example: MHEV = 3KW * 15$/KW * 1.56 (vol uplift)]	$ 70	$ 263	$ 1,053	$ 1,053	$ 1,755
Secondary Motor	$ -	$ -	$ 702	$ 1,053	$ 702
Primary Inverter	$ 47	$ 176	$ 702	$ 702	$ 1,170
Secondary Inverter	$ -	$ -	$ 468	$ 702	$ 468
Controls	$ 39	$ 78	$ 156	$ 156	$ 156
NiMH Battery Pack	$ -	$ 546	$ 1,092	$ 1,092	$ -
Li-Ion Battery Pack	$ -	$ -	$ -	$ -	$ 14,040
DC/DC Converter	$ 109	$ 468	$ 468	$ 468	$ 468
High Voltage Wiring	$ -	$ 195	$ 390	$ 390	$ 390
Supplemental heating	$ 131	$ 131	$ 131	$ 131	$ 131
Mechanical Transmission	$ -	$ -	$ (663)	$ -	$ (995)
Electric AC	$ -	$ -	$ 702	$ 702	$ 702
Blended Brakes	$ -	$ -	$ 624	$ 624	$ 624
Charger	$ -	$ -	$ -	$ -	$ 468
Automatic transmission pump	$ 75	$ 75	$ -	$ -	$ -
Total Hybrid System Cost @ Low Volume	$ 471	$ 1,932	$ 5,825	$ 7,073	$ 20,080
RPE (1.5) System Cost @ Low Volume	***$ 707***	***$ 2,898***	***$ 8,738***	***$ 10,610***	***$ 30,119***

* ISG replaces the MHEV technology on the Accessory/Electrification Decision Tree

(iii) Electrical Power Steering (EPS)

Electrical Power Steering (EPS) is advantageous over conventional hydraulic power-assisted steering in that it only draws power when the vehicle is being steered, which is typically a small percentage of the time a vehicle is operating. In fact, on the EPA test cycle no steering is done, so the CAFE fuel consumption effectiveness comes about by eliminating the losses from driving the hydraulic steering pump at engine speed. EPS systems use either an electric motor driving a hydraulic pump (this is a subset of EPS systems known as electro-hydraulic power steering) or an electric motor directly assisting in turning the steering column. EPS is seen as an enabler for all vehicle hybridization technologies, since it provides power steering when the engine is off. This was a primary consideration in placing EPS at the top of the Electrification/Accessory decision tree.

In the NPRM, NHTSA estimated the fuel consumption effectiveness for EPS at 1.5 to 2 percent at an incremental cost of $118 to $197, believing confidential manufacturer data most accurate. In response to the NPRM Sierra Research suggested EPS and high efficiency alternators combined is worth 1 to 1.8 percent on the CAFE test cycle,[197] and confidential manufacturer data indicated a 0.7 to 2.9 percent fuel consumption reduction. The cost range from confidential manufacturer data was $70 to $300. Sierra estimated EPS for cars at $82 and $150 for trucks.[198] A market study by Frost & Sullivan indicated the cost of an EPS system at roughly $65 more than a conventional hydraulic (HPS) system.[199] Because there is a wide range in the effectiveness for EPS depending on the vehicle size, NHTSA has increased the range from the NPRM to incorporate the lower ranges suggested by most manufacturers and estimates the fuel consumption effectiveness for EPS at 1 to 2 percent for the purpose of the final rule. The incremental costs are also estimated on range below the Sierra value for cars but above the Frost & Sullivan estimate at a piece cost range of $70 to $80 and included a 1.5 RPE uplift to $105 to $120 for the final rule.

EPS is currently in volume production in small to mid-sized vehicles with a standard 12V electrical system; however, heavier vehicles may require a higher voltage system, which adds cost and complexity. The Chevy Tahoe Hybrid, for example, uses a higher voltage EPS system. For purposes of the final rule, NHTSA has applied EPS to all vehicle subclasses except for Large trucks.

In the NPRM, NHTSA assumed a 25 percent phase in rate of EPS technologies. For the purposes of the final rule, EPS phase-in caps were limited to 10 percent in MY 2011 to address confidential manufacturer concerns over lead time. In the NPRM, NHTSA assumed a volume-based learning effect for EPS. For the final rule, however, NHTSA applied time-based learning for EPS since NHTSA's analysis indicated that this technology would be in high-volume use at the beginning of its first year of availability. NHTSA also assumed in the NPRM that EPS could be applied during refresh model years, which was consistent with information provided in confidential product plans, therefore for the purpose of the final rule, NHTSA again applied EPS at refresh timing.

(iv) Improved Accessories (IACC)

Improved accessories (IACC) was defined in the NPRM as improvements in accessories such as the alternator, coolant and oil pumps that are traditionally driven by the engine. Improving the efficiency or outright electrification of these accessories would provide opportunity to reduce the accessory loads on the engine. However, as the oil pump provides lubrication to the engine's sliding surfaces such as bearings pistons, and camshafts and oil flow is always required when the engine is spinning, and it is only supplied when the engine is spinning, there is no efficiency to be gained by electrifying the oil pump.[200]

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[197] Docket No. NHTSA-2008-0089-0179.1, Attachment 2, at 53.
[198] Docket No. NHTSA-2008-0089-0179.1, Attachment 2, at 59.
[199] Cost for EPS quoted at 48 Euros, at $1.35 per Euro exchange rate (Oct. 7, 2008) equates to $65, from Frost & Sullivan, Feb. 9, 2006 "Japanese Steering System Market Moves Into High Gear," http://www.theautochannel.com/news/2006/02/09/210036.html (last accessed Nov. 2, 2008).
[200] Oil pump electrification comes with an additional potential technical and financial risk (to warranty and consumer), in that significant engine damage can occur should the system fail to provide engine lubrication, even on a momentary basis.

Electrical air conditioning (EAC) could reduce fuel consumption by allowing the engine to be shut off when it is not needed to drive the vehicle. For this reason EAC is often used on hybrid vehicles. In highway driving, however, there is little opportunity to shut the engine off; furthermore EAC is less efficient when the engine is running because it requires mechanical energy from the engine to be converted to electrical energy and then back again to mechanical. Since air conditioning is not required on the EPA city or highway test cycles, there is no CAFE fuel consumption effectiveness from EAC. Therefore, EAC does not improve accessory efficiency apart from the hybrid technologies. For the purposes of the final rule, IACC refers strictly to improved engine cooling, since electrical lubrication and air conditioning are not effective stand-alone fuel saving technologies and improved alternator is considered as a separate technology given its importance to vehicle electrification.

Improved engine cooling, or intelligent cooling, can save fuel through two mechanisms: by reducing engine friction as the engine warms up faster; and by operating an electric coolant pump at a lower speed than the engine would (*i.e.*, independent of engine speed). Intelligent cooling can be applied to vehicles that do not typically carry heavy payloads. Larger vehicles with towing capacity present a challenge for electrical intelligent cooling systems, as these vehicles have high cooling fan loads. Therefore NHTSA did not apply IACC to the Large Truck and SUV class.

In the NPRM, NHTSA estimated the fuel consumption effectiveness for improved accessories at 1 to 2 percent at an incremental cost of $124 to $166 based on the 2002 NAS Report and confidential manufacturer data. Confidential manufacturer data received in response to the NPRM and Sierra Research both suggested a range for fuel consumption effectiveness from 0.5 to 2 percent. A comment from MEMA suggested that improved thermal control of the engine could produce between 4 and 8 percent fuel economy improvement;[201] however, NHTSA's independent review of intelligent cooling suggests this estimate is high and concurs with the estimates from NAS. Independent review found the cost for IACC at low volumes, assuming the base vehicle already has an electric fan, to be $180 to $220. These costs were adjusted to account for volume-based learning and then marked up to account for the 1.5 RPE factor. For the purposes of the final rule, NHTSA retained the fuel consumption effectiveness at 1 to 2 percent and estimated the incremental costs to be $173 to $211.

MEMA also suggested that NHTSA consider solar glass technology to reduce cabin thermal loading; however, air conditioning technologies were not considered as part of this technology.

In the NPRM, NHTSA proposed a 25 percent phase-in cap for Improved Accessories. To address manufacturer concerns over lead time in the early years, the IACC phase-in cap was limited to 10 percent for MY 2011for the final rule. In the NPRM, NHTSA assumed for improved accessories a volume-based learning curve. For the final rule, however, NHTSA applied time-based learning for IACC since NHTSA's analysis indicated that this technology would be in high-volume use at the beginning of its first year of

[201] Docket No. NHTSA-2008-0089-0193.1.

availability. NHTSA assumed in the NPRM that improved accessories could be applied during any model year. For the purpose of the final rule, NHTSA applied intelligent cooling at refresh model years due to the significant changes required to the vehicle cooling system that necessitate recertification testing.

(v) 12V Micro Hybrid (MHEV)

12V Micro-Hybrid (MHEV) systems are the most basic of hybrid systems and offer mainly idle-stop capability. Their low cost and easy adaptability to existing powertrains and platforms can make them attractive for some applications. The conventional belt-driven alternator is replaced with a belt-driven, enhanced power starter-alternator and a redesigned front-end accessory drive system that facilitates bi-directional torque application. Also, during idle-stop, some functions such as power steering and automatic transmission hydraulic pressure are lost with conventional arrangements; so electric power steering and an auxiliary transmission pump are needed. These components are similar to those that would be used in other hybrid designs. Also included in this technology is the Smart Starter Motor. This system is comprised of an enhanced starter motor, along with some electronic control that monitors the accelerator, brake, clutch positions, and the battery voltage as well as low-noise gears to provide fast and quiet engine starts. Despite its extended capabilities, the starter is compact and thus relatively easy to integrate in the vehicle.

12V micro hybrid was added to the technology list to address concerns from CARB and Delphi that the hybrid classifications used in the NPRM did not adequately represent these technologies.[202]

The effectiveness estimates by NHTSA for this technology are based on confidential manufacturer data and independent source data. For the vehicles equipped with (baseline) inline 4, those with smaller displacements, the effectiveness is between 1 and 2.9 percent, and for those equipped with V-6 or V-8, the effectiveness is between 3.4 and 4 percent. The 1 to 2.9 percent incremental fuel consumption savings applies to the Sub-Compact Car, Performance Sub-Compact Car, Compact Car, Midsized Car, and Small Truck/SUV variants. The 3.4 to 4 percent incremental fuel consumption applies to the remaining classes with the exception of Large Truck/SUV where MHEV is not applied due to payload and towing requirements for this class.

Confidential manufacturer comments submitted in response to the NPRM indicated a $200 to $1000 cost for the MHEV. The 12V micro-hybrid does not have a high voltage battery, and thus does not have a high-voltage wire cost. The 12V micro-hybrid system for the midsize vehicle has a 3kW electric motor. This agrees well with two commercially available systems used on smaller engines.[203] The value used for the DC/DC converter represents the cost for a 12V power conditioning circuit to allow uninterrupted power to the radio and a limited number of other accessories when the

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[202] Docket Nos. NHTSA-2008-0089-0173 and -0144.1, respectively.

[203] Citroen uses a 2kW system for a 1.4L diesel engine, and Valeo has a 1.6kW system applicable for engines up to 2L in displacement. The midsize vehicle class has an average engine size of 2.9L, and thus a 3kW starter is appropriate.

engine starter is engaged. The sizing for the rest of the components is shown in Table V-9.

The MHEV technology, which will be available from the 2011 model year, is projected to be in high volume use at the beginning of its first year of availability according to NHTSA's analysis, therefore volume based learning reductions (two cycles at 20 percent) were applied to "learn" the hybrid method costs and time based learning factors were applied throughout the remaining years. For the final rule, NHTSA established incremental costs ranging from $372 to $549 with the highest cost applying to the Performance Large Car class.

The 12V micro hybrid technology is applicable across all the vehicle segments except for the Large Truck/SUV class. Although this technology was not specifically stated in the NPRM, a phase-in cap of 3 percent for MY 2011 was assumed for hybrid technologies. For the final rule, this figure was retained since it is generally supportable within the industry as expressed at the SAE HEV Symposium in San Diego in Feb 2008.

The NPRM proposed that all of the hybrid technologies could be introduced during the redesign model year only. This view is consistent with manufacturer's views, therefore, for this rule making, NHTSA has assumed that 12V micro hybrids can only be introduced at the redesign model years.

(vi) High Voltage / Improved Alternator (HVIA)

In the NPRM, a 42V accessory technology was identified in the decision tree for Other Technologies. Several confidential manufacturer comments received by NHTSA related to 42V technology, and indicated that the effectiveness of 42V system were not realized when electrical conversion efficiencies were considered, and the cost of transitioning the industry from a 12V to 42V system made the technology unreasonable for deployment in the emerging technology time frame. As a result of these comments, NHTSA revised the technology from 42V technology to High Voltage / Improved Alternator (HVIA).

The "High Voltage/Improved Efficiency Alternator" technology block represents technologies associated with increased alternator efficiency. As most alternators in production vehicles today are optimized for cost and the process for increasing the efficiency of an alternator is well understood by the industry, this technology is applicable to all vehicle subclasses except Midsize and Large Truck and SUV where it is not considered applicable due to the high utility of these classes.

The NPRM identified fuel economy effectiveness that were based on 42V accessory systems, and are not directly applicable for this current technology definition. Confidential manufacturer data indicates that a midsized car with an improved efficiency alternator provided 0.2 to 0.9 percent fuel consumption effectiveness over the CAFE drive cycles, and a pickup truck provided 0.6 percent fuel consumption effectiveness over the same cycles. As this technology can be applied over a range of vehicles, NHTSA believes the fuel consumption effectiveness for larger vehicles will be biased downward.

For purposes of this final rule, NHTSA estimates the fuel consumption effectiveness for High Voltage/Improved Efficiency Alternator" technology at 0.2 to 0.9 percent.

The NPRM identified several sources for high voltage / improved efficiency alternators incremental costs, but focused this technology on 42V systems, thus making some of these references not representative of the current technology description. The NPRM "Engine accessory improvement" technology discussion, however, did quote the NESCCAF study that indicated a $56 cost for a high efficiency generator. An independent confidential study estimated that the incremental cost increase for a high efficiency generator at high volume was similar to the NESCCAF quoted cost, thus NHTSA concludes that the NESCCAF study cost of $56 is still a representative cost for this technology. At a 1.5 RPE value, this cost equates to $84.

As the definition of the technology has been revised from the NPRM, phase-in rates identified in the NPRM are not applicable. NHTSA believes the High voltage / Improved Efficiency Alternator technology represents an adjustment to the alternator manufacturing industry infrastructure, so for purposes of this final rule, phase-in caps for this technology were estimated at 10 percent for MY 2011.

Also, as the definition of the technology has been revised from the NPRM, learning curve assumptions from the NPRM are not applicable. The high voltage / improved alternator technology costs were based on high volume estimates, thus, for purposes of the final rule, NHTSA assumed time-based learning (3 percent YOY) for High Voltage Systems / Improved Alternator technology. For purposes of the final rule, NHTSA assumed the technology can be introduced during refresh or redesign model changes only.

(vii) Integrated Starter Generator (ISG)

The next hybrid technology that is considered is the Integrated Starter Generator (ISG) technology. There are 2 types of integrated starter generator hybrids that are considered: the belt mounted type and the crank mounted type.

A Belt Mounted Integrated Starter Generator (BISG) system is similar to a micro-hybrid system, except that here it is defined as a system with a 110 to 144V battery pack which thus can perform some regenerative braking, whereas the 12V micro-hybrid system cannot. The larger electric machine and battery enables additional hybrid functions of regenerative braking and a very limited degree of operating the engine independently of vehicle load. While having a larger electric machine and more battery capacity than a MHEV, this system has a smaller electric machine than stronger hybrid systems because of the limited torque capacity of the belt driven design.

BISG systems replace the conventional belt-driven alternator with a belt-driven, enhanced power starter-alternator and a redesigned front-end accessory drive system that facilitates bi-directional torque application utilizing a common electric machine. Also, during idle-stop, some functions such as power steering and automatic transmission hydraulic pressure are lost with conventional arrangements; so electric power steering and an auxiliary transmission pump need to be added. These components are similar to those that would be used in other hybrid designs.

A Crank Mounted Integrated Starter Generator (CISG) hybrid system, also called an Integrated Motor Assist (IMA) system, utilizes a thin axial electric motor (100-144V) bolted to the engine's crankshaft. The electric machine acts as both a motor for helping to launch the vehicle and a generator for recovering energy while slowing down. It also acts as the starter for the engine and is a higher efficiency generator. An example of this type of a system is found in the Honda Civic Hybrid. For purposes of the final rule, NHTSA assumed the electric machine is rigidly fixed to the engine crankshaft, thus making electric-only drive not practical.[204]

The fuel consumption effectiveness of the ISG systems are greater than those of micro-hybrids, because they are able to perform the additional hybrid function of regenerative braking and able to utilize the engine more efficiently because some transient power demands from the driver can be separated from the engine operation. Their transient performance can be better as well, because the larger electric machine can provide torque boost. The ISG systems are more expensive than the micro hybrids, but have lower cost than the strong hybrids described below because the electrical component sizes (batteries, electric machines, power electronics, etc.) are sized in between the micro-hybrid and the strong hybrid components. The engineering effort required to adapt conventional powertrains to these configurations is also in between that required for micro-hybrid and strong hybrid configurations. Packaging is a greater concern due to the fact that the engine-motor-transmission assembly is physically longer, and the battery pack, high voltage cabling and power electronics are larger.

The hybrid decision tree was modified to address several manufacturer comments and comments from CARB and Delphi asking for more appropriate separation of hybrid technology classifications (*i.e.*, 12V versus higher voltage Integrated Starter Generators, etc.). The inclusion of the ISG technology in the final rule is in response to these comments and those from subject matter experts.

The NPRM had proposed a fuel consumption savings of between 5 and 10 percent for ISG systems, and between 3.5 and 8.5 percent for the Honda IMA system, both of which fall in the ISG category described above. Confidential manufacturer comments submitted in response to the NPRM indicated an incremental 3.8 to 7.4 percent fuel consumption effectiveness and a $1,500 to $2,400 cost as compared to the baseline vehicle.

The incremental fuel consumption savings for the Compact Car variant for ISG over a 12V Micro-hybrid with start/stop was calculated using published data and confidential manufacturer data, while published Honda Civic Hybrid data was used to calculate the fuel consumption gains due to the hybrid system. For the final rule, gains for the other

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[204] A clutch between the engine and the electric motor would enable pure electric drive, but the Porsche Cayenne is the only example of such a system that is planned in the rulemaking time frame. Because of limited expected volumes of this type of system, and in the interest of reducing complexity, that variant is not included here.

technologies also included on this vehicle were subtracted out to give an incremental effectiveness of 5.7 to 6.5 percent for ISG. Data for these individual gains was taken from confidential manufacturer data. The 5.7 to 6.5 percent incremental fuel consumption savings was carried over from the Compact Car to all other vehicle subclasses. A 2 percent incremental effectiveness was subtracted from the Performance subclasses to allow for the improved baseline performance

The NPRM proposed a cost of $1,636 to $2,274 for these systems. For the final rule, NHTSA determined the cost for the ISG system using system sizing data for different available ISG hybrids. The 2006 Honda Civic has a Crank Mounted ISG and uses a 0.87 kW-hr battery pack. In light of the potential growth of vehicle electrification, a 1 kW-hr pack size was chosen for both the belt and crank mounted ISG systems. The crank mounted ISG was sized as 11kW continuous (15kW peak). This is an average of the 10kW system on the 2003 Honda Civic and the 12kW system on the 2005 Honda Accord. The 2006 Civic has a 15kW system. The belt mounted ISG has a slightly smaller electric machine (7.5kW continuous and 10kW peak) due to power transmission limitations of the belt.

For the final rule, the hybrid technology cost method projected costs ranging from $2,475 to $3,290 for the Sub-Compact car class through the Midsize Truck classes as compared to the conventional baseline vehicle and the incremental costs of $1,713 to $2,457 were calculated by backing out the prior hybrid technology costs. The ISG technology is projected to be in low volume use at the beginning of the rulemaking period therefore low volume costs are used and volume-based learning factors are applied.

Integrated starter generator systems are applicable to all vehicle subclasses except Large Truck. In the NPRM, a phase-in cap of 3 percent was assumed for both the "ISG with idle off" and "IMA" technologies. For the final rule, NHTSA has retained the phase-in cap of 3 percent. These values are generally supportable within the industry as expressed at the SAE HEV Symposium in San Diego in February 2008.

The NPRM proposed that all of the hybrid technologies could be introduced during the redesign model year only. This view is consistent with manufacturer's views as well, because all of the hybrid technologies under consideration require redesign of the powertrain (ranging from engine accessory drive to transmission redesign) and vehicle redesign to package the hybrid components (from high voltage cabling to the addition of large battery packs). Given this, for purposes of the final rule, they can only be introduced in redesign model years.

(viii) Power Split Hybrid

The Power Split hybrid (PSHEV) is described as a full or a strong hybrid since it has the ability to move the vehicle on electric power only. It replaces the vehicle's transmission with a single planetary gear and a motor/generator. A second, more powerful motor/generator is directly connected to the vehicle's final drive. The planetary gear splits the engine's torque between the first motor/generator and the final drive. The first motor/generator uses power from the engine to either charge the battery or supply power to the wheels. The speed of the first motor/generator determines the relative speed of the engine to the wheels. In this way, the planetary gear allows the engine to operate independently of vehicle speed, much like a CVT. The Toyota Prius and the Ford Hybrid Escape are two examples of power split hybrid vehicles.

In addition to providing the functions of idle engine stop and subsequent restart, regenerative braking, this hybrid system allows for pure EV operation. The two motor/generators are bigger and more powerful than those in an ISG hybrid, allowing the engine to be run in efficient operating zones more often. For these reasons, the power split system provides very good fuel consumption in city driving. During highway cycles, the hybrid functions of regenerative braking, engine start/stop and optimal engine operation cannot be applied as often as in city driving, and so the effectiveness in fuel consumption are less. Additionally, it is less efficient at highway speeds due to the fact that the first motor/generator must be spinning at a relatively high speed and therefore incurs losses.

The battery pack for PSHEV is assumed to be 300V NiMH for the time period considered in this rulemaking, as is used in current PSHEV systems today. Their reliability is proven (having been in hybrids for over 10 years) and their cost is lower than Li Ion, so it is likely that the battery technology used in HEVs will continue to be NiMH for the near future for hybrids that do not require high energy storage capability like a plug-in hybrid does.

The Power Split hybrid also reduces the cost of the transmission, replacing a conventional multi-speed unit with a single planetary gear. The electric components are bigger than those in an ISG configuration so the costs are correspondingly higher.

However, the Power Split system is not planned for use on full-size trucks and SUVs due to its limited ability to efficiently provide the torque needed by these vehicles. The drive torque is limited to the first motor/generator's capacity to resist the torque of the engine. It is anticipated that Large Trucks would use the 2-mode hybrid system.

In the NPRM, a phase-in rate of 3 percent was assumed for the power split technology. Although this system has been engineered for some vehicles by a couple of manufacturers, the required engineering resources both at OEMs and Tier 1 suppliers are high . and most importantly, require long product development lead times. Thus NHTSA believes it would be extremely difficult for manufacturers to implement in levels greater than that of the submitted product plans for MY 2011. For the final rule, NHTSA limited the volumes of power split hybrids to zero percent in MY 2011. Power split hybrid cost and effectiveness estimates will not be discussed here, given that the technology is not applied in MY 2011 beyond product plan levels in NHTSA's analysis, and NHTSA will consider them further in its future rulemaking actions.

The NPRM proposed that all of the hybrid technologies could be introduced during the redesign model year only, consistent with manufacturer's views. Given this, for this final rule NHTSA has retained the redesign application timing.

(ix) 2-Mode Hybrid

The 2-mode hybrid (2MHEV) is another strong hybrid system that has all-electric drive capability. The 2MHEV uses an adaptation of a conventional stepped-ratio automatic transmission by replacing some of the transmission clutches with two electric motors, which makes the transmission act like a CVT. Like the Power Split hybrid, these motors control the ratio of engine speed to vehicle speed. But unlike the Power Split system, clutches allow the motors to be bypassed, which improves both the transmission's torque capacity and efficiency for improved fuel economy at highway speeds. This type of system is used in the Chevy Tahoe Hybrid.

In addition to providing the hybrid functions of engine stop and subsequent restart and regenerative braking, the 2MHEV allows for pure EV operation. The two motor/generators are bigger and more powerful than those in an ISG hybrid, allowing the engine to be run in efficient operating zones more often. For these reasons, the 2-mode system also provides very good fuel economy in city driving. The primary motor/generator is comparable in size to that in the PSHEV system, but the secondary motor/generator is larger. The 2-mode system cost is greater than that for the power split system due to the additional transmission complexity and secondary motor sizing.

The battery pack for 2MHEV is assumed to be 300V NiMH for the time period considered in this rulemaking, as is used in current 2MHEV systems today. Their reliability is proven (having been in hybrids for over 10 years) and their cost is lower than Li Ion, so it is likely that the batteries will continue to be NiMH for the near future for hybrids that do not require high energy storage capability like a plug-in hybrid does.

Given the relatively large size of the 2 mode powertrain, this technology was assumed to be applicable to the Small through Large Truck/SUV classes. In the NPRM, a phase-in rate of 3 percent was assumed for 2 mode hybrids. The 2-modes have recently been introduced in the marketplace on a few vehicle platforms. The engineering resources that are needed both at the OEMs and Tier 1s to develop this across many more platforms are considerable, as discussed above for power split hybrids. For purposes of the final rule, the phase-in rate has been set to zero percent in MY 2011. 2 mode hybrid cost and effectiveness estimates will not be discussed here, given that the technology is not applied in MY 2011 beyond product plan levels in NHTSA's analysis, and NHTSA will consider them further in its future rulemaking actions.

The NPRM proposed that all of the hybrid technologies could be introduced during the redesign model year only, consistent with manufacturer's views. Given this, for this final rule NHTSA has retained the redesign application timing.

(x) Plug-In Hybrid

Plug-In Hybrid Electric Vehicles (PHEV) are very similar to other strong hybrid electric vehicles, but with significant functional differences. The key distinguishing feature is the ability to charge the battery pack from an outside source of electricity (usually the electric grid). A PHEV would have a larger battery pack with greater energy capacity, and an ability to be discharged further (referred to as "depth of discharge"). No major manufacturer currently has a PHEV in production, although both GM and Toyota have publicly announced that they will launch plug-in hybrids in limited volumes by 2010.

PHEVs offer a significant opportunity to displace petroleum-derived fuels with electricity from the electrical grid. The reduction in petroleum use depends on the electric-drive range capability and the vehicle usage (*i.e.*, trip distance between recharging, ambient temperature, etc.). PHEVs can have a wide variation in the All Electric Range (AER) that they offer. Some PHEVs are of the "blended" type where the engine is on during most of the vehicle operation, but the proportion of electric energy that is used to propel the vehicle is significantly higher than that used in a PSHEV or 2MHEV.

PHEVs were not projected to be in volume use in the NPRM, but due to confidential manufacturer product plans, PHEVs do, in fact, appear in limited volumes in the final rule analysis, and therefore low volume, unlearned costs are assumed. However, the manufacturer-stated production volumes of PHEVs are very low, so the phase-in cap for MY 2011 is zero—given the considerable engineering hurdles, the low availability of Li-Ion batteries in the MY 2011 time frame and the reasons discussed above for power split and 2 mode hybrids, NHTSA did not believe that PHEVs could be applied to more MY 2011 vehicles beyond what was indicated in the product plans. Additionally, plug-in hybrid cost and effectiveness estimates will not be discussed here, given that the technology is not applied in MY 2011 beyond product plan levels in NHTSA's analysis, and NHTSA will consider them further in its future rulemaking actions. The NPRM proposed that all of the hybrid technologies could be introduced during the redesign model year only, consistent with manufacturer's views. Given this, for this final rule NHTSA has allowed application of PHEVs in redesign model years only.

(e) Vehicle Technologies

(i) Material Substitution (MS1, MS2, MS5)

The term "material substitution" encompasses a variety of techniques with a variety of costs and lead times. These techniques may include using lighter-weight and/or higher-strength materials, redesigning components, and size matching of components. Lighter-weight materials involve using lower-density materials in vehicle components, such as replacing steel parts with aluminum or plastic. The use of higher-strength materials involves the substitution of one material for another that possesses higher strength and less weight. An example would be using high strength alloy steel versus cold rolled steel. Component redesign is an ongoing process to reduce costs and/or weight of components, while improving performance and reliability. The Aluminum Association commented that lightweight structures are a significant enabler for the new powertrain technologies. Smaller and less expensive powertrains are required and the combination of reduced power and weight reduction positively reinforce and result in optimal fuel economy performance. An example would be a subsystem replacing multiple components and mounting hardware.

However, the cost of reducing weight is difficult to determine and depends upon the methods used. For example, a change in design that reduces weight on a new model may or may not save money. On the other hand, material substitution can result in an increase in price per application of the technology if more expensive materials are used. As discussed further below, for purposes of this final rule, NHTSA has considered only vehicles weighing greater than 5,000 lbs (curb weight) for weight reduction through materials substitution. A typical BOM for Material Substitution would include primarily substitution of high strength steels for heavier steels or other structural, materials on a vehicle. This BOM was established for each class but was not adjusted for each class due to the fact that the vehicle technology of Material Substitution is already scaled by it being based on percent of curb weight at or over 5,000 lbs.

In the NPRM, NHTSA estimated fuel economy effectiveness of a 2 percent incremental reduction in fuel consumption per each 3 percent reduction in vehicle weight. Nissan commented that NHTSA's modeling of material substitution application was overly optimistic, but did not elaborate further. Confidential manufacturer comments in response to the NPRM did not provide standardized effectiveness estimates, but ranged from 3.3 to 3.9 percent mpg improvement for a 10 percent reduction in mass, to 0.20 to 0.75 percent per 1 percent weight reduction, to 1 percent reduction on the FTP city cycle per 100 lbs reduced, with a maximum possible weight reduction of 5 percent.

Bearing in mind that NHTSA only assumes material substitution for vehicles at or above 5,000 lbs curb weight and based on manufacturer comments which together suggest an incremental improvement in fuel consumption of approximately 0.60 percent to 0.9 percent per 3 percent reduction in material weight, NHTSA has estimated an incremental improvement in fuel consumption of 1 percent (corresponding to a 3 percent reduction in vehicle weight, or roughly 0.35 percent fuel consumption per 1 percent reduction in vehicle weight). This estimate is consistent with the majority of the manufacturer comments.

As for costs, in the NPRM NHTSA estimated incremental costs of $0.75 to $1.25 per pound reduced through material substitution. The costs for material substitution were not clearly commented on in the confidential manufacturer responses. Confidential manufacturer estimates ranged from $50 to $511 for 1 percent reduction, although in most cases the cost estimates were not for the entire range of substitution (1-5 percent) and did not provide any additional clarification on how they specifically applied to the material substitution technology. Consequently, for purposes of the final rule NHTSA retained the existing NPRM cost estimates with adjustments to 2007 dollar levels resulting in an incremental $1 to $2 per pound of substituted material, which applies to the MS1 and MS2 technology, and $2 to $4 per pound for the MS5 technology. Costs for material substitution are not adjusted by vehicle subclass, as the technology costs are based on a percentage of the vehicle weight (per pound) and limited to Medium and Large Truck/SUV Van subclasses above 5,000 lbs curb weight.

The agency notes that comments from the Alliance and the Aluminum Association associated engine downsizing with weight reduction/material substitution and quoted effectiveness for this action as well. NHTSA considers engine downsizing separately from typical material substitution efforts, and consequently did not include those cost and fuel economy effectiveness for this technology.

In the NPRM, NHTSA assumed a 17 percent phase-in rate for material substitution. NHTSA received only one confidential manufacturer comment regarding material substitution phase-in percentage, suggesting 17 to 30 percent, but the agency notes that it generally received comments suggesting a non-linear phase-in rate for this technology, that would start at a rate lower than the current NPRM value and increase over time. In response to these comments, NHTSA revised the MY 2011 phase-in percentage to 5 percent to account for lead time limitations.

For material substitution technologies, neither volume-based cost reductions nor time-based cost reductions are applied. This technology does not employ a particular list of components to employ credible cost reduction.

In the NPRM, NHTSA assumed that material substitution (1 percent) could be applied during a redesign model year only. For this final rule, based on confidential manufacturer comments, NHTSA estimated that material substitution (1 percent) could be applied during either a refresh or a redesign model year, due to minimal design changes with minimal component or vehicle-level testing required. However, NHTSA retained the assumption that material substitution (2 percent and 5 percent) could be applied during redesign model year only, as in the NPRM, because the agency neither received comments to contradict this assumption nor found other data to substantiate a change. The technology title was changed from Material Substitution (3 percent) to Material Substitution (5 percent) to more accurately represent the cumulative amount for the technology.

(ii) Low Drag Brakes (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 rotor. A typical BOM for Low Drag Brakes would typically include changes in brake caliper speed by changing the brake control system, springs, etc. on a vehicles brake system. This BOM was established for each class and was not adjusted for each class due to the fact that the vehicle technology BOM would not change by class across vehicle classes. Confidential manufacturer comments in response to the NPRM indicated that most passenger cars have already adopted this technology, but that ladder frame trucks have not yet adopted this technology. Consequently, in the final rule this technology was assumed to be applicable only to the Large Performance Passenger Car and Medium and Large Truck classes.

In the NPRM, NHTSA assumed an incremental improvement in fuel consumption of 1 to 2 percent for low drag brakes. Confidential manufacturer comments submitted in response to the NPRM indicated an effective range of 0.5-1.0 percent for this technology and this range was applied in the final rule. As for costs, NHTSA assumed in the NPRM incremental costs of $85 to $90 for the addition of low drag brakes. For the final rule, NHTSA took the average and adjusted it to 2007 dollars to establish an $89 final rule cost.

The NPRM assumed an annual average phase-in rate for low drag brakes of 25 percent. For the final rule, the phase-in cap is 20 percent. No learning curve was applied in the NPRM but for the final rule, low drag brakes were considered a high volume, mature and stable technology, and thus time-based learning was applied. Low drag brakes are assumed in the final rule to be applicable at refresh cycle only.

(iii) Low Rolling Resistance Tires (ROLL)

Tire rolling resistance is the frictional loss associated mainly with the energy dissipated in the deformation of the tires under load – and thus, influence fuel economy. Other tire design characteristics (*e.g.*, materials, construction, and tread design) influence durability, traction control (both wet and dry grip), vehicle handling, and ride comfort in addition to rolling resistance. A typical low rolling resistance tires BOM would include: tire inflation pressure, material change, and constructions with less hysteresis, geometry changes (*e.g.*, reduced aspect ratios), reduction in sidewall and tread deflection, potential spring and shock tuning. Low rolling resistance tires are applicable to all classes of vehicles, except for ladder frame light trucks and performance vehicles. NHTSA assumed that this technology should not be applied to vehicles in the Large truck class due to the increased traction and handling requirements for off-road and braking performance at payload and towing limits which cannot be met with low resistance tire designs. Likewise, this technology was not applied to vehicles in the Performance Car classes due to increased traction requirements for braking and handling which cannot be met with low roll resistance tire designs. Confidential manufacturer comments received regarding applicability of this technology to particular vehicle classes confirmed NHTSA's assumption.

In the NPRM, NHTSA assumed an incremental reduction in fuel consumption of 1 to 2 percent for application of low rolling resistance tires. Confidential manufacturer comments varied widely and addressed the conflicting objectives of increasing safety by increasing rolling resistance for better tire traction, and improving fuel economy with lower rolling resistance tires that provide reduced traction. Confidential manufacturer comments suggested fuel consumption effectiveness of negative impact to a positive 0.1 percent per year over the next five years from 2008, while other confidential manufacturer comments indicate that the percentage effectiveness of low rolling resistance tires would increase each year, although it would apply differently for performance classes. Confidential manufacturer comments also indicated that some manufacturers have already applied this technology and consequently would receive no further effectiveness from this technology. The 2002 NAS Report indicated that an assumed 10 percent rolling resistance reduction would provide an increase in fuel economy of 1 to 2 percent. NHTSA believes the NAS effectiveness is still valid and used 1 to 2 percent incremental reduction in fuel consumption for application of low rolling resistance tires in the final rule.

NHTSA estimated the incremental cost of four low rolling resistance tires to be $6 per vehicle in the NPRM, independent of vehicle class, although not applicable to large trucks. NHTSA received few specific comments on the costs of applying low rolling resistance tires however confidential manufacturer comments that were received provided widely ranging and higher costs. NHTSA increased the range from the NPRM cost estimates to $6 to $9 per vehicle in the final rule.

In the NPRM, NHTSA assumed an annual phase-in rate of 25 percent for low rolling resistance tires. Confidential manufacturer comments on the phase-in rate for low rolling resistance tires varied, with some suggesting that many vehicle classes already had high phase-in rates planned or accomplished. As discussed above, the comments also suggested a non-linear phase-in plan over the 5-year period. Confidential manufacturer data was in the 25-30 percent range. Based on confidential manufacturer comments received and NHTSA's analysis, the final rule includes a phase-in cap for low rolling resistance tires with a phase-in rate of 20 percent for MY 2011.

For low rolling resistant tire technology, neither volume-based cost reductions nor time-based cost reductions are applied. This technology is presumed to be significantly dependent on commodity raw material prices and to be priced independent of particular design or manufacturing savings.

In the NPRM, NHTSA assumed that low rolling resistance tires could be applied during any model year. However, based on confidential manufacturer comments NHTSA recognizes that there are some vehicle attribute impacts which may result from application of low rolling resistance tires, such as changes to vehicle dynamics and braking. Vehicle validation testing for safety and vehicle attribute prove-out is not usually planned for every model year, so NHTSA assumed that this technology can be applied during a redesign or refresh model year for purposes of the final rule.

(iv) Front or Secondary Axle Disconnect for Four-Wheel Drive Systems (SAX)

To provide shift-on-the-fly capabilities, reduce wear and tear on secondary axles, and improve performance and fuel economy, many part-time four-wheel drive (4WD) systems use some type of axle disconnect. Axle disconnects are typically used on 4WD vehicles with two-wheel drive (2WD) operating modes. When shifting from 2WD to 4WD "on the fly" (while moving), the front axle disconnect couples the front driveshaft to the front differential side gear only when the transfer case's synchronizing mechanism has spun the front driveshaft, transfer case chain or gear set and differential carrier up to the same speed as the rear driveshaft. 4WD systems that have axle disconnect typically do not have either manual- or automatic-locking hubs. For example, 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. The effectiveness to fuel efficiency is created by reducing inertial, chain, bearing and gear losses (parasitic losses).

Full time 4WD or all-wheel-drive (AWD) systems used for on-road performance and safety do not use axle disconnect systems due to the need for instantaneous activation of torque to wheels, and the agency is not aware of any manufacturer or suppliers who are developing a system to allow secondary axle disconnect suitable for use on AWD systems at this time. Secondary axle disconnect technology is primarily found on solid axle 4WD systems and not on the transaxle and/or independent axle systems typically found in AWD vehicles; thus, the application of this technology to AWD systems has not been considered for purposes of this rulemaking. The technology will be evaluated in future rulemakings.

Vehicle technology BOM information was not adjusted by vehicle classes due to the fact that the vehicle technology is limited to transfer case and front axle design changes. Scaling of components might be impacted but the components themselves will be the same. This is consistent with NHTSA's assumptions in the NPRM, and is supported by comments from confidential supplier and manufacturers. Secondary Axle Disconnect BOM typically involves a transfer case which includes electronic solenoid with clutch system to disconnect front drive and using axle mounted vacuum or electric disconnect that still allows driveshaft rotation without connection to wheel ends.

In the NPRM, NHTSA employed "unibody" and "ladder frame" terms to differentiate application of this technology, and had suggested "unibody" AWD systems could apply this same technology. In actuality, most 4WD vehicles are "ladder frame" technology and AWD are "unibody" designs (which for the reasons stated above will not be considered for this technology). Ladder frame technology is typically associated with greater payload, towing, and off-road capability, whereas unibody designs are typically used in smaller, usually front-wheel drive vehicles, and are typically not associated with higher payload, towing, and off-road use. For the final rule, NHTSA removed these vehicle design criteria since it is not a requirement to incorporate axle disconnect technology, only a historical design point and vehicle manufacturers should not be limited to a specific vehicle or chassis configuration to apply this technology. Therefore, this technology is applicable to 4WD vehicles in all vehicle classes (independent of chassis or frame design).

In the NPRM, NHTSA estimated an incremental reduction in fuel consumption of 1 to 1.5 percent for axle disconnect. Confidential manufacturer comments suggested an incremental effectiveness of 1 to 1.5 percent. Supported by this confidential manufacturer data, NHTSA maintained an incremental effectiveness of 1 to 1.5 percent for axle disconnect for the final rule.

As for costs, the NPRM estimated the incremental cost for adding axle disconnect technology at $114 for 4WD systems and the $676 estimate was for the AWD systems which are not applied in the final rule. NHTSA received no specific comments on costs for this technology and found no additional sources to support a change from this value for the 4WD value of $114, so for purposes of the final rule, NHTSA revised the $114 figure to 2007 dollars to establish a $117 final rule cost.

In the NPRM, NHTSA assumed a phase-in cap of 17 percent for secondary axle disconnect for each model year covered by the rulemaking. No specific comments were received regarding the phase-in rate for this technology, but as discussed above, manufacturers generally argued for a non-linear phase-in plan over the 5-year period covered by the rulemaking. Based on general comments received and NHTSA's analysis, the final rule includes an average annual phase-in rate for secondary axle disconnect of 17 percent for MY 2011.

In the NPRM, NHTSA assumed a volume-based learning curve factor of 20 percent for secondary axle disconnect. For the final rule, secondary axle disconnect learning was established as time-based due to confidential manufacturer data demonstrating that this is a mature technology, such that additional volumes will provide no additional advantage for incorporation by manufacturers.

In the NPRM, NHTSA assumed that secondary axle disconnect could be applied to a vehicle either during refresh or redesign model years. NHTSA received no comments and found no sources to disagree with this assumption, and since testing to validate the functional requirements and vehicle attribute prove-out testing is usually not planned for every model year, NHTSA has retained this assumption for the final rule.

(v) Aerodynamic Drag Reduction (AERO)

Several factors affect a vehicle's aerodynamic drag and the resulting power required to move it through the air. While these values change with air density and the square and cube of vehicle speed, respectively, the overall drag effect is determined by the product of its frontal area and drag coefficient. Reductions in these quantities can therefore reduce fuel consumption. While 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 fleet aerodynamic drag reductions may require incorporation into a manufacturer's new model phase-in schedules depending on the mix of vehicle classes distributed across the manufacturer's lineup. However, shorter-term aerodynamic reductions, with less of a fuel economy 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 in general circulation today. 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 more efficient exterior mirrors.

Vehicle technology BOM information was not adjusted by vehicle classes due to the fact that Aero Drag Reductions are already scaled based on percent overall vehicle coefficient of drag CdA. Aero Drag Reduction BOM could include (but would not be limited to) the following components or subsystems: underbody covers, front lower air dams, overall front fascia changes, headlights, hood, fenders, grill, windshield angle, A-Pillar angle, door seal gaps, roof (which would both be high impact and very high cost), side view mirrors, door handles (low impact), ride height, rear deck lip, wheels, wheel covers, and optimizing the cooling flow path.

In the NPRM, NHTSA estimated an incremental aerodynamic drag reduction of 20 percent for cars, and 10 percent for trucks. Confidential manufacturer comments received indicated that the 20 percent reduction for cars in the NPRM may have been overly optimistic, as significant changes in aero drag have already been applied to those vehicle classes. However, confidential manufacturer comments agreed with the 10 percent aerodynamic drag reduction for trucks, since there are still significant opportunities to improve aero drag in trucks designed for truck-related utility. The Sierra Research study submitted by the Alliance concluded that a 10 percent incremental aerodynamic drag reduction for mid-size cars gives a 1.5 percent improvement in vehicle fuel economy. Thus, for purposes of the final rule, NHTSA has estimated that a fleet average of 10 percent total aerodynamic drag reduction is attainable (with a caveat for "high-performance" vehicles described below), which equates to incremental reductions in fuel consumption of 2 percent and 3 percent for cars and trucks, respectively. These numbers are in agreement with publicly-available technical literature[205] and are supported by confidential manufacturer information. Performance car classes are excluded from this technology improvement because they have largely applied this technology already.

As for costs, in the NPRM NHTSA assumed an incremental cost of $0 to $75 for aero drag reduction on both cars and trucks. After reviewing the 2008 Martec Report, however, NHTSA concluded that a lower-bound cost of $0 was not supportable. NHTSA replaced the lower-bound cost with $40 (non-RPE) based on the assumptions that the underbody cover and acoustic covers described in the Martec report approximates the cost for one large underbody cover as might be required for minimal aero drag reduction actions.[206] The upper limit was determined by updating the NPRM upper cost to 2007 dollars and applying an RPE uplift thereby establishing the incremental cost, independent of vehicle class, to range from $60 to $116 (RPE) for the final rule

In the NPRM, NHTSA assumed a 17 percent phase-in rate for aero drag reduction for each model year covered by the rulemaking. No specific comments were received regarding the phase-in rate for this technology, but as discussed above, manufacturers generally argued for a non-linear phase-in plan over a 5-year period. Based on comments received and NHTSA's analysis, the final rule includes an phase-in rate for aero drag reduction of 17 percent in MY 2011. Neither volume-based cost reductions nor time-based cost reductions are applied. In the NPRM, NHTSA assumed that aero drag reduction could be applied in either a refresh or a redesign model year and that assumption has been retained for the final rule.

(f) Technologies considered but not included in the final rule analysis

Although discussed and considered as potentially viable in the NPRM, NHTSA has determined that three technologies will be unavailable in the time frame considered. These technologies have been identified as either pre-emerging or not technologically feasible. Pre-emerging technologies are those that are still in the research phase at this time, and which are not expected to be under development for production vehicles for

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[205] Sue Elliott-Sink, "Improving Aerodynamics to Boost Fuel Economy," May 2, 2006. *Available at* http://www.edmunds.com/advice/fueleconomy/articles/106954/article.html (last accessed Oct. 5, 2008).

[198] 2008 Martec Report, at 25. NHTSA also assumed that the cost of fuel pulsation dampening technology noted in the Martec report grouped with the underbody cover and acoustic covers does not significantly impact the $40 cost as fuel pulsation dampening technology is very low in cost relative to the other actions. Therefore NHTSA did not modify the $40 estimate.

several years. In another case, the technology depends on a fuel that is not readily available. Thus, for the reasons discussed below, these technologies were not considered in NHTSA's analysis for the final rule. The technologies are camless valve actuation (CVA), lean burn gasoline direct injection (LBDI), homogeneous charge compression ignition (HCCI), and electric assist turbocharging. Although not applied in this rulemaking, NHTSA will continue to monitor the industry and system suppliers for progress on these technologies, and should they become available, consider them for use in any future rulemaking activity.

(i) Camless Valve Actuation

Camless valve actuation relies on electromechanical actuators instead of camshafts to open and close the cylinder valves. When electromechanical actuators are used to replace cams and coupled with sensors and microprocessor controls, valve timing and lift can be optimized over all conditions. An engine valvetrain that operates independently of any mechanical means provides the ultimate in flexibility for intake and exhaust timing and lift optimization. With it comes infinite valve overlap variability, the rapid response required to change between operating modes (such as HCCI and GDI), intake valve throttling, cylinder deactivation, and elimination of the camshafts (reduced friction). This level of control can enable even further incremental reductions in fuel consumption.

As noted in the NPRM, this technology has been under research for many decades and although some progress is being made, NHTSA has found no evidence to support that the technology can be successfully implemented, costed, or have defined fuel consumption effectiveness at this time.

(ii) Lean-Burn Gasoline Direct Injection Technology

One way to improve an engine's thermodynamic efficiency dramatically is by operating at a lean air-fuel mixture (excess air). 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 NO_x after-treatment, lean-burn GDI engines may eventually be a possibility in North America.

However, as noted in the NPRM, a key technical requirement for lean-burn GDI engines to meet EPA's Tier 2 NO_x emissions levels is the availability of low-sulfur gasoline, which is projected to be unavailable during the time frame considered. Therefore the technology was not applied in the final rule

(iii) Homogeneous Charge Compression Ignition

Homogeneous charge compression ignition (HCCI), also referred to as controlled auto ignition (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 ignition. The resulting burn is much shorter in duration with higher thermal efficiency. Shorter combustion times and higher EGR tolerance permit very high compression ratios (which also increase thermodynamic efficiency), and additionally, pumping losses are reduced because the engine can run unthrottled.

NHTSA noted in the NPRM that several manufacturers had made public statements about the viability of incorporating HCCI into production vehicles over the next 10 years. Upon further review of confidential product plan information, and reviewing comments received in response to the NPRM, NHTSA has determined the technology will not be available within the time frame considered. Consequently, the technology was not applied in the final rule.

(iv) Electric Assist Turbocharging

The Alliance commented that global development of electric assist turbocharging 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 application over the next decade.[207] While hybrid vehicles lower the incremental hardware requirements for higher-voltage, higher-power EAT systems, NHTSA believes that significant development work is required to demonstrate effective systems and that implementation in significant volumes will not occur in the time frame considered. Thus, this technology was not included on the decision trees.

E. Cost and effectiveness tables

The tables representing the Volpe model input files for 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.

[207] NHTSA-2008-0089-0169.1, at 41.

Table V-15. Technology Incremental Cost Estimates, Passenger Cars

VEHICLE TECHNOLOGY RETAIL PRICE EQUIVALENT INCREMENTAL COSTS PER VEHICLE ($) BY VEHICLE TECHNICAL CLASS - PASSENGER CARS					
		Subcompac Car	Compact Car	Midsize Car	Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	Inline 4	Inline 4	V6
Low Friction Lubricants	LUB	5	5	5	5
Engine Friction Reduction	EFR	52 - 196	52 - 196	52 - 196	78 - 294
VVT - Coupled Cam Phasing (CCP) on SOHC	CCPS	61	61	61	122
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	201	201	201	306
Cylinder Deactivation on SOHC	DEACS	n.a.	n.a.	n.a.	75
VVT - Intake Cam Phasing (ICP)	ICP	61	61	61	122
VVT - Dual Cam Phasing (DCP)	DCP	61	61	61	122
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	201	201	201	306
Continuously Variable Valve Lift (CVVL)	CVVL	306	306	306	432
Cylinder Deactivation on DOHC	DEACD	n.a.	n.a.	n.a.	75
Cylinder Deactivation on OHV	DEACO	n.a.	n.a.	n.a.	306
VVT - Coupled Cam Phasing (CCP) on OHV	CCPO	61	61	61	122
Discrete Variable Valve Lift (DVVL) on OHV	DVVLO	201	201	201	76
Conversion to DOHC with DCP	CDOHC	373	373	373	590
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	293 - 440	293 - 440	293 - 440	384 - 558
Turbocharging and Downsizing	TRBDS	1223	1223	1223	822
Conversion to Diesel following CBRST	DSLC	2,963 - 3,254	2,963 - 3,254	2,963 - 3,254	4,105 - 4,490
Conversion to Diesel following TRBDS	DSLT	1,567 - 1,858	1,567 - 1,858	1,567 - 1,858	3,110 - 3,495
Electric Power Steering	EPS	105 - 120	105 - 120	105 - 120	105 - 120
Improved Accessories	IACC	173 - 211	173 - 211	173 - 211	173 - 211
12V Micro-Hybrid	MHEV	372	408	453	490
Higher Voltage/Improved Alternator	HVIA	84	84	84	84
Integrated Starter Generator (Belt/Crank)	ISG	1713	2019	2190	2386
6-Speed Manual/Improved Internals	6MAN	338	338	338	338
Improved Auto. Trans. Controls/Externals	IATC	59	59	59	59
Continuously Variable Transmission	CVT	300	300	300	300
6/7/8-Speed Auto. Trans with Improved Internals	NAUTO	323	323	323	323
Dual Clutch or Automated Manual Transmission	DCTAM	68	68	218	218
Material Substitution (1%)	MS1	n.a.	n.a.	n.a.	n.a.
Material Substitution (2%)	MS2	n.a.	n.a.	n.a.	n.a.
Material Substitution (5%)	MS5	n.a.	n.a.	n.a.	n.a.
Low Rolling Resistance Tires	ROLL	6 - 9	6 - 9	6 - 9	6 - 9
Low Drag Brakes	LDB	n.a.	n.a.	n.a.	n.a.
Secondary Axle Disconnect	SAX	117	117	117	117
Aero Drag Reduction	AERO	60 - 116	60 - 116	60 - 116	60 - 116

Table V-16. Technology Incremental Cost Estimates, Performance Passenger Cars

VEHICLE TECHNOLOGY RETAIL PRICE EQUIVALENT INCREMENTAL COSTS PER VEHICLE ($) BY VEHICLE TECHNICAL CLASS - PERFORMANCE CARS					
		Perform. Subcomp. Car	Perform. Compact Car	Perform. Midsize Car	Perform. Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Low Friction Lubricants	LUB	5	5	5	5
Engine Friction Reduction	EFR	52 - 196	78 - 294	78 - 294	104 - 392
VVT - Coupled Cam Phasing (CCP) on SOHC	CCPS	61	122	122	122
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	201	306	306	396
Cylinder Deactivation on SOHC	DEACS	n.a.	75	75	75
VVT - Intake Cam Phasing (ICP)	ICP	61	122	122	122
VVT - Dual Cam Phasing (DCP)	DCP	61	122	122	122
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	201	306	306	396
Continuously Variable Valve Lift (CVVL)	CVVL	306	432	432	582
Cylinder Deactivation on DOHC	DEACD	n.a.	75	75	75
Cylinder Deactivation on OHV	DEACO	n.a.	306	306	400
VVT - Coupled Cam Phasing (CCP) on OHV	CCPO	61	122	122	122
Discrete Variable Valve Lift (DVVL) on OHV	DVVLO	201	76	76	76
Conversion to DOHC with DCP	CDOHC	373	590	590	746
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	293 - 440	384 - 558	384 - 558	512 - 744
Turbocharging and Downsizing	TRBDS	1,223	822	822	1,229
Conversion to Diesel following CBRST	DSLC	2,963 - 3,254	4,105 - 4,490	4,105 - 4,490	5,125 - 5,617
Conversion to Diesel following TRBDS	DSLT	1,567 - 1,858	3,110 - 3,495	3,110 - 3,495	3,723 - 4,215
Electric Power Steering	EPS	105 - 120	105 - 120	105 - 120	105 - 120
Improved Accessories	IACC	173 - 211	173 - 211	173 - 211	173 - 211
12V Micro-Hybrid	MHEV	406	443	494	549
Higher Voltage/Improved Alternator	HVIA	84	84	84	84
Integrated Starter Generator (Belt/Crank)	ISG	1,789 - 1,864	2,054	2,183	2,351
6-Speed Manual/Improved Internals	6MAN	338	338	338	338
Improved Auto. Trans. Controls/Externals	IATC	59	59	59	59
Continuously Variable Transmission	CVT	300	300	300	n.a.
6/7/8-Speed Auto. Trans with Improved Internals	NAUTO	323 - 638	323 - 638	323 - 638	323 - 638
Dual Clutch or Automated Manual Transmission	DCTAM	(97) - 218	(97) - 218	(97) - 218	(97) - 218
Material Substitution (1%)	MS1	n.a.	n.a.	n.a.	n.a.
Material Substitution (2%)	MS2	n.a.	n.a.	n.a.	n.a.
Material Substitution (5%)	MS5	n.a.	n.a.	n.a.	n.a.
Low Rolling Resistance Tires	ROLL	n.a.	n.a.	n.a.	n.a.
Low Drag Brakes	LDB	n.a.	n.a.	n.a.	n.a.
Secondary Axle Disconnect	SAX	117	117	117	117
Aero Drag Reduction	AERO	60 - 116	60 - 116	60 - 116	60 - 116

Table V-17. Technology Incremental Cost Estimates, Light Trucks

VEHICLE TECHNOLOGY RETAIL PRICE EQUIVALENT INCREMENTAL COSTS PER VEHICLE ($) BY VEHICLE TECHNICAL CLASS - LIGHT TRUCKS					
		Minivan LT	Small LT	Midsize LT	Large LT
Nominal Baseline Engine (For Cost Basis)		V6	Inline 4	V6	V8
Low Friction Lubricants	LUB	5	5	5	5
Engine Friction Reduction	EFR	78 - 294	52 - 196	78 - 294	104 - 392
VVT - Coupled Cam Phasing (CCP) on SOHC	CCPS	122	61	122	122
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	306	201	306	396
Cylinder Deactivation on SOHC	DEACS	75	n.a.	75	75
VVT - Intake Cam Phasing (ICP)	ICP	122	61	122	122
VVT - Dual Cam Phasing (DCP)	DCP	122	61	122	122
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	306	201	306	396
Continuously Variable Valve Lift (CVVL)	CVVL	432	306	432	582
Cylinder Deactivation on DOHC	DEACD	75	n.a.	75	75
Cylinder Deactivation on OHV	DEACO	306	n.a.	306	400
VVT - Coupled Cam Phasing (CCP) on OHV	CCPO	122	61	122	122
Discrete Variable Valve Lift (DVVL) on OHV	DVVLO	76	201	76	76
Conversion to DOHC with DCP	CDOHC	590	373	590	746
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	384 - 558	293 - 440	384 - 558	512 - 744
Turbocharging and Downsizing	TRBDS	822	1223	822	1229
Conversion to Diesel following CBRST	DSLC	4,105 - 4,490	2,963 - 3,254	4,105 - 4,490	5,125 - 5,617
Conversion to Diesel following TRBDS	DSLT	3,110 - 3,495	1,567 - 1,858	3,110 - 3,495	3,723 - 4,215
Electric Power Steering	EPS	105 - 120	105 - 120	105 - 120	n.a.
Improved Accessories	IACC	173 - 211	173 - 211	n.a.	n.a.
12V Micro-Hybrid	MHEV	490	427	502	n.a.
Higher Voltage/Improved Alternator	HVIA	84	84	84	n.a.
Integrated Starter Generator (Belt/Crank)	ISG	2386	2029	2457	n.a.
6-Speed Manual/Improved Internals	6MAN	338	338	338	338
Improved Auto. Trans. Controls/Externals	IATC	59	59	59	59
Continuously Variable Transmission	CVT	300	300	n.a.	n.a.
6/7/8-Speed Auto. Trans with Improved Internals	NAUTO	323	323 - 638	323 - 638	323 - 638
Dual Clutch or Automated Manual Transmission	DCTAM	218	(97) - 218	(97) - 218	(97) - 218
Material Substitution (1%)	MS1	n.a.	n.a.	1 - 2	1 - 2
Material Substitution (2%)	MS2	n.a.	n.a.	1 - 2	1 - 2
Material Substitution (5%)	MS5	n.a.	n.a.	2 - 4	2 - 4
Low Rolling Resistance Tires	ROLL	6 - 9	6 - 9	6 - 9	n.a.
Low Drag Brakes	LDB	n.a.	n.a.	89	89
Secondary Axle Disconnect	SAX	117	117	117	117
Aero Drag Reduction	AERO	60 - 116	60 - 116	60 - 116	60 - 116

The tables representing the Volpe 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-18. Technology Incremental Effectiveness Estimates, Passenger Cars

VEHICLE TECHNOLOGY INCREMENTAL FUEL CONSUMPTION REDUCTION (-%) BY VEHICLE TECHNOLOGY CLASS - 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	LUB	0.5	0.5	0.5	0.5
Engine Friction Reduction	EFR	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
VVT - Coupled Cam Phasing (CCP) on SOHC	CCPS	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0
Cylinder Deactivation on SOHC	DEACS	n.a.	n.a.	n.a.	2.5 - 3.0
VVT - Intake Cam Phasing (ICP)	ICP	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
VVT - Dual Cam Phasing (DCP)	DCP	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0
Continuously Variable Valve Lift (CVVL)	CVVL	1.5 - 3.5	1.5 - 3.5	1.5 - 3.5	1.5 - 3.5
Cylinder Deactivation on DOHC	DEACD	n.a.	n.a.	n.a.	0 - 0.5
Cylinder Deactivation on OHV	DEACO	n.a.	n.a.	n.a.	3.9 - 5.5
VVT - Coupled Cam Phasing (CCP) on OHV	CCPO	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5
Discrete Variable Valve Lift (DVVL) on OHV	DVVLO	0.5 - 2.6	0.5 - 2.6	0.5 - 2.6	0.5 - 2.6
Conversion to DOHC with DCP	CDOHC	1.0 - 2.6	1.0 - 2.6	1.0 - 2.6	1.0 - 2.6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	1.9 - 2.9	1.9 - 2.9	1.9 - 2.9	1.9 - 2.9
Turbocharging and Downsizing	TRBDS	4.5 - 5.2	4.5 - 5.2	4.5 - 5.2	2.1 - 2.2
Conversion to Diesel following CBRST	DSLC	15.0 - 15.3	15.0 - 15.3	13.8 - 14.2	11.1 - 12.0
Conversion to Diesel following TRBDS	DSLT	6.6 - 7.7	6.6 - 7.7	5.3 - 6.5	5.3 - 6.5
Electric Power Steering	EPS	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
Improved Accessories	IACC	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
12V Micro-Hybrid	MHEV	1.0 - 2.9	1.0 - 2.9	3.4 - 4.0	3.4 - 4.0
Higher Voltage/Improved Alternator	HVIA	0.2 - 0.9	0.2 - 0.9	0.2 - 0.6	0.2 - 0.6
Integrated Starter Generator (Belt/Crank)	ISG	5.7 - 6.5	5.7 - 6.5	5.7 - 6.5	5.7 - 6.5
6-Speed Manual/Improved Internals	6MAN	1	1	1	1
Improved Auto. Trans. Controls/Externals	IATC	1.5 - 2.5	1.5 - 2.5	1.5 - 2.5	1.5 - 2.5
Continuously Variable Transmission	CVT	0.7 - 2.0	0.7 - 2.0	0.7 - 2.0	0.7 - 2.0
6/7/8-Speed Auto. Trans with Improved Internals	NAUTO	1.4 - 3.4	1.4 - 3.4	1.4 - 3.4	1.4 - 3.4
Dual Clutch or Automated Manual Transmission	DCTAM	5.5 - 7.5	5.5 - 7.5	2.7 - 4.1	2.7 - 4.1
Material Substitution (1%)	MS1	n.a.	n.a.	n.a.	n.a.
Material Substitution (2%)	MS2	n.a.	n.a.	n.a.	n.a.
Material Substitution (5%)	MS5	n.a.	n.a.	n.a.	n.a.
Low Rolling Resistance Tires	ROLL	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
Low Drag Brakes	LDB	n.a.	n.a.	n.a.	n.a.
Secondary Axle Disconnect	SAX	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5
Aero Drag Reduction	AERO	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0

Table V-19. Technology Incremental Effectiveness Estimates, Performance Cars

VEHICLE TECHNOLOGY INCREMENTAL FUEL CONSUMPTION REDUCTION (-%) BY VEHICLE TECHNOLOGY CLASS - PERFORMANCE CARS					
		Perform. Subcomp. Car	Perform. Compact Car	Perform. Midsize Car	Perform. Large Car
Nominal Baseline Engine (For Cost Basis)		Inline 4	V6	V6	V8
Low Friction Lubricants	LUB	0.5	0.5	0.5	0.5
Engine Friction Reduction	EFR	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
VVT - Coupled Cam Phasing (CCP) on SOHC	CCPS	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0
Cylinder Deactivation on SOHC	DEACS	n.a.	2.5 - 3.0	2.5 - 3.0	2.5 - 3.0
VVT - Intake Cam Phasing (ICP)	ICP	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
VVT - Dual Cam Phasing (DCP)	DCP	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0
Continuously Variable Valve Lift (CVVL)	CVVL	1.5 - 3.5	1.5 - 3.5	1.5 - 3.5	1.5 - 3.5
Cylinder Deactivation on DOHC	DEACD	n.a.	0 - 0.5	0 - 0.5	0 - 0.5
Cylinder Deactivation on OHV	DEACO	n.a.	3.9 - 5.5	3.9 - 5.5	3.9 - 5.5
VVT - Coupled Cam Phasing (CCP) on OHV	CCPO	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5
Discrete Variable Valve Lift (DVVL) on OHV	DVVLO	0.5 - 2.6	0.5 - 2.6	0.5 - 2.6	0.5 - 2.6
Conversion to DOHC with DCP	CDOHC	1.0 - 2.6	1.0 - 2.6	1.0 - 2.6	1.0 - 2.6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	1.9 - 2.9	1.9 - 2.9	1.9 - 2.9	1.9 - 2.9
Turbocharging and Downsizing	TRBDS	4.5 - 5.2	2.1 - 2.2	2.1 - 2.2	2.1 - 2.2
Conversion to Diesel following CBRST	DSLC	15.0 - 15.3	12.3 - 13.1	11.1 - 12.0	11.1 - 12.0
Conversion to Diesel following TRBDS	DSLT	6.6 - 7.7	6.6 - 7.7	5.3 - 6.5	5.3 - 6.5
Electric Power Steering	EPS	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
Improved Accessories	IACC	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
12V Micro-Hybrid	MHEV	1.0 - 2.9	1.2 - 2.9	3.4 - 4.0	3.4 - 4.0
Higher Voltage/Improved Alternator	HVIA	0.2 - 0.9	0.2 - 0.9	0.2 - 0.6	0.2 - 0.6
Integrated Starter Generator (Belt/Crank)	ISG	1.8 - 2.6	1.8 - 2.6	1.8 - 1.9	1.8 - 2.6
6-Speed Manual/Improved Internals	6MAN	0.5	0.5	0.5	0.5
Improved Auto. Trans. Controls/Externals	IATC	1.5 - 2.5	1.5 - 2.5	1.5 - 2.5	1.5 - 2.5
Continuously Variable Transmission	CVT	0.7 - 2.0	0.7 - 2.0	0.7 - 2.0	n.a.
6/7/8-Speed Auto. Trans with Improved Internals	NAUTO	1.4 - 3.4	1.4 - 3.4	1.4 - 3.4	1.4 - 3.4
Dual Clutch or Automated Manual Transmission	DCTAM	2.7 - 4.1	2.7 - 4.1	2.7 - 4.1	2.7 - 4.1
Material Substitution (1%)	MS1	n.a.	n.a.	n.a.	n.a.
Material Substitution (2%)	MS2	n.a.	n.a.	n.a.	n.a.
Material Substitution (5%)	MS5	n.a.	n.a.	n.a.	n.a.
Low Rolling Resistance Tires	ROLL	n.a.	n.a.	n.a.	n.a.
Low Drag Brakes	LDB	n.a.	n.a.	n.a.	n.a.
Secondary Axle Disconnect	SAX	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5
Aero Drag Reduction	AERO	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0

Table V-20. Technology Incremental Effectiveness Estimates, Light Trucks

VEHICLE TECHNOLOGY INCREMENTAL FUEL CONSUMPTION REDUCTION (-%) BY VEHICLE TECHNOLOGY CLASS - LIGHT TRUCKS					
Nominal Baseline Engine (For Cost Basis)		Minivan LT V6	Small LT Inline 4	Midsize LT V6	Large LT V8
Low Friction Lubricants	LUB	0.5	0.5	0.5	0.5
Engine Friction Reduction	EFR	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
VVT - Coupled Cam Phasing (CCP) on SOHC	CCPS	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0
Discrete Variable Valve Lift (DVVL) on SOHC	DVVLS	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0
Cylinder Deactivation on SOHC	DEACS	2.5 - 3.0	n.a.	2.5 - 3.0	2.5 - 3.0
VVT - Intake Cam Phasing (ICP)	ICP	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0
VVT - Dual Cam Phasing (DCP)	DCP	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0
Discrete Variable Valve Lift (DVVL) on DOHC	DVVLD	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0	1.0 - 3.0
Continuously Variable Valve Lift (CVVL)	CVVL	1.5 - 3.5	1.5 - 3.5	1.5 - 3.5	1.5 - 3.5
Cylinder Deactivation on DOHC	DEACD	0 - 0.5	n.a.	0 - 0.5	0 - 0.5
Cylinder Deactivation on OHV	DEACO	3.9 - 5.5	n.a.	3.9 - 5.5	3.9 - 5.5
VVT - Coupled Cam Phasing (CCP) on OHV	CCPO	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5
Discrete Variable Valve Lift (DVVL) on OHV	DVVLO	0.5 - 2.6	0.5 - 2.6	0.5 - 2.6	0.5 - 2.6
Conversion to DOHC with DCP	CDOHC	1.0 - 2.6	1.0 - 2.6	1.0 - 2.6	1.0 - 2.6
Stoichiometric Gasoline Direct Injection (GDI)	SGDI	1.9 - 2.9	1.9 - 2.9	1.9 - 2.9	1.9 - 2.9
Turbocharging and Downsizing	TRBDS	2.1 - 2.2	4.5 - 5.2	2.1 - 2.2	2.1 - 2.2
Conversion to Diesel following CBRST	DSLC	11.1 - 12.0	13.8 - 14.2	9.9 - 12.0	10.0 - 10.9
Conversion to Diesel following TRBDS	DSLT	5.3 - 6.5	5.3 - 6.5	4.0 - 6.5	4.0 - 5.3
Electric Power Steering	EPS	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	n.a.
Improved Accessories	IACC	1.0 - 2.0	1.0 - 2.0	n.a.	n.a.
12V Micro-Hybrid	MHEV	3.4 - 4.0	1.0 - 2.9	3.4 - 4.0	n.a.
Higher Voltage/Improved Alternator	HVIA	0.2 - 0.6	0.2 - 0.9	0.2 - 0.6	n.a.
Integrated Starter Generator (Belt/Crank)	ISG	5.7 - 6.5	5.7 - 6.5	5.7 - 6.5	n.a.
6-Speed Manual/Improved Internals	6MAN	0.5	0.5	0.5	0.5
Improved Auto. Trans. Controls/Externals	IATC	1.5 - 2.5	1.5 - 2.5	1.5 - 2.5	1.5 - 2.5
Continuously Variable Transmission	CVT	0.7 - 2.0	0.7 - 2.0	n.a.	n.a.
6/7/8-Speed Auto. Trans with Improved Internals	NAUTO	1.4 - 3.4	1.4 - 3.4	1.4 - 3.4	1.4 - 3.4
Dual Clutch or Automated Manual Transmission	DCTAM	2.7 - 4.1	2.7 - 4.1	2.7 - 4.1	2.7 - 4.1
Material Substitution (1%)	MS1	n.a.	n.a.	0.4	0.4
Material Substitution (2%)	MS2	n.a.	n.a.	0.4	0.4
Material Substitution (5%)	MS5	n.a.	n.a.	1.0	1.0
Low Rolling Resistance Tires	ROLL	1.0 - 2.0	1.0 - 2.0	1.0 - 2.0	n.a.
Low Drag Brakes	LDB	n.a.	n.a.	0.5 - 1.0	0.5 - 1.0
Secondary Axle Disconnect	SAX	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5	1.0 - 1.5
Aero Drag Reduction	AERO	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0	2.0 - 3.0

The tables representing the Volpe model input files for 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-21. Approximate Net (Accumulated) Technology Costs, Passenger Cars

APPROXIMATE RETAIL PRICE EQUIVALENT NET COSTS PER VEHICLE ($) BY VEHICLE CLASS TO KEY TECHNOLOGIES (Rounded to nearest $100)				
Final Technology (As compared to baseline vehicle before any technologies are applied)	Subcompact Car	Compact Car	Midsize Car	Large Car
Stoichiometric Gas Direct Injection (SGDI)	600 - 1,100	600 - 1,100	600 - 1,100	1,000 - 1,900
Turbocharge and Downsize (TRBDS)	2,000 - 2,600	2,000 - 2,600	2,000 - 2,600	1,900 - 2,700
Diesel Engine (DSLT/DSLC)	4,000	4,000	4,000	5,600
Dual Clutch Transmission (DCTAM)	500	500	600	600
Integrated Starter Generator Mild-hybrid (ISG)	2,400 - 2,500	2,800	3,000 - 3,100	3,200 - 3,300

Table V-22. Approximate Net (Accumulated) Technology Costs, Performance Passenger Cars

APPROXIMATE RETAIL PRICE EQUIVALENT NET COSTS PER VEHICLE ($) BY VEHICLE CLASS TO KEY TECHNOLOGIES (Rounded to nearest $100)				
Final Technology (As compared to baseline vehicle before any technologies are applied)	Performance Subcompact Car	Performance Compact Car	Performance Midsize Car	Performance Large Car
Stoichiometric Gas Direct Injection (SGDI)	600 - 1,100	1,000 - 1,700	1,000 - 1,900	1,200 - 2,400
Turbocharge and Downsize (TRBDS)	2,000 - 2,600	1,900 - 2,700	1,900 - 2,700	2,600 - 3,700
Diesel Engine (DSLT/DSLC)	4,000	5,600	5,600	7,000
Dual Clutch Transmission (DCTAM)	600	600	600	600
Integrated Starter Generator Mild-hybrid (ISG)	2,500 - 2,700	2,900	3,000 - 3,100	3,300

Table V-23. Approximate Net (Accumulated) Technology Costs, Light Trucks

APPROXIMATE RETAIL PRICE EQUIVALENT NET COSTS PER VEHICLE ($) BY VEHICLE CLASS TO KEY TECHNOLOGIES (Rounded to nearest $100)				
Final Technology (As compared to baseline vehicle before any technologies are applied)	Minivan LT	Small LT	Midsize LT	Large LT
Stoichiometric Gas Direct Injection (SGDI)	1,000 - 1,900	600 - 1,100	1,000 - 1,900	1,200 - 2,400
Turbocharge and Downsize (TRBDS)	1,900 - 2,700	2,000 - 2,600	1,900 - 2,700	2,600 - 3,700
Diesel Engine (DSLT/DSLC)	5,600	4,000	5,600	7,000
Dual Clutch Transmission (DCTAM)	600	600	600	600
Integrated Starter Generator Mild-hybrid (ISG)	3,200 - 3,300	2,800 - 2,900	3,200	n.a.

The tables representing the Volpe 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-24. Approximate Net Technology Effectiveness, Passenger Cars

NET EFFECTIVENESS ESTIMATES FUEL CONSUMPTION REDUCTION PER VEHICLE (-%) BY VEHICLE CLASS TO KEY TECHNOLOGIES				
Final Technology (As compared to baseline vehicle before any technologies are applied)	Subcompact Car	Compact Car	Midsize Car	Large Car
Stoichiometric Gas Direct Injection (SGDI)	4.8 - 13.1	4.8 - 13.1	4.8 - 13.1	7.2 - 14.1
Turbocharge and Downsize (TRBDS)	11.2 - 17.4	11.2 - 17.4	11.2 - 17.4	11.2 - 17.4
Diesel Engine (DSLT/DSLC)	21.2 - 25.9	21.2 - 25.9	20.2 - 24.9	20.2 - 24.9
Dual Clutch Transmission (DCTAM)	8.2 - 12.9	8.2 - 12.9	5.5 - 9.7	5.5 - 9.7
Integrated Starter Generator Mild-hybrid (ISG)	8.7 - 13.6	8.7 - 13.6	10.9 - 14.3	10.9 - 14.3

Table V-25. Approximate Net Technology Effectiveness, Performance Passenger Cars

NET EFFECTIVENESS ESTIMATES FUEL CONSUMPTION REDUCTION PER VEHICLE (-%) BY VEHICLE CLASS TO KEY TECHNOLOGIES				
Final Technology (As compared to baseline vehicle before any technologies are applied)	Performance Subcompact Car	Performance Compact Car	Performance Midsize Car	Performance Large Car
Stoichiometric Gas Direct Injection (SGDI)	4.8 - 13.1	7.2 - 14.1	7.2 - 14.1	7.2 - 14.1
Turbocharge and Downsize (TRBDS)	11.2 - 17.4	11.2 - 17.4	11.2 - 17.4	11.2 - 17.4
Diesel Engine (DSLT/DSLC)	21.2 - 25.9	21.2 - 25.9	20.2 - 24.9	20.2 - 24.9
Dual Clutch Transmission (DCTAM)	5.5 - 9.7	5.5 - 9.7	5.5 - 9.7	5.5 - 9.7
Integrated Starter Generator Mild-hybrid (ISG)	4.9 - 10.0	5.1 - 10.0	7.2 - 10.1	7.2 - 10.7

Table V-26. Approximate Net Technology Effectiveness, Light Trucks

NET EFFECTIVENESS ESTIMATES FUEL CONSUMPTION REDUCTION PER VEHICLE (-%) BY VEHICLE CLASS TO KEY TECHNOLOGIES				
Final Technology (As compared to baseline vehicle before any technologies are applied)	Minivan LT	Small LT	Midsize LT	Large LT
Stoichiometric Gas Direct Injection (SGDI)	7.2 - 14.1	4.8 - 13.1	7.2 - 14.1	7.2 - 14.2
Turbocharge and Downsize (TRBDS)	11.2 - 17.4	11.2 - 17.4	11.2 - 17.4	11.2 - 17.4
Diesel Engine (DSLT/DSLC)	20.2 - 24.9	20.2 - 24.9	20.2 - 23.9	19.2 - 23.9
Dual Clutch Transmission (DCTAM)	5.5 - 9.7	5.5 - 9.7	5.5 - 9.7	5.5 - 9.7
Integrated Starter Generator Mild-hybrid (ISG)	10.9 - 14.3	8.7 - 13.6	10.0 - 12.6	n.a.

C. Penetration of Technologies by Alternative

Tables V-27 shows the penetration of technologies by alternative for passenger cars and Tables V-28 shows the penetration of technologies for light trucks for the alternatives. These tables are for the whole fleet combined, not by specific manufacturers. They allow the reader to see the progression of technologies applied as the alternatives get stricter.

Table V-27
Penetration Rate of New Technologies to Passenger Cars

Technology	25% Below	Opt. 7%	25% Above	50% Above	Opt. 3%	TC = TB	Tech Ex.
Low Friction Lubricants	59%	59%	59%	59%	71%	71%	96%
Engine Friction Reduction	5%	7%	11%	11%	15%	19%	33%
VVT - Coupled Cam Phasing (CCP) on SOHC	9%	9%	10%	10%	10%	10%	10%
Discrete Variable Valve Lift (DVVL) on SOHC	0%	0%	0%	0%	0%	0%	4%
Cylinder Deactivation on SOHC	0%	0%	0%	0%	0%	0%	0%
VVT - Intake Cam Phasing (ICP)	37%	35%	34%	34%	34%	33%	25%
VVT - Dual Cam Phasing (DCP)	38%	41%	42%	42%	42%	43%	52%
Discrete Variable Valve Lift (DVVL) on DOHC	0%	1%	4%	4%	4%	6%	12%
Continuously Variable Valve Lift (CVVL)	0%	0%	0%	0%	0%	0%	1%
Cylinder Deactivation on DOHC	3%	3%	3%	3%	3%	3%	1%
Cylinder Deactivation on OHV	1%	1%	1%	1%	2%	2%	0%
VVT - Coupled Cam Phasing (CCP) on OHV	4%	4%	4%	4%	4%	3%	4%
Discrete Variable Valve Lift (DVVL) on OHV	0%	0%	0%	1%	1%	1%	2%
Conversion to DOHC with DCP	0%	0%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	12%	12%	12%	13%	13%	15%	13%
Combustion Restart	0%	0%	0%	0%	0%	0%	11%
Turbocharging and Downsizing	7%	7%	7%	9%	9%	9%	8%
Exhaust Gas Recirculation (EGR) Boost	0%	0%	0%	0%	0%	0%	2%
Conversion to Diesel following TRBDS	0%	0%	1%	1%	1%	2%	16%
Conversion to Diesel following CBRST	0%	0%	0%	0%	0%	0%	0%
6-Speed Manual/Improved Internals	5%	5%	6%	6%	6%	6%	6%
Improved Auto. Trans. Controls/Externals	6%	6%	6%	4%	4%	4%	9%
Continuously Variable Transmission	11%	11%	11%	11%	11%	11%	11%
6/7/8-Speed Auto. Trans with Improved Internals	36%	36%	36%	34%	34%	34%	33%
Dual Clutch or Automated Manual Transmission	7%	7%	7%	12%	13%	13%	13%
Electric Power Steering	36%	37%	37%	39%	42%	40%	45%
Improved Accessories	36%	37%	37%	39%	39%	38%	44%
12V Micro-Hybrid	0%	1%	2%	1%	1%	3%	0%
Higher Voltage/Improved Alternator	1%	1%	3%	5%	5%	8%	11%
Integrated Starter Generator	0%	0%	0%	1%	1%	1%	4%
Power Split Hybrid	5%	5%	5%	5%	5%	5%	12%
2-Mode Hybrid	0%	0%	0%	0%	0%	0%	0%
Plug-in Hybrid	0%	0%	0%	0%	0%	0%	0%
Material Substitution (1%)	0%	0%	0%	0%	0%	0%	0%
Material Substitution (2%)	0%	0%	0%	0%	0%	0%	0%
Material Substitution (5%)	0%	0%	0%	0%	0%	0%	0%
Low Rolling Resistance Tires	32%	34%	34%	34%	34%	34%	53%
Low Drag Brakes	4%	5%	5%	5%	6%	7%	7%
Secondary Axle Disconnect – Unibody	0%	0%	0%	0%	0%	0%	0%
Secondary Axle Disconnect - Ladder Frame	1%	1%	1%	1%	1%	1%	1%
Aero Drag Reduction	11%	11%	11%	11%	12%	12%	27%

Table V-28
Penetration Rate of New Technologies to Light Trucks

Technology	25% Below	Opt. 7%	25% Above	50% Above	Opt. 3%	TC = TB	Tech Ex.
Low Friction Lubricants	80%	80%	80%	80%	80%	80%	96%
Engine Friction Reduction	25%	25%	26%	26%	25%	26%	34%
VVT - Coupled Cam Phasing (CCP) on SOHC	6%	6%	6%	6%	6%	6%	6%
Discrete Variable Valve Lift (DVVL) on SOHC	0%	0%	0%	0%	0%	0%	2%
Cylinder Deactivation on SOHC	0%	0%	0%	0%	0%	0%	1%
VVT - Intake Cam Phasing (ICP)	25%	25%	25%	25%	25%	25%	23%
VVT - Dual Cam Phasing (DCP)	36%	36%	36%	36%	36%	36%	37%
Discrete Variable Valve Lift (DVVL) on DOHC	0%	0%	1%	1%	0%	1%	4%
Continuously Variable Valve Lift (CVVL)	0%	0%	2%	2%	0%	2%	0%
Cylinder Deactivation on DOHC	1%	1%	1%	1%	1%	1%	6%
Cylinder Deactivation on OHV	11%	11%	11%	11%	11%	10%	12%
VVT - Coupled Cam Phasing (CCP) on OHV	13%	13%	13%	13%	13%	13%	17%
Discrete Variable Valve Lift (DVVL) on OHV	2%	2%	2%	2%	2%	2%	2%
Conversion to DOHC with DCP	0%	0%	0%	0%	0%	0%	0%
Stoichiometric Gasoline Direct Injection (GDI)	10%	10%	12%	12%	10%	10%	9%
Combustion Restart	1%	1%	1%	1%	1%	1%	19%
Turbocharging and Downsizing	5%	5%	7%	7%	5%	7%	6%
Exhaust Gas Recirculation (EGR) Boost	0%	0%	0%	0%	0%	0%	0%
Conversion to Diesel following TRBDS	1%	1%	1%	1%	1%	2%	8%
Conversion to Diesel following CBRST	3%	3%	3%	3%	3%	3%	3%
6-Speed Manual/Improved Internals	0%	0%	0%	0%	0%	0%	0%
Improved Auto. Trans. Controls/Externals	14%	14%	14%	14%	14%	15%	15%
Continuously Variable Transmission	3%	3%	3%	3%	3%	3%	3%
6/7/8-Speed Auto. Trans with Improved Internals	39%	39%	39%	39%	39%	39%	38%
Dual Clutch or Automated Manual Transmission	10%	10%	10%	10%	10%	10%	12%
Electric Power Steering	34%	34%	34%	34%	34%	34%	33%
Improved Accessories	19%	19%	19%	19%	19%	19%	22%
12V Micro-Hybrid	2%	2%	2%	2%	2%	2%	0%
Higher Voltage/Improved Alternator	5%	5%	5%	5%	5%	5%	10%
Integrated Starter Generator	1%	1%	1%	1%	1%	1%	7%
Power Split Hybrid	1%	1%	1%	1%	1%	1%	2%
2-Mode Hybrid	1%	1%	1%	1%	1%	1%	1%
Plug-in Hybrid	0%	0%	0%	0%	0%	0%	0%
Material Substitution (1%)	3%	3%	3%	3%	3%	3%	6%
Material Substitution (2%)	1%	1%	1%	1%	1%	1%	2%
Material Substitution (5%)	0%	0%	1%	1%	0%	1%	2%
Low Rolling Resistance Tires	39%	39%	39%	39%	39%	41%	49%
Low Drag Brakes	17%	17%	17%	17%	17%	17%	28%
Secondary Axle Disconnect - Unibody	0%	0%	0%	0%	0%	0%	0%
Secondary Axle Disconnect - Ladder Frame	25%	25%	25%	25%	25%	25%	27%
Aero Drag Reduction	18%	18%	18%	18%	18%	18%	27%

VI. MANUFACTURER SPECIFIC CAFE CAPABILITIES

Table VI-1 shows the CAFE product plans for each of the manufacturers, based on the manufacturer's plans without taking into account any alternative or dual fuel vehicle attributes.

Table VI-2 shows the **ADJUSTED BASELINE**. Note that when we do cost and benefit analyses, we use the **ADJUSTED BASELINE** throughout the analysis. The adjusted baseline is essentially the higher of the manufacturer's plans or the MY 2010 fuel economy standard. The adjusted baseline assumes for the analysis that each manufacturer, below the MY 2010 standard applicable to that manufacturer, (except Ferrari, Maserati, Daimler, Porsche and Volkswagen) would apply technology to achieve the MY 2010 standard. Those mpg levels of those manufacturers with product plans above the MY 2010 standard, or above their required reform level standard in any model year, are retained for the adjusted baseline. Our rationale for this adjustment of the baseline is that the costs and benefits of achieving MY 2010 mpg levels for light trucks have already been analyzed and estimated in previous analyses. The methodology in this analysis is to apply technologies to the manufacturers' plans and increase them to the adjusted baseline. The costs of these technologies are estimated, but they are not considered part of this rule. We then estimate the costs and benefits of going from the adjusted baseline to the level of the alternatives.[208]

The required standard levels are shown in Table VI-3 for passenger cars and for light trucks. Table VI-4 provides the estimated achieved levels for passenger cars and light trucks. All of the analyses compared the estimated achieved levels versus the adjusted baseline. Table VI-5 for passenger cars and Table VI-6 for light trucks shows what we believe the manufacturers' fuel economy could be for "meeting" the alternative levels analyzed in this analysis. They include in some cases manufacturers' plans at levels higher than the alternative standards would require. Note that not all manufacturers are assumed to attempt to "meet" the alternatives. We assume that Ferrari, Maserati, Daimler, Porsche and Volkswagen would not meet these levels because, for them, the cost of meeting these levels is more than the cost of paying penalties. These manufacturers have shown, in the past, the willingness to pay penalties rather than spend more money to improve the fuel economy of their products.

The agency has performed an analysis of how manufacturers could respond to changes in the proposed CAFE levels. The "Technology Application Analysis" (or the "Volpe 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), 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 Volpe analysis shows the economic impact of the standards in terms of increases in new vehicle prices on a manufacturer-wide, industry-wide, and average

[208] Some manufacturer's plans are above the level of the standard already and are assumed to remain at that level. Some manufacturer's levels go slightly above the proposed mark for them 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.

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 the Volpe model has been updated and refined with respect to its representation of some fuel-saving technologies, but the model remains fundamentally unchanged. 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.[209]

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.

[209] *See* Docket Nos. NHTSA-20005-22223-3, 4, 5.

Table VI-1

Manufacturers Production Plans – MY 2011

Estimated mpg

Manufacturer	Passenger Cars	Light Trucks
BMW	27.0	23.0
Chrysler	28.2	23.1
Daimler	25.2	20.6
Ferrari	16.2	N.A.
Ford	29.3	22.5
General Motors	30.3	21.4
Honda	32.3	25.2
Hyundai	31.7	26.0
Maserati	18.2	N.A.
Mitsubishi	29.3	26.7
Nissan	31.3	21.4
Porsche	27.2	20.0
Subaru	28.6	28.6
Suzuki	28.7	24.0
Tata	24.7	23.9
Toyota	33.2	22.7
Volkswagen	28.5	20.1
Total/Average	30.4	22.6

Table VI-2

Adjusted Baseline – MY 2011

Estimated mpg

Manufacturer	Passenger Cars	Light Trucks
BMW	27.5	23.9
Chrysler	28.2	23.3
Daimler	25.9	20.6
Ferrari	16.2	N.A.
Ford	29.3	22.6
General Motors	30.3	22.2
Honda	32.3	25.2
Hyundai	31.7	26.0
Maserati	18.2	N.A.
Mitsubishi	29.3	26.7
Nissan	31.3	21.8
Porsche	27.5	20.0
Subaru	28.6	28.6
Suzuki	28.7	24.0
Tata	26.0	24.9
Toyota	33.2	23.1
Volkswagen	28.5	20.1
Total/Average	30.5	23.0

Table VI-3

Estimated Required Levels by Final Rule MY 2011

Estimated mpg

Manufacturer	Passenger Cars	Light Trucks
BMW	30.2	25.7
Chrysler	28.6	24.2
Daimler	28.9	24.5
Ferrari	30.7	NA
Ford	30.1	23.6
General Motors	30.0	23.3
Honda	30.6	25.4
Hyundai	30.3	25.3
Maserati	27.5	NA
Mitsubishi	30.9	26.7
Nissan	30.5	24.0
Porsche	31.2	25.5
Subaru	30.9	26.6
Suzuki	31.0	26.4
Tata	27.5	26.1
Toyota	30.6	24.8
Volkswagen	30.9	24.9
Total/Average	30.2	24.1

Table VI-4

Estimated Achievable Levels – MY 2011

Estimated mpg

Manufacturer	Passenger Cars	Light Trucks
BMW	27.7	23.9
Chrysler	28.6	24.2
Daimler	25.9	20.6
Ferrari	16.2	NA
Ford	30.1	22.6
General Motors	30.3	22.2
Honda	32.3	25.5
Hyundai	31.7	26.0
Maserati	18.2	NA
Mitsubishi	31.2	26.7
Nissan	31.3	21.8
Porsche	28.2	20.0
Subaru	30.0	28.6
Suzuki	29.5	24.0
Tata	26.1	25.9
Toyota	33.2	23.1
Volkswagen	29.0	20.1
Total/Average	30.7	23.2

Table VI-5

Estimated Achievable Fuel Economy Levels

By Alternative – MY 2011

Passenger Cars

(mpg)

Manufacturer	25% Below	Opt. 7%	25% Above	50% Above	Opt. 3%	TC = TB	Tech Ex.
BMW	27.7	27.7	27.7	27.7	27.7	27.7	27.9
Chrysler	28.4	28.6	28.9	29.5	29.5	29.8	31.5
Daimler	25.9	25.9	25.9	25.9	25.9	25.9	25.9
Ferrari	16.2	16.2	16.2	16.2	16.2	16.2	16.2
Ford	29.9	30.1	30.4	30.5	30.5	30.5	31.2
General Motors	30.3	30.3	30.3	30.6	31.0	31.3	32.0
Honda	32.3	32.3	32.3	32.3	32.3	32.3	36.0
Hyundai	31.7	31.7	31.7	31.7	31.7	31.7	35.4
Maserati	18.2	18.2	18.2	18.2	18.2	18.2	18.2
Mitsubishi	30.6	31.2	31.2	31.2	31.2	31.2	31.9
Nissan	31.3	31.3	31.3	31.3	31.6	31.9	32.1
Porsche	28.2	28.2	28.2	28.2	28.2	28.2	28.4
Subaru	30.0	30.0	30.0	30.0	30.0	30.0	30.5
Suzuki	29.5	29.5	29.5	29.5	29.5	29.5	29.7
Tata	26.1	26.1	26.1	26.1	26.1	26.1	27.2
Toyota	33.2	33.2	33.2	33.2	33.2	33.2	33.9
Volkswagen	29.0	29.0	29.0	29.0	29.0	29.0	29.1
Total/Average	30.7	30.7	30.8	31.0	31.0	31.2	32.4

Table VI-6

Estimated Achievable Fuel Economy Levels

By Alternative – MY 2011

Light Trucks

(mpg)

Manufacturer	25% Below	Opt. 7%	25% Above	50% Above	Opt. 3%	TC = TB	Tech Ex.
BMW	23.9	23.9	23.9	23.9	23.9	23.9	23.9
Chrysler	24.2	24.2	24.3	24.3	24.2	24.5	25.4
Daimler	20.6	20.6	20.6	20.6	20.6	20.6	20.6
Ferrari	NA	NA	NA	NA	NA	NA	NA
Ford	22.6	22.6	22.6	22.6	22.6	22.6	22.6
General Motors	22.2	22.2	22.2	22.2	22.2	22.2	22.6
Honda	25.5	25.5	25.5	25.5	25.5	25.6	28.0
Hyundai	26.0	26.0	26.0	26.0	26.0	26.0	28.2
Maserati	NA	NA	NA	NA	NA	NA	NA
Mitsubishi	26.7	26.7	27.2	27.2	26.7	27.2	32.1
Nissan	21.8	21.8	21.8	21.8	21.8	21.8	21.9
Porsche	20.0	20.0	20.0	20.0	20.0	20.0	20.0
Subaru	28.6	28.6	28.6	28.6	28.6	28.6	28.7
Suzuki	24.0	24.0	24.0	24.0	24.0	24.0	24.0
Tata	25.9	25.9	25.9	25.9	25.9	25.9	27.8
Toyota	23.1	23.1	23.1	23.1	23.1	23.1	23.2
Volkswagen	20.1	20.1	20.1	20.1	20.1	20.1	20.1
Total/Average	23.2	23.2	23.2	23.2	23.2	23.2	23.7

VII. COST IMPACTS

Technology Costs

Table V-1 provides the technology cost estimates used in this analysis. These are meant to represent consumer costs for high-volume production of these technologies after sufficient experience with their application have resulted in all "learning curve" effects being fully realized. The method taken to get to this consumer cost estimate starts with an initial estimate of the incremental manufacturers' direct costs (or variable costs) for high-volume production of these technologies. In the case of some very new technologies, the agency may have only had cost estimates from low volume products and has assumed that the products have not matured in the development production cycle and that a "learning curve" will result in a reduction in the variable cost of the product. The variable costs are marked up by a factor of 1.5 to take into account fixed costs of R&D, burden, manufacturer's profits, and dealer's profits. The final results are shown in Table V1.

The variable costs are incremental costs in material, labor, and variable burden for the product. For example, if a vehicle already has a 4-speed automatic transmission, the cost of applying a 5-speed transmission is assumed to be the incremental cost, calculated as the cost of applying a 5-speed transmission less the cost of applying the previously applied 4-speed automatic transmission.

Manufacturers' actual costs for applying these technologies to specific vehicle models are likely to include significant additional outlays for accompanying design or engineering changes to each model, development and testing of prototype versions, recalibrating engine operating parameters, and integrating the technology with other attributes of the vehicle. Manufacturers may also incur additional corporate overhead, marketing, or distribution and selling expenses as a consequence of their efforts to improve the fuel economy of individual vehicle models and their overall product lines.

In order to account for these additional costs, the agency applies an indirect cost multiplier of 1.5 to its estimate of the vehicle manufacturers' direct costs for producing or acquiring each fuel economy-improving technology to arrive at a consumer cost. This estimate was developed by Argonne National Laboratory in a recent review of vehicle manufacturers' indirect costs. The Argonne study was specifically intended to improve the accuracy of future cost estimates for production of vehicles that achieve high fuel economy by employing many of the same advanced technologies considered in the agency's analysis.[210] Thus, its recommendation that a multiplier of 1.5 be applied to direct manufacturing costs to reflect manufacturers' increased indirect costs for deploying advanced fuel economy technologies appears to be appropriate for use in the agency's current analysis. Historically, NHTSA has used almost the exact same multiplier, a multiplier of 1.51[211], as the markup from variable costs or direct manufacturing costs to

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[210] Vyas, Anant, Dan Santini, and Roy Cuenca, ***Comparison of Indirect Cost Multipliers for Vehicle Manufacturing***, Center for Transportation Research, Argonne National Laboratory, April 2000.

[211] Spinney, Bruce C., CPA, NHTSA "Advanced Air Bag System Cost Weight and Leadtime Analysis Summary Report" Docket No. 2007-27453-10.

consumer costs. This markup takes into account fixed costs, burden, manufacturer's profit, and dealers profit. NHTSA's methodology for developing this markup factor was recently peer reviewed (see Docket No.27453-4).

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 NAS in its 2002 analysis of the costs and benefits of improving fuel economy by raising CAFE standards.[212] 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. However, the agency believes its cost estimates for fuel economy technologies are generally sufficient to prevent significant reductions in consumer welfare.

The technology application algorithm implemented with the Volpe model was used as the basis for estimating costs for the fleet. The agency did estimate the costs or fines to bring passenger car manufacturers up to the 27.5 mpg level in place for MY 2010 as shown in Table VII-2. Table VII-3 shows the estimates for those light truck manufacturers that are not planning on meeting the CAFE reform level for MY 2011, without using fuel economy adjustments for alternative fueled vehicles, up to the level required for them for MY 2011. These costs have been estimated, but they are not considered to be part of the costs of meeting the proposed requirements. Those costs, and commensurate benefits, are considered part of the costs and benefits of complying with previously issued rules.

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[212] National Academy of Sciences, ***Costs and Effectiveness of Increasing Corporate Average Fuel Economy Standards***, 2002.

Tables VII-4a through 4n for passenger cars and Tables VII-5a through 5n show the costs for light trucks (on an average cost-per-vehicle basis and on a total cost basis) of applying technology necessary to move each manufacturer's planned fuel economy levels up to the level of the alternative. Thus, if a manufacturer's product plans resulted in a fuel economy level of 22.2 mpg during each model year, the cost represents the cumulative cost of technologies necessary to bring that manufacturer's fleet average up to the levels of the alternative. The costs for several manufacturers are the fines that these manufacturers would have to pay on an average vehicle basis. We assume that the costs of fines will be passed on to consumers. The second part of each of these tables shows the estimated total manufacturer costs in millions of dollars. Fines are not included in the second part of these tables, since these are transfer payments and not technology costs.

Table VII-1
Estimated Incremental Costs or Fines over Manufacturer's Plans
To get to Adjusted Baseline – MY 2011
Average Cost per Vehicle (2007$)

Manufacturer	Passenger Cars	Light Trucks
BMW	(64.6)	(215.8)
Chrysler	-	(19.0)
Daimler	(300.6)	(137.5)
Ferrari	(621.5)	
Ford	-	(67.0)
General Motors	-	(529.8)
Honda	-	-
Hyundai	-	-
Maserati	(511.5)	
Mitsubishi	-	-
Nissan	-	(269.8)
Porsche	(80.7)	(214.5)
Subaru	-	-
Suzuki	-	(88.0)
Tata	(1,112.9)	(355.0)
Toyota	-	(137.4)
Volkswagen	-	(181.5)
Total/Average	(8.8)	(205.1)

Table VII-2
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2007$)
MY 2011 Passenger Cars

Manufacturer	25% Below	Opt. 7%	25% Above	50% Above	Opt. 3%	TC = TB	Tech Ex.
BMW	200	217	233	255	272	288	536
Chrysler	16	44	140	425	425	642	3,440
Daimler	66	77	94	110	127	143	341
Ferrari	160	176	193	215	237	253	479
Ford	70	119	391	633	655	666	1,661
General Motors	0	0	0	29	118	396	1,727
Honda	0	0	0	0	0	0	1,427
Hyundai	0	0	0	0	0	0	2,260
Maserati	0	0	11	28	39	55	231
Mitsubishi	280	787	787	872	894	910	1,767
Nissan	0	0	0	0	47	265	847
Porsche	441	458	474	496	518	535	763
Subaru	343	360	376	398	420	437	810
Suzuki	233	250	261	283	305	321	572
Tata	0	0	11	28	44	55	231
Toyota	0	0	0	0	0	0	388
Volkswagen	186	203	219	241	258	274	516
Total/Average	40	64	120	193	220	310	1,445

Table VII-3
Estimated Incremental Costs or Fines over Adjusted Baseline
Average Cost per Vehicle (2007$)
MY 2011 Light Trucks

Manufacturer	25% Below	Opt. 7%	25% Above	50% Above	Opt. 3%	TC = TB	Tech Ex.
BMW	72	72	77	77	72	83	380
Chrysler	473	473	690	690	473	1,079	2,919
Daimler	77	77	83	83	77	88	358
Ferrari	0	0	0	0	0	0	0
Ford	33	33	39	39	33	44	292
General Motors	44	44	50	50	44	55	739
Honda	35	35	35	35	35	42	2,912
Hyundai	0	0	0	0	0	0	2,602
Maserati	0	0	0	0	0	0	0
Mitsubishi	0	0	54	54	0	54	3,915
Nissan	44	44	50	50	44	55	314
Porsche	88	88	94	94	88	99	391
Subaru	0	0	0	0	0	0	225
Suzuki	44	44	50	50	44	55	369
Tata	2,274	2,274	2,279	2,279	2,274	2,285	7,220
Toyota	55	55	61	61	55	66	336
Volkswagen	83	83	88	88	83	94	374
Total/Average	126	126	169	169	126	242	1,177

Table VII-4
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2007$)
MY 2011 Passenger Cars

Manufacturer	25% Below	Opt. 7%	25% Above	50% Above	Opt. 3%	TC = TB	Tech Ex.
BMW	68	74	79	87	93	98	183
Chrysler	11	31	99	300	300	454	2,433
Daimler	3	4	5	6	7	8	18
Ferrari	0	0	0	0	0	0	1
Ford	114	192	632	1,022	1,058	1,076	2,683
General Motors	0	0	0	49	201	674	2,936
Honda	0	0	0	0	0	0	1,783
Hyundai	0	0	0	0	0	0	1,480
Maserati	0	0	0	0	0	0	1
Mitsubishi	59	165	165	183	188	191	371
Nissan	0	0	0	0	37	210	669
Porsche	6	6	6	7	7	7	10
Subaru	32	33	35	37	39	40	75
Suzuki	24	26	27	29	32	33	59
Tata	0	0	0	1	2	2	8
Toyota	0	0	0	0	0	0	545
Volkswagen	58	63	68	75	80	85	160
Total/Average	375	595	1,117	1,796	2,042	2,878	13,415

Table VII-5
Estimated Incremental Costs or Fines over Adjusted Baseline
Total Incremental Costs in Millions (2007$)
MY 2011 Light Trucks

Manufacturer	25% Below	Opt. 7%	25% Above	50% Above	Opt. 3%	TC = TB	Tech Ex.
BMW	7	7	7	7	7	8	37
Chrysler	575	575	839	839	575	1,312	3,549
Daimler	2	2	2	2	2	2	8
Ferrari	0	0	0	0	0	0	0
Ford	38	38	44	44	38	50	333
General Motors	81	81	91	91	81	101	1,363
Honda	16	16	16	16	16	20	1,367
Hyundai	0	0	0	0	0	0	576
Maserati	0	0	0	0	0	0	0
Mitsubishi	0	0	1	1	0	1	66
Nissan	21	21	24	24	21	26	150
Porsche	2	2	2	2	2	3	10
Subaru	0	0	0	0	0	0	29
Suzuki	1	1	1	1	1	1	8
Tata	58	58	58	58	58	59	185
Toyota	60	60	66	66	60	72	367
Volkswagen	4	4	4	4	4	4	17
Total/Average	865	865	1,157	1,157	865	1,660	8,065

Financial Impacts of Raising CAFE Standards

As has been widely reported in the public domain throughout this rulemaking, and as shown in public comments, the national and global economies are in crisis. Even before those recent developments, the automobile manufacturers were already facing substantial difficulties. Together, these problems have made NHTSA's economic practicability analysis particularly important and challenging in this rulemaking.

Automobile sales have dropped significantly. U.S. motor vehicle sales in 2008 were 18 percent below 2007 levels. January 2009 industry sales were 37 percent lower than in January 2008.[213] The sales of every major manufacturer declined. Vehicle manufacturers have not been able to raise prices to offset declining unit sales.[214]

The financial state of the major U.S. automotive manufacturers is particularly difficult.. General Motors' 2008 U.S. vehicle sales were down 23 percent, and January 2009 sales were down 51 percent.[215] GM last earned an accounting profit in 2004, and has lost a cumulative $72 billion between 2005 and the third quarter of 2008.[216] GM has a negative net worth of $60 billion, and consumed more than $3.5 billion in cash in the third quarter. GM is largely unable to borrow additional funds in capital markets, and must rely on a dwindling pool of cash to fund any further operating losses and capital investments.

Ford Motor Company's 2008 sales declined 20 percent.[217] The firm has lost nearly $30 billion since 2006. The firm has a negative net worth of $2 billion, and consumed some $5.5 billion in cash in the fourth quarter of 2008.[218] Ford is also largely unable to borrow additional funds in capital markets, and must also rely on a dwindling pool of cash to fund any further operating losses and capital investments.

Chrysler is closely held, and consequently does not publish financial statements. However, Chrysler's 2008 unit sales were 30 percent below last year's sales, and January 2009 sales were off 55 percent.[219] In a report to submitted to the Senate Banking Committee in December 2008, Chrysler indicated that, if the Federal Government provided $13 billion in financing, Chrysler

[213] Ward's Automotive, "Ward's U.S. Light Vehicle Sales Summary," December 2008. Available at: http://wardsauto.com/keydata/USSalesSummary0812.xls / (Last accessed February 6, 2008).
[214] Commerce Department data indicates no apparent change in nominal prices of new vehicle sales over the past few years.
[215] General Motors Corp, monthly sales report for December 2008. Available at: http://www.gm.com/corporate/investor_information/sales_prod/hist_sales.jsp (last accessed February 6, 2009).
[216] General Motors Corp. annual report for 2007, quarterly earnings announcement for the third quarter of 2008. *Available at* http://www.gm.com/corporate/investor_information/earnings/index.jsp (last accessed November 12, 2008).
[217] Ford Motor Company, Fourth quarter 2008 financial results. Available at: http://www.ford.com/about-ford/investor-relations/company-reports/financial-results (last accessed February 6, 2009).
[218] Ford Motor Company, Annual Report 2007, p. 121 and fourth quarter 2008 earning release, Slide 26..
[219] Ward's Automotive, op. cit.

expected to end 2009 with some $6.7 billion in net cash.[220] However, absent federal intervention, it is not clear that Chrysler would be able to survive 2009 in one piece.

As the figures set forth above demonstrate, the automobile industry is already experiencing substantial economic hardship, even in the absence of new fuel economy standards. All three firms have announced a steady stream of plant closings, layoffs, and employment of new employees at reduced wages.

NHTSA believes these hardships have much to do with the condition of the national economy and perhaps the price of gasoline, and little, if anything, to do with the stringency of CAFE standards for the current or recent model years. We believe that given the scale of the recent decline in industry sales, and the restrictiveness of private credit markets, that near-term developments will be compelled by the industry's immediate financial situation, rather than by the long-term financial consequences of this rulemaking.

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 announcements in recent weeks. The improvements in fleet fuel economy required by this rule are consistent with the pressure induced by changing consumer preferences.

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 assessing the costs and benefits of the rule.

On the other hand, the agency is mindful that CAFE standards do affect the relative competitiveness of different vehicle manufacturers, and recognizes that standards more stringent than those promulgated here could have a more detrimental effect.

However, the core of the problem for the agency is to determine what new standards might be economically practicable within the MY 2011 time frame, given the state of both the domestic and the international auto industries. The complexity of an economic practicability determination has been materially increased by the decision of GM and Chrysler to seek, and the U.S. Government to provide, substantial financial assistance. Congress has appropriated $7.5 billion (to support a maximum of $25 billion in loans under Section 136 of EISA to support the development of advanced technology vehicles and components in the United States.[221] DOE reports that 75 requests for funding, totaling some $38 billion have been received by the deadline date, of which 23 requests were deemed "substantially complete," and hence eligible for further consideration among the initial tranche of projects.

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[220] Robert Nardelli, "Chrysler's Plan for Short-Term and Long-Term Viability," submitted to Senate Committee on Banking, Housing, and Urban Affairs, December 2, 2008. Available at: http://banking.senate.gov/public/files/ChryslerUSSenateViabilityPlan.pdf (last accessed February 6, 2009).

[221221] The authorizing language for this provision is in Section 136 of EISA. This language is amended and funds are appropriated in the Emergency Economic Stabilization Act of 2008 (H.R. 1424, Pub.L. 110-343). *See also* the DOE Advanced Technology Vehicle Manufacturing Loan Program website: http://www.atvmloan.energy.gov/ (last accessed February 6, 2009).

The Treasury Department has also advanced substantial funding to GM, Chrysler and GMAC under the Troubled Asset Relief Program (TARP). (Ford elected not to accept public funding under the TARP). GM received a loan of $13.4 billion, while Chrysler received $4 billion.[222] GM and Chrysler have also submitted restructuring plans to the Treasury Department in February 2009 requesting additional Federal assistance to "achieve and sustain long-term viability" while "comply[ing] with applicable Federal fuel efficiency and emission requirements." Since this rule had not been promulgated at the time the report was submitted, GM and Chrysler were left with a degree of doubt about exactly what CAFE standards would apply to MYs 2011 and thereafter.

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 2011 standards are "within the financial capability of the industry, but not so stringent as to threaten substantial economic hardship for the industry," no matter who contributes the funds. This is an operational definition of a standard set using cost-benefit analysis. We have attempted to set the MY 2011 CAFE standards so that they are both technologically and economically feasible while providing the maximum national public social benefit. In principle, most vehicles meeting the standard will provide social benefits to the public at large and private benefits to automobile owners greater than their extra cost.

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.

A number of manufacturers commented that the proposed standards were too stringent in the early years and were therefore not economically practicable. In reevaluating the range of fuel-saving technologies expected to be available in MY 2011, the agency has developed more realistic estimates of the set of technologies available, the extent to which these technologies are most likely to be applied either at a vehicle freshening or redesign, and the limits (*i.e.*, caps) that should be applied to the rates at which these technologies can be phased in. NHTSA believes the resultant MY 2011 standards, which also reflect all other inputs to NHTSA analysis, are not inappropriately "front loaded," particularly given that they cover only one model year.

NHTSA further considers the sales and employment impacts of the final standards on individual manufacturers as part of its efforts to determine whether the standards are economically practicable. The sales analysis looks at a purchasing decision from the eyes of a knowledgeable and rational consumer, comparing the estimated cost increase versus the payback in fuel savings

[222]U.S. Department of the Treasury, "Indicative Summary of Terms for Secured Term Loan Facility," December 19, 2008, for Chrsyler and GM. *Available at* http://www.treasury.gov/press/releases/hp1333.htm (last accessed February 6, 2009).

over 5 years (the average new vehicle loan) for each manufacturer. This relationship depends on the cost-effectiveness of technologies available to each manufacturer. Overall, based on a 7 percent discount rate for future fuel savings, while the sales and employment impacts estimated from the final standards are higher than those estimated in the NPRM, they are still relatively small compared to the impacts estimated from the higher alternatives discussed above, such as the standards set such that total costs equal total benefits.

The agency does not have 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. The agency asked for comments to provide us with information about the ability of manufacturers to provide the capital investment needs for the various alternatives. However, no responses were provided.

The Impact of Higher Prices on Sales

Higher fuel economy standards are expected to increase the price of passenger cars and light trucks. The potential impact of higher vehicle prices on sales was examined on a manufacturer-specific basis, since the estimated cost of improving fuel economy and the fuel economy improvement is different for each manufacturer. There is a broad consensus in the economic literature that the price elasticity for demand for automobiles is approximately –1.0.[223,224,225] Thus, every one percent increase in the price of the vehicle would reduce sales by one percent. Elasticity estimates assume no perceived change in the quality of the product. However, in this case, vehicle price increases result from adding technologies that improve fuel economy. If consumers do not value improved fuel economy at all, and consider nothing but the increase in price in their purchase decisions, then the estimated impact on sales from price elasticity could be applied directly. However, we believe that consumers do value improved fuel economy, because they reduce the operating cost of the vehicles. We also believe that consumers consider other factors that affect their costs and have included these in the analysis.

One issue that significantly affects this sales analysis is: How much of the retail price increase needed to cover the fuel economy technology investments will manufacturers be able to pass on to consumers? The estimates reported above assume that manufacturers will be able to pass all of their costs to improve fuel economy on to consumers. However, the ability of manufacturers to pass the compliance costs on to consumers will depend upon how consumers value the fuel economy improvements. Consumer valuation of fuel economy improvements often depends upon the price of gasoline, which has recently been very volatile. To the extent that we have accurately predicted the price of gasoline and consumers reactions, and manufacturers can pass on all of the costs to consumers, then the sales and employment impact analyses are reasonable. If manufacturers only increase retail prices to the extent that consumers value these fuel economy improvements, then there would be no impact on sales.

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[223] Kleit, A.N. (1990). "The Effect of Annual Changes in Automobile Fuel Economy Standards." *Journal of Regulatory Economics*, vol. 2, pp 151-172.

[224] Bordley, R. (1994). "An Overlapping Choice Set Model of Automotive Price Elasticities," *Transportation Research B*, vol 28B, no 6, pp 401-408.

[225] 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.

Sales losses are predicted to occur only if consumers fail to value fuel economy improvements at least as much as they pay in higher prices. Our analysis indicates that during the first 5 years, on average initial purchasers will not yet recoup their added investment and this leads to our prediction of sales losses. If manufacturers are unable to raise prices beyond the level of consumer's valuation of fuel savings, then manufacturer's profit levels would fall but there would be no impact on sales. Likewise, if fuel prices rise beyond levels used in this analysis, consumer's valuation of improved fuel economy could increase to match or exceed their initial investment, resulting in no impact or even an increase in sales levels.

To estimate the average value consumers place on fuel savings at the time of purchase, we assume that the average purchaser considers the fuel savings they would receive over a 5 year timeframe. We chose 5 years because this is the average length of time of a financing agreement. [226] The present values of these savings were calculated using a 7 percent discount rate for those alternatives that were based on a 7 percent discount rate and using a 3 percent discount rate for the one alternative based on a 3 percent discount rate. We used a fuel price forecast (see Table VIII-3) that included taxes, because this is what consumers must pay. Fuel savings were calculated over the first 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 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. We took sales taxes in 2007 by state and weighted them by population by state to determine a national weighted-average sales tax of 5.5 percent.

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. According to the National Association of Insurance Commissioners (NAIC) the national average premium for collision + comprehensive insurance in 2000 was $389 while the average new car transaction price was $20,600. If we assume that this premium is proportional to the new car price, it represents about 1.9 percent of the new car price and insurance is paid each year for the five year period we are considering for payback. 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 8.7 percent of the vehicle's price at a 3 percent discount rate and 8.0 percent of the vehicle's price at a 7 percent discount rate.

Third, we considered that 70 percent of new vehicle purchasers take out loans to finance their purchase. The average new vehicle loan is for 5 years at a 6 percent rate[227]. At these terms the average person taking a loan will pay 16 percent more for their vehicle over the 5 years than a

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[226] 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/

[227] New car loan rates in 2007 average about 7.8 percent at commercial banks and 4.5 percent at auto finance companies, so their average is close to 7 percent

consumer paying cash for the vehicle at the time of purchase[228]. Discounting the additional 3.2 percent (16 percent / 5 years) per year over the 5 years using a 3 percent mid-year discount rate[229] results in a discounted present value of 14.87 percent higher for those taking a loan, and at a 7 percent discount rate results in a 13.58 percent higher for those taking a loan. Multiplying that by the 70 percent that take a loan, means that the average consumer would pay 10.4 percent more than the retail price for loans the consumer discounted at a 3 percent discount rate and 9.5 percent more than the retail price for loans the consumer discounted at a 7 percent discount rate.

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. In other words, if the price of the vehicle increases due to fuel economy technologies, the resale value of the vehicle will go up proportionately. To estimate that value, we looked at 138 model year 2002 vehicles to compare their original MSRP values (based on www.nadaguides.com) to their current trade-in values (5 years later in 2007 based on www.edmunds.com). The sales weighted average residual value for this group of vehicles was 37.5 percent. Discounting the residual value back 5 years using a 3 percent discount rate (37.5 percent * .8755) gives an effective residual value at new of 32.8 percent. Discounting the residual value back 5 years using a 7 percent discount rate (37.5 percent * 0.7375) gives an effective residual value at new of 27.7 percent.

We add these four factors together. At a 3 percent discount rate, the consumer considers he could get 32.8 percent back upon resale in 5 years, but will pay 10.4 percent more for loans, 5.5 percent more for taxes and 8.7 percent more in insurance, results in a 8.2 percent return on the increase in price for fuel economy technology (32.8 percent – 10.4 percent - 5.5 percent – 8.7 percent). Thus, the increase in price per vehicle is multiplied by 0.918 (1 – 0.082) before subtracting the fuel savings to determine the overall net consumer valuation the increase of costs on his purchase decision. At a 7 percent discount rate, the consumer considers he could get 27.7 percent back upon resale in 5 years, but will pay 9.5 percent more for loans, 5.5 percent more for taxes and 8.0 percent more in insurance, results in a 4.7 percent return on the increase in price for fuel economy technology (27.7 percent – 9.5 percent - 5.5 percent – 8.0 percent). Thus, the increase in price per vehicle is multiplied by 0.953 (1 – 0.047) before subtracting the fuel savings to determine the overall net consumer valuation the increase of costs on his purchase decision.

Using sales volumes from Ward's Automotive Yearbook 2008 for MY 2007 sales and the MY 2008 base vehicle average prices, we determined an average passenger car and an average light truck price per manufacturer. The average base price for all passenger cars using this method was $26,201 and for all light trucks was $29,678. While this method does not give an exact price, the results are reasonable and specific to individual manufacturers[230]. These prices are in

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[228] Based on www.bankrate.com auto loan calculator for a 5 year loan at 6 percent.

[229] For a 3 percent discount rate, the summation of 3.2 percent x 0.9853 in year one, 3.2 x 0.9566 in year two, 3.2 x 0.9288 in year three, 3.2 x 0.9017 in year 4, and 3.2 x 0.8755 in year five. For a 7 percent discount rate, the summation of 3.2 percent x 0.9667 in year one, 3.2 x 0.9053 in year two, 3.2 x 0.8444 in year 3, 3.2 x 0.7891 in year 4, and 3.2 x 0.7375 in year 5.

[230] The base price does not include the more expensive lines of a model or purchased optional equipment; nor does it count discounts given. Thus, it is not an average light truck purchase transaction price, but a price that we can track.

2007 dollars. Average prices and estimated sales volumes are needed because price elasticity is an estimate of how a percent increase in price affects the percent decrease in sales.

A sample calculation for Ford passenger cars under the Optimized 7% alternative in MY 2011 is an estimated retail price increase of $119 which is multiplied by 0.953 to get a residual price increase of $113. The estimated fuel savings over the 5 years of $176 at a 7 percent discount rate results in a net benefit to consumers of $63. Comparing that to the $25,373 average price is a 0.247 percent price decrease. Ford sales were estimated to be about 1,615,000 passenger cars for MY 2011. With a price elasticity of –1.0, a 0.247 percent decrease in net cost to consumers could result in an estimated increase in sales of 3,997 passenger cars.

Combined passenger car and light truck sales decreases are estimated for every alternative. As the alternatives get stricter, there are progressively larger losses in sales. Table VII-6 shows the estimated impact on sales for passenger cars and light trucks combined.

Our projections indicate that CAFE standards will result in sales increases for some manufacturers under some scenarios, but overwhelmingly decreases for the industry total. As the alternatives get progressively more stringent, the projected sales loss increases. For the TC = TB alternative the MY 2011 sales loss is projected to be 86,000 or 0.5 percent and for the Technology Exhaustion alternative the sales loss is projected to be 585,000 or 3.6 percent of the total sales of 16.136 million light vehicles.

Note that there is no feedback loop between this sales analysis and the Volpe model. These sales estimates are not used to determine additional or less mileage traveled or fuel consumed. The Volpe model does not attempt to estimate the extent to which the sales volumes of different vehicle models might change in response to fuel economy increases, financial outlays for additional technology, and increases in civil penalties that could all result from increased CAFE standards. As NHTSA explained in the NPRM, (1) Volpe Center staff tested many potential specifications of multinomial logit model that could be used to estimate such effects, but none produced plausible coefficients, (2) NHTSA and Volpe Center staff were not confident that baseline vehicle transaction prices could be reliably predicted, and (3) NHTSA and Volpe Center staff were not confident a basis would be available to estimate manufacturers' decisions regarding the allocation of compliance costs.[231]

As NHTSA further acknowledged in the NPRM, Resources for the Future (RFF) has, under contract to EPA, been working toward the development of a market share model. Although RFF did not complete this work in time for consideration as part of this rulemaking, depending on the extent to which these efforts are eventually successful, the Volpe model could at some point be modified to include cost allocation and market share models.

Among the attachments to its comments, the Alliance of Automobile Manufacturers submitted a study prepared by NERA, which used its model of the vehicle market "to estimate the value that consumers place on reductions in fuel operating cost while controlling for other factors."[232]

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[231] **Federal Register** / Vol. 73, No. 86 / Friday, May 2, 2008 / Proposed Rules, p. 24394.
[232] NERA Economic Consulting, "Evaluation of NHTSA's Benefit-Cost Analysis of 2011-2015 CAFE Standards", 2008, p. 18.

NERA states that its model "operates at the level of individual vehicle models" and "utilizes data on transaction prices (as distinct from manufacturers' suggested retail prices), sales volumes, and detailed vehicle characteristics for model years 2001 through 2007."[233] With such a model, NERA may, in principle, have had the ability to estimate shifts in the market shares of individual vehicle models from these model years, if NERA had also been able to estimate how manufacturers would allocate overall compliance costs. Of course, representing only past model years, such an analysis would have had uncertain relevance to future model years. In any event, NERA apparently did not attempt to do so, but instead used NHTSA's estimate of the own-price elasticity of demand for new vehicles to estimate the overall change in sales of new vehicles.[234] NHTSA and Volpe Center staff will continue to consider the potential to integrate a market share model into the Volpe model, and will give careful consideration to the above-mentioned RFF effort when that work is complete. However, NHTSA received no concrete recommendations in response to its request for comments regarding the formulation and calibration of a market share model, the estimation of future vehicle prices (*i.e.*, transaction prices), and the estimation of manufacturers' decisions regarding the allocation of compliance costs. The Agency does not have a sufficient basis to include a market share model into its Volpe model and analysis at this time.

[233] *Ibid.*, p. 18.
[234] *Ibid.*, p. 27.

Table VII-6
Potential Impact on Sales by Manufacturer
MY 2011 Passenger Cars and Light Trucks Combined

Manufacturer	25% Below	Opt. 7%	25% Above	50% Above	Opt. 3%	TC = TB	Tech Ex.
BMW	-1,123	-1,246	-1,381	-1,545	-1,529	-1,803	-3,934
Chrysler	-3,232	-2,530	-10,394	-14,330	-3,892	-29,894	-156,924
Daimler	-87	-97	-115	-130	-137	-162	-452
Ferrari	-1	-1	-1	-2	-2	-2	-4
Ford	3,055	2,805	-9,883	-23,010	-21,059	-25,210	-85,413
General Motors	-2,560	-2,560	-2,876	-924	186	-15,661	-123,844
Honda	818	818	818	818	963	1,360	-70,331
Hyundai	0	0	0	0	0	0	-71,561
Maserati	0	0	0	-1	-1	-2	-8
Mitsubishi	85	-3,156	-3,105	-3,731	-3,336	-4,063	-11,798
Nissan	-661	-661	-744	-744	78	-4,936	-24,752
Porsche	-88	-92	-98	-102	-96	-113	-263
Subaru	-81	-136	-190	-263	-185	-390	-2,058
Suzuki	-338	-443	-517	-657	-608	-906	-2,515
Tata	-688	-688	-694	-701	-662	-713	-2,221
Toyota	-1,993	-1,993	-2,192	-2,192	-1,920	-2,392	-24,986
Volkswagen	-601	-777	-957	-1,191	-1,122	-1,547	-4,208
Total/Average	-7,496	-10,757	-32,329	-48,704	-33,323	-86,434	-585,272

Potential Impact on Employment

There are three potential areas of employment that fuel economy standards could impact. 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 does not anticipate a huge number of incremental jobs in the engineering field. Often people would be diverted from one area to another and the incremental number of jobs might be a few thousand.

The second area is the impact that new technologies would have on the production line. Again, we don't anticipate a large number of incremental workers, as for the most part you are replacing one engine with another or one transmission with another. In some instances the technology is more complex, requiring more parts and there would be a small increase in the number of production employees, but we don't anticipate a large change.

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. In the past, the agency and others have made estimates of the impact of sales losses on employment. In the final rule reducing the light truck fuel economy standard for MY 1985, the agency concluded that sales losses of 100,000 to 180,000 would result in employment losses of 12,000 to 23,000 (49 FR 41252, October 22, 1984).[235] In the final rule reducing the MY 1986 passenger car fuel economy standard, the agency concluded that while it was difficult to precisely estimate the impacts, "there would be a likelihood of sales losses well into the hundreds of thousands of units and job losses well into the tens of thousands. Sales and employment losses of these magnitudes would have significant adverse effects on the economy … " (50 FR 40538, October 4, 1985). In the final rule amending the passenger car standards for MY 1987 and 1988, the agency said that "… domestic car production may fall by more than 900,000 units. The short employment effects are substantial: over 130,000 jobs…" (51 FR 35598, October 6, 1986). These estimates imply a ratio between the number of vehicles sales lost and the number of employees laid off in the 1980s of between 6.9 (900,000/130,000) and 8.3 (100,000/12,000).

Certainly productivity has increased since that time. In order to get an estimate of potential job losses per sales loss, we examined more 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 Equipment Manufacturing sector of the economy at 1,313,600. Since then there has been a decline to 1,108,000 in 2003 and to 1,098,000 in 2005[236]. Averaging those three years, the average U.S. domestic employee produces 10.5 vehicles. Thus, one could assume that projected sales loss divided by 10.5 would give an estimate of the potential employment loss.

[235] The agency's decision to lower standards based on that amount of impacts identified in the 1985 rule was upheld by the DC Circuit in Public Citizen v. NHTSA, 848 F.2d 256.

[236] Based on "U.S. Automotive Industry Employment Trends", Office of Aerospace and Automotive Industries, U.S. Department of Commerce, March 30, 2005, and Ward's Automotive Yearbook, 2006, pgs. 215, 222, and 270.

Table VII-7

U.S. Light Duty Vehicle Production and Employment

	U.S. Light Vehicle Production	U.S. Employment	Production per Employee
2000	12,773,714	1,313,600	9.7
2003	12,087,028	1,108,000	10.9
2005	11,946,653	1,098,000	10.9
Total/Average	36,807,396	3,519,600	10.5

At this time, the agency considers these effects to occur in the short to medium term (meaning up to 5 years). Over the next few years, consumers can elect to defer vehicle purchases by continuing to operate existing vehicles. Eventually, however, the rising maintenance costs for aging vehicles will make replacements look more attractive.

However, vehicle owners may also react to persistently higher vehicle costs by permanently owning fewer vehicles, and keeping existing vehicles in service for somewhat longer. In this case, the possibility exists that there may be permanent sales losses, compared with a situation in which vehicle prices are lower.

Table VII-8

Impact on Auto Industry Employment by Alternative

(Jobs)

MY 2011

	Passenger Cars	Light Trucks	Passenger Cars and Light Trucks Combined
25% Below Optimized (7%)	272	-986	-714
Optimized (7%)	-39	-986	-1,024
25% Above Optimized (7%)	-1,336	-1,743	-3,079
50% Above Optimized (7%)	-2,896	-1,743	-4,638
Optimized (3%)	-2,419	-755	-3,174
TC = TB (7%)	-5,375	-2,857	-8,232
Technology Exhaustion (7%)	-37,260	-18,481	-55,740

Table VII-9 provides further information relating to the stringency of the different alternatives. It looks at the largest 17 passenger car manufacturers and the 15 light truck manufacturers and examines whether or not they run out of technologies that the agency believes they have available. As the alternatives get more stringent, more manufacturers run out of technologies.

It should be noted that Table VII-9 does not take into account any of the flexibilities that manufacturers have available to comply with a standard. It does not consider credits, credit trading, etc.

Table VII-9
Number of Manufacturers That Run Out of Technology

	Cars	Light Trucks
25% Below Optimized (7%)	7	10
Optimized (7%)	7	10
25% Above Optimized (7%)	9	10
50% Above Optimized (7%)	11	10
Optimized (3%)	11	10
TC = TB (7%)	11	10
Technology Exhaustion (7%)	16	15

VIII. BENEFITS

Economic Impacts from Higher CAFE Standards

Economic impacts from adopting a more stringent CAFE standard for passenger cars and light trucks were estimated separately for each model year over the lifespan of those vehicles in the U.S. vehicle fleet, extending from the initial year when a model is offered for sale through the year when nearly all vehicles from that model year have been retired or scrapped (assumed to be 26 years for passenger cars and 36 years for light trucks in this analysis). The principal source of the economic and environmental impacts considered in this analysis is the reduction in gasoline use resulting from the improvement in fuel economy of new light-duty vehicles produced. Reducing gasoline consumption provides consumer benefits through decreased fuel costs, through reduced costs for externalities such as demand price inflation, economic disruption, and military security, through reduced economic and health impacts from criteria pollutants and green house gas emissions, through increased driving ranges for vehicles, and through consumer surplus from added driving. Offsetting a part of these benefits are added costs from congestion, crashes, and noise, as well as some offset to fuel consumption and pollution savings, all due to an increase in driving that results from lower driving costs (the rebound effect). Each of these impacts is measured by comparing their value under each alternative approach to their value under the adjusted baseline. Future impacts are estimated after discounting to the year the vehicle is sold to determine their present value.[237]

Basic Inputs for Analysis of Economic Impacts

The variety of impacts discussed above are a function of basic factors which determine their magnitude and define their value. These include the discount rate, the level of vehicle sales, the magnitude of the rebound effect, and the relationship between EPA measured fuel efficiency and actual on-road fuel efficiency.

The Discount Rate

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 setting the standards using a marginal cost/marginal benefit methodology we used two different discount rates. The inter-generational discount rate used for the long term social cost of carbon benefits is 3 percent and the conventional discount rate used for the fuel and other savings over the next 36 year is 7 percent. See the discussion in Chapter I on docket comments for the basis for selecting these rates.

[237] Discounting to the year when each model year was produced allows future economic benefits from improving each model year's fuel economy to be compared to added production costs for making those vehicles more fuel-efficient, which are assumed to be incurred at the time those vehicles are manufactured.

Vehicle Classification

Passenger automobiles were defined in EPCA as "any automobile (other than an automobile capable of off-highway operation) which the Secretary [*i.e.*, NHTSA] decides by rule is manufactured primarily for use in the transportation of not more than 10 individuals." Thus, under EPCA, there are two general groups of automobiles that qualify as non-passenger automobiles or light trucks: (1) those defined by NHTSA in its regulations as other than passenger automobiles due to their having not been manufactured "primarily" for transporting up to ten individuals; and (2) those expressly excluded from the passenger category by statute due to their capability for off-highway operation, regardless of whether they were manufactured primarily for passenger transportation. NHTSA's classification rule directly tracks those two broad groups of non-passenger automobiles in subsections (a) and (b), respectively, of 49 CFR Part 523.5.

In the NPRM, NHTSA took a fresh look at the regulatory definitions in light of its desire to ensure clarity in how vehicles are classified, the passage of EISA, and the Ninth Circuit's decision in *CBD*. The NPRM proposed to tighten the coverage of its regulatory definition of "light truck" to ensure that, starting in MY 2011, 2WD versions of SUVs are no longer classified as off-highway capable light trucks under 49 CFR Part 523.5(b), simply because the SUV also comes in a 4WD version.

NHTSA has tightened the coverage of its regulatory definition of "light truck" to ensure that 2 wheel drive (2WD) versions of an SUV are not classified as light trucks under Part 523.5(b) simply because the SUV also comes in a 4WD version. In order to be properly classifiable as a light truck under Part 523, a 2WD SUV must either be over 6,000 lbs GVWR and meet 4 out of 5 ground clearance characteristics to make it off-highway capable under Part 523.5(b), or meet one of the functional characteristics under Part 523.5(a) (*e.g.*, greater cargo carrying capacity than passenger carrying capacity). In other words, a 2WD vehicle of 6,000 lbs GVWR or less, even if it has a sufficient number of clearance characteristics, cannot be considered off-highway capable. This is based on the plain meaning of Part 523.5(b) (which refers to a vehicle that "has" 4WD) and the statute (49 U.S.C. § 32901(a)(18)(b) speaks of a vehicle that "is a 4-wheel drive automobile"). Additionally, 2WD SUVs may not be properly classified as light trucks simply because a manufacturer asserts that their base form has no back seat and thus would "provide greater cargo-carrying than passenger-carrying volume" according to Part 523.5(a)(4). No change in the regulatory definition is needed. The clarification accomplishes NHTSA's purpose. This clarification, which the vehicle manufacturers largely supported, resulted in the re-classification of an average of 1,400,000 2WD SUVs from light trucks to passenger cars in each of the five model years covered by the standards.

Additional discussion of vehicle classification is contained in the preamble to the final rule..

Sales Estimates

A critical variable affecting the total economic benefits from improving light truck fuel economy is the number of vehicles likely to be produced under stricter fuel economy. Projections of total passenger cars and light truck sales for future years (see Table VIII-1a and VIII-1b) were obtained from the Energy Information Administration's (EIA) *Annual Energy Outlook 2008*

(*AEO 2008*), a standard government reference for projections of energy production and consumption in different sectors of the U.S. economy.[238] These values will be used as multipliers to estimate the overall impacts (both costs and benefits) of changes in fuel economy standards.

In all cases, manufacturers' respective sales volumes were normalized to produce passenger car and light truck fleets which reflected manufacturers' respective MY 2008 market shares within the construct of the projected aggregate vehicle sales volumes that were forecasted in EIA's 2008 Annual Energy Outlook. NHTSA does so in order to develop a market forecast that is realistic in terms of both its overall size and manufacturers' market shares. The product mix for each manufacturer that submitted product plans was preserved and in the case of those than did not submit plans, the product mix was the same as indicated in their pre-model year 2008 CAFE data.

NHTSA has relied on product plans from manufacturers to help the agency determine the composition of the future fleets. The product plans are provided in response to NHTSA's request for information from the manufacturers, and respond to very detailed questions about vehicle model characteristics that influence fuel economy.[239] The baseline market forecast mix of products (make/model, engines, transmissions, etc.) that NHTSA has used in its analysis is based significantly on the confidential product plan information manufacturers submit to the agency. See the preamble to the final rule for more information on how we used the manufacturers' confidential product plans.

[238] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2007*, Supplemental Table 47, http://www.eia.doe.gov/oiaf/aeo/supplement/suptab_47.xls.

[239] *Id.*

Table VIII-1

Sales Projections – MY 2011

(1,000s of vehicles)

Manufacturer	Passenger Cars	Light Trucks	Combined
BMW	340.9	96.2	437.1
Chrysler	707.3	1,215.9	1,923.2
Daimler	52.9	23.0	75.9
Ferrari	1.9		1.9
Ford	1,615.0	1,143.9	2,759.0
General Motors	1,700.1	1,844.1	3,544.2
Honda	1,249.9	469.5	1,719.5
Hyundai	655.1	221.3	876.4
Maserati	4.4		4.4
Mitsubishi	209.8	16.9	226.8
Nissan	789.4	479.3	1,268.7
Porsche	13.5	25.8	39.3
Subaru	92.1	126.7	218.8
Suzuki	103.8	21.6	125.5
Tata	35.0	25.7	60.7
Toyota	1,405.1	1,094.5	2,499.6
Volkswagen	310.7	45.2	355.9
Total/Average	9,286.9	6,849.7	16,136.7

The "Rebound Effect"

The rebound effect refers to the tendency for owners to increase the number of miles they drive a vehicle in response to an increase in its fuel economy, as would result from more stringent fuel economy standards. The rebound effect occurs because an increase in a vehicle's fuel economy reduces its owner's fuel cost for driving each mile, which is typically the largest single component of the cost of operating a vehicle. Even with the vehicle's higher fuel economy, this additional driving uses some fuel, so the rebound effect will reduce the net fuel savings that result when the fuel economy standards require manufacturers to increase fuel economy. The rebound effect is usually expressed as the percentage by which annual vehicle use increases when average fuel cost per mile driven decreases in response to a change in the marginal cost of driving an extra mile, due either an increase in fuel economy or a reduction in the price of fuel.

The magnitude of the rebound effect is one of the determinants of the actual fuel savings that are likely to result from adopting stricter standards, and thus an important parameter affecting NHTSA's evaluation of alternative standards for future model years. The rebound effect can be measured directly by estimating the elasticity of vehicle use with respect to fuel economy itself, or indirectly by the elasticity of vehicle use with respect to fuel cost per mile driven.[240] When expressed as a positive percentage, either of these parameters gives the fraction of fuel savings that would otherwise result from adopting stricter standards, but is offset by the increase in fuel consumption that results when vehicles with increased fuel economy are driven more.

Research on the magnitude of the rebound effect in light-duty vehicle use dates to the early 1980s, and almost unanimously concludes that a statistically significant rebound effect occurs when vehicle fuel efficiency improves.[241] The most common approach to estimating its magnitude has been to analyze statistically household survey data on vehicle use, fuel consumption, fuel prices (often obtained from external sources), and other determinants of household travel demand to isolate the response of vehicle use to higher fuel economy. Other studies have relied on econometric analysis of annual U.S. data on vehicle use, fuel economy, fuel prices, and other variables to identify the response of total or average vehicle use to changes in fleet-wide average fuel economy and its effect of fuel cost per mile driven. Two recent studies analyzed yearly variation in vehicle ownership and use, fuel prices, and fuel economy among individual states over an extended time period in order to measure the response of vehicle use to changing fuel economy.[242]

An important distinction among studies of the rebound effect is whether they assume that the effect is constant, or varies over time in response to the absolute levels of fuel costs, personal income, or household vehicle ownership. Most studies using aggregate annual data for the U.S.

[240] Fuel cost per mile is equal to the price of fuel in dollars per gallon divided by fuel economy in miles per gallon, so this figure declines when a vehicle's fuel economy increases.

[241] 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 is most appropriate for evaluating the fuel savings and emissions reductions resulting from stricter standards that would apply to future model years.

[242] 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.

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 economy alter fuel cost per mile driven. Many studies using household survey data estimate significantly different rebound effects for households owning varying numbers of vehicles, although they arrive at differing conclusions about whether the rebound effect is larger among households that own more vehicles. One recent study using state-level 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.

In order to arrive at an estimate of the rebound effect for use in assessing the fuel savings, emissions reductions, and other impacts of alternative standards, NHTSA reviewed 22 studies of the rebound effect conducted from 1983 through 2005. We then conducted a detailed analysis of the 66 separate estimates of the long-run rebound effect reported in these studies, which is summarized in the table below.[243] As the table indicates, these 66 estimates of the long-run rebound effect range from as low as 7 percent to as high as 75 percent, with a mean value of 23 percent.

Limiting the sample to 50 estimates reported in the 17 published studies of the rebound effect yields the same range but a slightly higher mean (24 percent), while focusing on the authors' preferred estimates from published studies narrows this range and lowers its average only slightly. The median estimate of the rebound effect in all three samples, which is generally regarded as a more reliable indicator of their central tendency than the average because it is less influenced by unusually small and large estimates, is 22 percent. As Table VIII-2 indicates, approximately two-thirds of all estimates reviewed, of all published estimates, and of authors' preferred estimates fall in the range of 10-30 percent.

Table VIII-2
Summary of Rebound Effect Estimates

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%
Authors' Preferred Estimates	17	17	9%	75%	22%	22%	15%
U.S. Time-Series Estimates	7	34	7%	45%	14%	18%	9%
Household Survey Estimates	13	23	9%	75%	31%	31%	16%
Pooled U.S. State Estimates	2	9	8%	58%	22%	25%	14%
Constant Rebound Effect (1)	15	37	7%	75%	20%	23%	16%
Variable Rebound Effect: (1) Reported Estimates	10	29	10%	45%	23%	23%	10%
Updated to 2006 (2)	10	29	6%	46%	16%	19%	12%

(1) Three studies estimate both constant and variable rebound effects.

243 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, we computed a weighted average of the reported values using the distribution of households among vehicle ownership categories.

(2) Reported estimates updated to reflect 2006 values of vehicle use, fuel prices, fleet fuel efficiency, household income, and household vehicle ownership.

The type of data used and authors' assumption about whether the rebound effect varies over time have important effects on its estimated magnitude. The 34 estimates derived from analysis of U.S. annual time-series data produce a median estimate of 14 percent for the long-run rebound effect, while the median of 23 estimates based on household survey data is more than twice as large (31 percent), and the median of 9 estimates based on pooled state data matches that of the entire sample (22 percent). The 37 estimates assuming a constant rebound effect produce a median of 20 percent, while the 29 originally reported estimates of a variable rebound effect have a slightly higher median value (23 percent).

In selecting a single value for the rebound effect to use in analyzing alternative standards for future model years, NHTSA attaches greater significance to studies that allow the rebound effect to vary in response to changes in the various factors that have been found to affect its magnitude. However, it is also important to update authors' originally-reported estimates of variable rebound effects to reflect current conditions. Recalculating the 29 original estimates of variable rebound effects to reflect current (2006) values for retail fuel prices, average fuel economy, personal income, and household vehicle ownership reduces their median estimate to 16 percent.[244] NHTSA also tentatively attaches greater significance to the recent study by Small and Van Dender (2005), which finds that the rebound effect tends to decline as average fuel economy, personal income, and suburbanization of U.S. cities increase, but – in accordance with previous studies – rises with increasing fuel prices.[245]

Considering the empirical evidence on the rebound effect as a whole, but according greater importance to the updated estimates from studies allowing the rebound effect to vary – particularly the Small and Van Dender study – NHTSA has selected a rebound effect of 15 percent to evaluate the fuel savings and other effects of alternative standards for the time period

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[244] As an illustration, Small and Van Dender (2005) allow the rebound effect to vary over time in response to changes in real per capita income as well as average fuel cost per mile driven. While their estimate for the entire interval (1966-2001) they analyze is 22 percent, updating this estimate using 2006 values of these variables reduces the rebound effect to approximately 10 percent. Similarly, updating Greene's 1992 original estimate of a 15 percent rebound effect to reflect 2006 fuel prices and average fuel economy reduces it to 6 percent. *See* David L. Greene, "Vehicle Use and Fuel Economy: How Big is the Rebound Effect?" The Energy Journal, 13:1 (1992), 117-143. In contrast, the distribution of households among vehicle ownership categories in the data samples used by Hensher et al. (1990) and Greene et al. (1999) are nearly identical to the most recent estimates for the U.S., so updating their original estimates to current U.S. conditions changes them very little. *See* David A. Hensher, Frank W. Milthorpe, and Nariida C. Smith, "The Demand for Vehicle Use in the Urban Household Sector: Theory and Empirical Evidence," Journal of Transport Economics and Policy, 24:2 (1990), 119-137; and David L. Greene, James R. Kahn, and Robert C. Gibson, "Fuel Economy Rebound Effect for Household Vehicles," The Energy Journal, 20:3 (1999), 1-21.

[245] In the most recent light truck CAFE rulemaking, NHTSA chose not to preference the Small and Van Dender study over other published estimates of the value of the rebound effect, stating that since it "remains an unpublished working paper that has not been subjected to formal peer review, …the agency does not yet consider the estimates it provides to have the same credibility as the published and widely-cited estimates it relied upon." *See* 71 FR 17633 (Apr. 6, 2006). The study has subsequently been published and peer-reviewed, so NHTSA is now prepared to "consider it in developing its own estimate of the rebound effect for use in subsequent CAFE rulemakings."

covered by this rulemaking. However, we do not believe that evidence of the rebound effect's dependence on fuel prices or household income is sufficiently convincing to justify allowing its future value to vary in response to forecast changes in these variables. A range extending from 10 percent to at least 20 percent appears to be appropriate for the required analysis of the uncertainty surrounding these estimates.

NHTSA has updated the 29 estimates from studies that allowed the rebound effect to vary to reflect current (2008 to date) fuel prices, fuel economy, vehicle ownership levels, and household income. The resulting updated estimates are significantly higher than those reported in the NPRM, primarily because of the large increase in fuel prices since 2006 (the date to which the estimates reported in the NPRM were updated). The updated 2008 estimates of the fuel economy rebound effect range from 8 percent to 46 percent, with a median value of 19 percent. Using the average retail gasoline price forecast for 2011-30 from the AEO 2008 High Price case, the projected estimates of the rebound effect for those years would range from 7 percent to 46 percent, with a median value of 19 percent. Finally, NHTSA notes that the forecast of fuel prices used to develop its adopted CAFE standards for model years 2011 projects that retail gasoline prices will continue to rise by somewhat more than 1 percent annually over the lifetimes of vehicles affected by those standards. At the same time, real household incomes are projected to grow by about 2 percent annually over this same period. Given the relative sensitivity of the Small and Van Dender rebound effect estimate to changes in fuel prices and income, these forecasts suggest that future growth in fuel prices is likely to offset a significant fraction of the projected decline in the rebound effect that would result from income growth.

In light of these results, NHTSA has elected to continue to use a 15 percent rebound effect in its analysis of fuel savings and other benefits from higher CAFE standards for this final rule. Recognizing the uncertainty surrounding this estimate, the agency has analyzed the sensitivity of its benefits estimates to a range of values for the rebound effect from 10 percent to 20 percent. In its future CAFE rulemaking activities, NHTSA plans to prepare detailed year-by-year forecasts of the magnitude of the rebound effect using the published studies it regards as most reliable, in conjunction with forecasts of fuel prices, household income growth, and vehicle ownership levels. This analysis will indicate whether the combined effect of future changes in the factors that past research has shown to influence the rebound effect is likely to be an increase or a reduction in its future magnitude. NHTSA will base the estimate of the rebound effect it employs in analyzing future CAFE standards on the projected future values of the rebound effect over the lifetimes of vehicles affected by those standards.

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.[246]

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.[247] 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 2011-2018 passenger cars and MY 2012-18 light trucks.

Benefits from Fuel Savings

The main source of economic benefits from a fuel economy standard is the value of the resulting fuel savings over the lifetimes of vehicles that are required to comply with the stricter standards. These fuel savings for each scenario are measured by the difference between the adjusted baseline fuel economy for each model year and the fuel economy levels corresponding to that alternative. The sum of these annual fuel savings over each calendar year that a vehicle remains in service represents the cumulative fuel savings resulting from applying the alternative to vehicles produced during that model year.

As previously noted, 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.[248]

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.[249] The agency has employed EPA's revised estimate of this on-road fuel economy gap in

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[246] 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.

[247] 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.

[248] 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.

[249] 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.

its analysis of the fuel savings resulting from alternative CAFE standards for MY 2011-2018 passenger cars and MY 2012-18 light trucks.

The number of light vehicles manufactured during each model year that remains in service during each subsequent calendar year is estimated by multiplying the estimated proportions of vehicles expected to survive to each age up to 26 years for passenger cars (Table VIII-3a) and 36 years for light trucks (Table VIII-3b) by the number of cars and light trucks forecast to be produced during each year. 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.[250] Updated estimates of average annual miles driven by vehicle age were developed from the Federal Highway Administration's 2001 National Household Transportation Survey, and these also differ from the estimates of annual mileage employed in past NHTSA analyses.[251] The total number of miles driven by vehicles of a single model year during each year of its life span in the fleet in effect is estimated by multiplying these age-specific estimates of annual miles driven per vehicle by the number of vehicles projected to remain in service at each age.

Table VIII-3a and VIII-3b provide the new schedules of vehicle miles traveled and survivability based on updated analyses performed by NHTSA. These were developed from registration data for 1977 through 2003, and from a 2001 survey of household vehicle use. In this analysis, the maximum vehicle age was defined as the age when the number remaining in service has declined to approximately two percent of the vehicles originally produced. Based on and examination of recent registration data for older model years, typical maximum ages appear to be 26 years for passenger cars and 36 years for light trucks. Using the 36-year estimate of the maximum lifetimes of light trucks results in survival-weighted or "expected" lifetime mileage of 190,066 miles. Fuel savings and other benefits resulting from higher light truck CAFE standards are calculated over this expected 36 year lifetime and total mileage. In contrast, NHTSA's previous estimate of lifetime VMT in the 2006 final rule was 179,954 miles over a 36-year lifetime for light trucks. The resulting survival-weighted mileage over the 26-year maximum lifetime of passenger cars is 161,847 miles, and fuel savings and other benefits resulting from higher passenger car CAFE standards are calculated over this 26-year lifetime and total mileage. It should be noted, however, that survival-weighted VMT is extremely low (less than 1,000 miles per year) after age 20 for cars and age 25 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.

The primary source of data for determining vehicles in operation is the National Vehicle Population Profile (NVPP) compiled by R.L. Polk and Company. The NVPP is an annual census, as of July 1 of each year, of passenger cars and light trucks registered for on-road operation in the United States. NVPP registration data was used from vehicle model years 1977

[250] The survival rates were calculated from R.L. Polk, National Vehicle Population Profile, 1977-2003; see NHTSA, "Vehicle Survivability and Travel Mileage Schedules," Office of Regulatory Analysis and Evaluation, NCSA, January 2006, pp. 9-11, Docket No. 22223-2218.

[251] See also NHTSA, "Vehicle Survivability and Travel Mileage Schedules," Office of Regulatory Analysis and Evaluation, January 2006, pp. 15-17.

to 2003. Survival rates were averaged for the five most recent model years for vehicles up to 20 years old, and regression models were fitted to these data to develop smooth relationships between age and the proportion of cars or light trucks surviving to that age. The survival rates predicted by these models are used to develop the estimates of annual mileage and fuel consumption used to calculate fuel savings and other impacts of higher fuel economy.

The 2001 National Household Travel Survey (NHTS) sponsored by the Federal Highway Administration, Bureau of Transportation Statistics, and the National Highway Traffic Safety Administration attempted to develop up-to-date information on household vehicle ownership and use. The NHTS is the integration of two previous national travel surveys: the Federal Highway Administration-sponsored Nationwide Personal Transportation Survey (NPTS) and the Bureau of Transportation Statistics-sponsored American Travel Survey (ATS).[252] The 2001 NHTS was the source of updated information on annual miles driven by age for passenger cars and light trucks.

Finally, it should be noted that the estimates of average annual miles driven by passenger cars and light trucks, while new for NHTSA, are based on data collected during 2001-2002, and reflect the historically low gasoline prices that prevailed at the time the survey was conducted. To account for the effect on vehicle use of subsequent increases in fuel prices, the estimates of annual vehicle use derived from the NHTS are adjusted to reflect projected future gasoline prices using the rebound effect, which is discussed in detail later in this chapter. Two factors affect the cost of gasoline per mile driven - fuel prices per gallon, and fuel economy in miles-per-gallon. Because the intensity of vehicle use depends partly on the cost per mile of driving, the estimates of vehicle use developed from NHTS data reflect both fuel prices and fuel economy levels that prevailed during 2001 and 2002, when the survey was conducted. In analyzing the final rule, the agency adjusted the annual usage estimates derived from the NHTS data to reflect the effect of the higher EIA fuel prices that are forecast over the covered vehicles' expected lifetimes, which exceed those that existed during 2001-2002.

Specifically, the adjustment accounted for the difference between the average price per gallon of fuel forecast over the expected lifetimes of model year 2011 passenger cars and light trucks[253] and the average price that prevailed during 2000 and 2001. When expressed in percentage terms, this difference was assumed to represent the percent increase in fuel cost per mile driven between the time the survey was conducted and the time period when model year 2011 passenger cars and light trucks would be in service.

The same elasticity of annual vehicle use with respect to fuel cost per mile that was used to estimate the increase in vehicle use resulting from improved fuel economy (see detailed discussion of the "rebound effect" earlier in this chapter), assumed to be –0.15, was applied to this percent difference to adjust the estimates of vehicle use derived from the survey to reflect the effect of higher future fuel prices. In contrast, this adjustment reduces model year 2011 passenger cars' and light trucks' average annual usage at each age to account for the fact that fuel cost per mile driven is expected to be higher throughout their expected lifetimes than at the time the NHTS was conducted. The results of this adjustment are shown in Table VIII-2c for passenger cars and in Table VIII-2d for light trucks. The unadjusted average lifetime mileage is estimated to be 161,847 for passenger cars and 190,066 for

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[252] For details on survey coverage and procedures, see http://nhts.ornl.gov/quickStart.shtml.
[253] Based on the AEO High price forecast from the AEO 2008 report.

light trucks. After adjusting for the rebound effect, the average lifetime mileage is estimated to be 146,547 for passenger cars and 171,590 for light trucks.

Table VIII-3a
Survival Rates and Unadjusted Annual Vehicle-Miles Traveled (VMT)
by Age for Passenger Cars

Vehicle Age	Estimated Survivability (1977 to 2002 NVPP)	Estimated VMT (2001 NHTS)	Weighted Yearly Travel Miles
1	0.9950	14,231	14,160
2	0.9900	13,961	13,821
3	0.9831	13,669	13,438
4	0.9731	13,357	12,998
5	0.9593	13,028	12,497
6	0.9413	12,683	11,938
7	0.9188	12,325	11,324
8	0.8918	11,956	10,662
9	0.8604	11,578	9,961
10	0.8252	11,193	9,237
11	0.7866	10,804	8,499
12	0.7170	10,413	7,466
13	0.6125	10,022	6,138
14	0.5094	9,633	4,907
15	0.4142	9,249	3,831
16	0.3308	8,871	2,934
17	0.2604	8,502	2,214
18	0.2028	8,144	1,652
19	0.1565	7,799	1,220
20	0.1200	7,469	896
21	0.0916	7,157	656
22	0.0696	6,866	478
23	0.0527	6,596	348
24	0.0399	6,350	253
25	0.0301	6,131	185
26	0.0227	5,940	135
Estimated Passenger Car Lifetime VMT			161,847

Table VIII-3b
Survival Rates and Unadjusted Annual Vehicle-Miles Traveled (VMT)
by Age for Light Trucks

Vehicle Age	**Estimated Survivability (1977 to 2002 NVPP)**	**Estimated VMT (2001 NHTS)**	**Weighted Yearly Travel Miles**
1	0.9950	16,085	16,004
2	0.9741	15,782	15,374
3	0.9603	15,442	14,829
4	0.9420	15,069	14,195
5	0.9190	14,667	13,479
6	0.8913	14,239	12,691
7	0.8590	13,790	11,845
8	0.8226	13,323	10,960
9	0.7827	12,844	10,053
10	0.7401	12,356	9,145
11	0.6956	11,863	8,252
12	0.6501	11,369	7,391
13	0.6042	10,879	6,573
14	0.5517	10,396	5,735
15	0.5009	9,924	4,971
16	0.4522	9,468	4,281
17	0.4062	9,032	3,669
18	0.3633	8,619	3,131
19	0.3236	8,234	2,665
20	0.2873	7,881	2,264
21	0.2542	7,565	1,923
22	0.2244	7,288	1,635
23	0.1975	7,055	1,393
24	0.1735	6,871	1,192
25	0.1522	6,739	1,026
26	0.1332	6,663	887
27	0.1165	6,648	774
28	0.1017	6,648	676
29	0.0887	6,648	590
30	0.0773	6,648	514
31	0.0673	6,648	447
32	0.0586	6,648	390
33	0.0509	6,648	338
34	0.0443	6,648	294
35	0.0385	6,648	256
36	0.0334	6,648	222
Estimated Lifetime Light Truck VMT			190,066

Table VIII-3c
Survival Rates and Annual Vehicle-Miles Traveled (VMT) Adjusted for Rebound Effect by Age for Passenger Cars

Vehicle Age	Estimated Survivability	Adjusted VMT	Weighted Yearly Travel Miles
1	0.9950	12,885	12,821
2	0.9900	12,641	12,515
3	0.9831	12,377	12,167
4	0.9731	12,094	11,769
5	0.9593	11,796	11,316
6	0.9413	11,484	10,810
7	0.9188	11,160	10,253
8	0.8918	10,825	9,654
9	0.8604	10,483	9,020
10	0.8252	10,135	8,363
11	0.7866	9,783	7,695
12	0.7170	9,429	6,760
13	0.6125	9,075	5,558
14	0.5094	8,722	4,443
15	0.4142	8,374	3,469
16	0.3308	8,032	2,657
17	0.2604	7,698	2,005
18	0.2028	7,374	1,495
19	0.1565	7,061	1,105
20	0.1200	6,763	812
21	0.0916	6,481	594
22	0.0696	6,217	433
23	0.0527	5,972	315
24	0.0399	5,750	229
25	0.0301	5,551	167
26	0.0227	5,379	122
Adjusted Lifetime Passenger Car VMT			146,547

Table VIII-3d
Survival Rates and Annual Vehicle-Miles Traveled (VMT) Adjusted for rebound Effect
by Age for Light Trucks

Vehicle Age	Estimated Survivability	Adjusted VMT	Weighted Yearly Travel Miles
1	0.9950	14,521	14,449
2	0.9741	14,248	13,879
3	0.9603	13,941	13,388
4	0.9420	13,604	12,815
5	0.9190	13,241	12,168
6	0.8913	12,855	11,457
7	0.8590	12,449	10,694
8	0.8226	12,028	9,895
9	0.7827	11,596	9,076
10	0.7401	11,155	8,256
11	0.6956	10,710	7,450
12	0.6501	10,264	6,673
13	0.6042	9,821	5,934
14	0.5517	9,385	5,178
15	0.5009	8,960	4,488
16	0.4522	8,548	3,865
17	0.4062	8,154	3,312
18	0.3633	7,781	2,827
19	0.3236	7,434	2,406
20	0.2873	7,115	2,044
21	0.2542	6,829	1,736
22	0.2244	6,579	1,476
23	0.1975	6,369	1,258
24	0.1735	6,203	1,076
25	0.1522	6,084	926
26	0.1332	6,015	801
27	0.1165	6,001	699
28	0.1017	6,001	610
29	0.0887	6,001	532
30	0.0773	6,001	464
31	0.0673	6,001	404
32	0.0586	6,001	352
33	0.0509	6,001	305
34	0.0443	6,001	266
35	0.0385	6,001	231
36	0.0334	6,001	200
Adjusted Lifetime Light Truck VMT			171,590

In interpreting the survivability and annual mileage estimates reported in Tables VIII-2a through VIII-2d, it is important to understand that vehicles are considered to be of age 1 during the calendar year that coincides with their model year   Thus for example, model year 2010 vehicles will be considered to be of age 1 during calendar year 2010. This convention is used in order to account for the fact that vehicles produced during a model year typical are first offered for sale in June through September of the preceding calendar year (for example, sales of a model year typically begin in June through September of the previous 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.[254] As an illustration, virtually the entire production of model year 2008 vehicles will have been sold and placed in service by the end of calendar year 2008, so model year 2008 vehicles are defined to be of age 1 during calendar year 2008.Model year 2008 vehicles are subsequently defined to be of age 2 during calendar year 2009, age 3 during calendar year 2010, and so on, until they reach their maximum age of 36 years in calendar year 2043 (2008 + 35 = 2043).

To determine the impact of improved CAFE standards, fuel consumption is calculated using both current and revised CAFE levels. The difference between these estimates represents the net savings from increased CAFE standards. With the current CAFE standard assumed to remain in effect, total fuel consumption by each model year's vehicles during each calendar year they remain in service is calculated by dividing the total number of miles they are driven during that year by the average on-road fuel economy level they would achieve under the higher of either the manufacturer-specific standard or their production plans. With the final rule in effect, total fuel consumption by each model year's vehicles during each future calendar year is calculated by dividing the total number of miles they are driven by the higher on-road fuel economy level associated with that stricter CAFE standard. The total number of miles that vehicles are driven each year is different under the final rule than with the current standards remaining in effect as a result of the fuel economy "rebound effect," which is discussed in detail later in this chapter.

The economic benefits to vehicle owners that result from future fuel savings are valued in this analysis over the complete expected lifetimes of the vehicles affected by the final rule. This reflects the assumption that while the purchaser and first owner of a new vehicle might not realize the full lifetime benefits of improved fuel economy, subsequent owners of that same vehicle will continue to experience the resulting fuel savings until the vehicle is retired from service. It is important to note, however, that not all vehicles produced during a model year remain in service for the complete lifetime (26-year for passenger cars or 36 –year for light trucks) of each model year assumed in this analysis. Due to the pattern of vehicle retirement over this period, the expected or average lifetime of a representative vehicle is approximately half of that figure.

CAFE's most immediate impacts are on individual consumers, but regulating fuel economy also has a broader societal impact that must be considered. The agency believes that CAFE standards should reflect the true economic value of resources that are saved when less fuel is produced and

[254] 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.

consumed, higher vehicle prices, and, to the extent possible, any externalities that impact the broader society. Consumers' perceptions of these values may differ from their actual impacts, but they will nonetheless experience the full value of actual fuel savings just as they will pay the full increased cost when the vehicle is purchased.

Moreover, the first and any subsequent owners of a vehicle will together realize these savings throughout its entire on-road lifetime. While a vehicle's buyer may only experience fuel savings for the limited time he or she typically owns that vehicle, any subsequent purchasers and owners of that used vehicle will continue to experience the fuel savings resulting from its higher fuel economy throughout the remainder of its useful life. The agency restricts its analysis of the sales impacts of higher new vehicle prices to the length of time the buyers of new vehicles typically own the vehicles they purchase, under the assumption that their purchase decisions will be influenced only by the benefits they receive during the time they expect to own the vehicles they purchase new. The agency estimates the length of this period using the average term of new car loans, which has recently averaged almost exactly 5 years.[255] However, the agency believes that the value of fuel savings resulting from more efficient operation over the entire lifetime of vehicles should be reflected in its analysis of the societal impacts that will determine fuel economy standards.

As noted in Chapter 1, the economic value of fuel savings resulting from the final rule is estimated by applying the forecast of future fuel prices from the High Price Case from the Energy Information Administration's *Annual Energy Outlook 2008* to each future year's estimated fuel savings.[256] (The uncertainty analysis reported in Chapter X uses fuel price forecasts from the Low and Reference Oil Price Scenarios included in *AEO 2008* to examine the effects a range of possible fuel price scenarios) The *AEO 2008* forecast of future fuel prices, which is reported in Table VIII-4, represents retail prices per gallon of fuel, which includes 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 price are necessary in order to reflect the economic value of fuel savings to society as a whole.

First, Federal and State 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 one segment of the population to another. Any reduction in State and Federal fuel tax payments by consumers 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 provided to society.

Second, the economic cost of externalities generated by imports and consumption of petroleum products will be reduced in proportion to gasoline savings resulting from the final rule. The

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[255] This estimate is derived from Federal Reserve Board, Federal Reserve Statistical Release G. 19: Consumer Credit, November 7, 2007, http://www.federalreserve.gov/releases/g19/Current/.

[256] U.S. Department of Energy, Energy Information Administration, *Annual Energy Outlook 2008*, High Price Case Table 12, http://www.eia.doe.gov/oiaf/aeo/excel/aeohptab_12.xls.

estimated economic value of these externalities 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 from reduced fuel production and use, which represents the most important component of the social benefits from saving gasoline. A discussion of these externality values is included in the next section of this chapter

Table VIII-4 illustrates the adjustment of forecast retail fuel prices to remove the value of fuel taxes and add the value of economic externalities from petroleum imports and use. The derivation of the estimated value of reduced economic externalities from petroleum use shown in the table is explained in detail in the following section. While the High Price Case fuel price forecasts reported in *AEO 2008* extend through 2030, the agency's analysis of the value of fuel savings over the 26-year maximum lifetimes of MY 2011 passenger cars and 36-year maximum lifetimes MY 2011 light trucks requires forecasts extending through calendar year 2050. The agency assumes that retail fuel prices will remain at the 2030 forecast values reported in the *AEO 2008 High Price* Case forecast over the period from 2030 through 2052 (in constant-dollar terms). As Table VIII-4 shows, the projected retail price of gasoline expressed in 2007 dollars rises steadily over most of the forecast period, from $2.95 in 2011 to $3.51 in 2024, and then decreasing for a few years until it reaches $3.62 in 2030. As mentioned above, it is assumed to remain at that level through 2052.

Since gasoline taxes are a transfer payment and not a societal cost, the value of gasoline taxes is subtracted from the estimated gasoline price to estimate the value to society of saving gasoline. The agency has updated its estimates of gasoline taxes, using updated State tax rates reported for January 1, 2006[257] expressed in 2007 dollars, Federal gasoline taxes are currently $0..184, while State and local gasoline taxes together average $0.236 per gallon, for a total tax burden of $0.420 per gallon.

Following the assumptions used by EIA in its National Energy Modeling System (NEMS), state and local gasoline taxes are assumed to keep pace with inflation in nominal terms, and thus to remain constant when expressed in constant 2007dollars. In contrast, federal gasoline taxes are assumed to remain unchanged in nominal terms, and thus to decline throughout the forecast period when expressed in constant 2007 dollars. These differing assumptions about the likely future behavior of federal and state/local fuel taxes are consistent with recent historical experience, and reflect the fact that Federal motor fuel taxes and most State 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.

Actual fuel economy levels achieved by light-duty vehicles in on-road driving fall somewhat 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 CAFE standards, NHTSA has previously adjusted the actual fuel economy performance of each light truck model downward from its rated value to reflect the expected size

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[257] FHWA, ***Highway Statistics 2006***, Section I: Motor Fuel -- Rates and Revenues, Table MF-121T, available at http://www.fhwa.dot.gov/policy/ohim/hs06/pdf/mf121t.pdf.

of this on-road fuel economy "gap." On December 27, 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.[258]

In its Final Rule, EPA estimated that actual on-road fuel economy for light-duty vehicles averages 20 percent lower than published fuel economy levels. 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). NHTSA has employed EPA's revised estimate of this on-road fuel economy gap in this analysis of the fuel savings resulting from alternative CAFE standards proposed in this rulemaking.

[258] 71 FR 77871 (Dec. 27, 2006).

Table VIII-4
Adjustment of Forecast Retail Gasoline Price to Reflect Social Value of Fuel Savings

Year	AE0 2008 Forecast of Retail Gasoline Price (2007 $/gallon)	Estimated Federal and State Taxes (2007 $/gallon)	Forecast Gasoline Price Excluding Taxes (2007 $/gallon)	Forecast Gasoline Price Including Externalities (2007 $/gallon)
2011	$2.949	$0.420	$2.529	$2.911
2012	$2.974	$0.416	$2.558	$2.939
2013	$3.023	$0.412	$2.611	$2.993
2014	$3.077	$0.409	$2.668	$3.049
2015	$3.093	$0.405	$2.688	$3.069
2016	$3.138	$0.402	$2.736	$3.117
2017	$3.200	$0.399	$2.801	$3.182
2018	$3.241	$0.395	$2.846	$3.228
2019	$3.301	$0.392	$2.909	$3.291
2020	$3.363	$0.388	$2.975	$3.357
2021	$3.451	$0.385	$3.066	$3.447
2022	$3.491	$0.381	$3.110	$3.491
2023	$3.492	$0.378	$3.114	$3.496
2024	$3.510	$0.374	$3.136	$3.518
2025	$3.485	$0.371	$3.114	$3.496
2026	$3.494	$0.371	$3.123	$3.504
2027	$3.518	$0.371	$3.147	$3.529
2028	$3.545	$0.371	$3.174	$3.555
2029	$3.576	$0.371	$3.205	$3.586
2030-2052	$3.618	$0.371	$3.247	$3.628

Other Economic Benefits from Reducing Petroleum Use

The agency believes that assessing the economic case for increasing the stringency of fuel economy standards requires a comprehensive analysis of the resulting benefits and costs to the U.S economy, rather than simply comparing the direct costs associated with petroleum use and fuel production to current fuel taxes. The benefits of more stringent fuel economy standards include the market value of the savings in resources from producing less fuel, together with the resulting reductions in the costs of economic externalities associated with petroleum consumption, and of environmental externalities caused by fuel consumption and production. Environmental externalities include adverse health impacts associated with criteria pollutants and environmental damage associated with greenhouse gases. The costs imposed on the U.S. economy by more stringent fuel economy regulation include those costs for manufacturing more fuel-efficient vehicles, as well as the increased external costs of congestion, crashes, noise and pollution from added driving caused by the rebound effect.

Vehicle buyers value improved fuel economy using retail fuel prices and miles per gallon, but may consider fuel savings only over the time they expect to own a vehicle, while the value to the U.S. economy of saving fuel is measured by its pre-tax price, and includes fuel savings over the entire lifetime of vehicles. Thus, it cannot simply be assumed that the interaction of manufacturers' costs and vehicle buyers' demands in the private marketplace will determine optimal fuel economy levels, and that these levels should only be adjusted by Federal regulation if the external costs of fuel production and use exceed current fuel taxes.

The Agency's analysis estimates the value of each category of benefits and costs separately, and it compares the total benefits resulting from each alternative level to its total costs in order to assess its desirability. This more complete accounting of benefits and costs to the U.S. economy from reducing fuel use is necessary to assess the case for fuel economy regulation generally, and for increasing the stringency of the current passenger car and light truck fuel economy standards in particular.

U.S. consumption and imports of petroleum products also impose 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. Higher U.S. imports of crude oil or refined petroleum products 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 U.S. imports of crude petroleum or refined fuels or reducing fuel consumption can reduce these external costs. Any reduction in their total value that results from improved vehicle fuel economy represents an economic benefit of raising fuel economy standards in addition to the value of fuel savings and emissions reductions itself.

Demand costs

Increased U.S. oil imports 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 price. The effect of U.S. petroleum imports 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 exerted by the U.S. The combination 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.[259] 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."

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[259] 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-

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.[260] 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.[261]

In analyzing benefits from its recent actions to increase 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.[262] More recently, ORNL 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. [263] These include world oil prices, current and anticipated future levels of OPEC petroleum production, U.S. oil import levels, the estimated responsiveness of oil supplies and demands to prices in different regions of the world, and the likelihood of oil supply disruptions. ORNL's prepared its updated estimates of oil import externalities were for use by EPA in evaluating the benefits of reductions in U.S. oil consumption and imports expected to result from its recently-issued Renewable Fuel Standard Rule of 2007 (RFS)[264].

The updated ORNL study was subjected to a detailed peer review and its estimates of the value of oil import externalities were subsequently revised to reflect their comments and recommendations. [265] 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. After making

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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.

[260] 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://dmses.dot.gov/docimages/pdf93/343894_web.pdf (last accessed Dec. 2, 2007).
[261] *Id.*, at 18-19.
[262] 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://dmses.dot.gov/docimages/pdf93/343894_web.pdf (last accessed Dec. 2, 2007).

[263] 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://pzl1.ed.ornl.gov/energysecurity.html (click on link below "Oil Imports Costs and Benefits") (last accessed Sept. 10, 2007).
[264] Federal Register Vol.72, #83, May 1, 2007 pp.23,900-24,014
[265] *Peer Review Report Summary: Estimating the Energy Security Benefits of Reduced U.S. Oil Imports*, ICF, Inc., September 2007.

the revisions recommended by peer reviewers, ORNL's updated estimates of the monopsony cost associated with U.S. oil imports range from $2.77 to $13.11per barrel, with a most likely estimate of $7.41 per barrel (2005$). These estimates imply that each gallon of fuel saved as a result of adopting higher CAFE standards will reduce the monopsony costs of U.S. oil imports by $0.066 to $0.312 per gallon, with the actual value most likely to be $0.176 per gallon saved (2005$). The agency notes, however, that the monopsony cost varies directly with world oil prices, and that the forecast of world oil prices used in this analysis differs significantly from that assumed in the ORNL study. Thus NHTSA has further adjusted the updated ORNL estimate of the monopsony cost to reflect the AEO 2008 High Price case forecast of world oil prices, which averages $88 per barrel (in 2007 dollars) over the period from 2011-30. Expressed in 2007 dollars, NHTSA's revised estimates of the reductions in monopsony costs are $0.266 per gallon of fuel saved. This represents an economic benefit in addition to the value of savings in fuel production costs that would result from improving fuel economy.

Disruption and Adjustment Costs

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 these expected disruption costs resulting from a measure that lowers U.S. oil imports represents an additional economic benefit 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 thought 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 oil imports, the expected value of the costs from a supply disruption will also depend on the level of imports.

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 likely reduced the potential costs of disruptions to the supply of imported oil, consumers of petroleum products are unlikely to take account of costs they impose on others, so these costs are probably not 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 during the 1970s.

ORNL's updated and revised estimates of the increase in the expected costs associated with oil supply disruptions to the U.S. and the resulting rapid increase in prices for petroleum products amount to $2.10 to $7.40 per barrel, although its most likely estimate of $4.59 per barrel is very close to the lower end of this range. According to these estimates, each gallon of fuel saved will reduce the expected costs disruptions to the U.S. economy by $0.050 to $0.176, with the actual value most likely to be $0.109 per gallon (2005$). Updated to 2007 dollars, the value of oil supply disruptions is estimated to be $.116 per gallon. Like the reduction in monopsony costs, the reduction in expected disruption costs represents an economic benefit in addition to the value of savings in fuel production costs that would result from improving fuel economy.

Military Security and Strategic Petroleum Reserve Costs

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 to protect against their interruption. Some analysts also include outlays for maintaining the U.S. Strategic Petroleum Reserve (SPR), which is intended to cushion the U.S. economy against the consequences of disruption in the supply of imported oil, as additional costs of protecting the U.S. economy from oil supply disruptions.

NHTSA currently 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 concludes 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.

Nevertheless, the agency conducted a sensitivity analysis of the potential effect of assuming that some reduction military spending would result from fuel savings and reduced petroleum imports in order to investigate its impacts on the standards and fuel savings. Assuming that the preceding estimate of total U.S. military costs for securing Persian Gulf oil supplies is correct, and that approximately half of these expenses could be reduced in proportion to a reduction in U.S. oil imports from the region, the estimated savings would range from $0.02 to $0.08 (in 2007 dollars) for each gallon of fuel savings that was reflected in lower U.S. imports of petroleum from the Persian Gulf. 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 $0.05 per gallon, the midpoint of this range. NHTSA employs this estimate in its sensitivity analysis.

Similarly, while the optimal size of the SPR 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 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 agencies' analysis of benefits from alternative CAFE standards does not include cost savings from either reduced outlays for U.S. military operations or maintaining a smaller SPR among the external benefits of reducing gasoline consumption and petroleum imports by means of tightening future standards. 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 for these purposes are unlikely to result form modest reductions in consumption of petroleum products and oil imports.

Thus, for purposes of setting the MY 2011 standards, NHTSA has included only the likely reductions in monopsony and disruption costs from lower U.S. petroleum imports in its estimate of the savings in external economic costs from reducing fuel consumption. The updated and revised ORNL estimates suggest that the combined reduction in monopsony costs and expected costs to the U.S. economy from oil supply disruptions resulting from lower fuel consumption total $0.152 to $0.657 per gallon, with a most likely estimate of $0.381 per gallon. This represents the additional economic benefit likely to result from each gallon of fuel saved by higher CAFE standards, *beyond* the savings in resource costs for producing and distributing each gallon of fuel saved. NHTSA employed this estimate in its analysis of the benefits from fuel savings projected to result from alternative CAFE standards for model year 2011.

<u>The Effect of Fuel Savings on Fuel Supply</u>

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 2008*, the agency 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. 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. 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.[266]

Emissions Reductions Resulting from Fuel Savings

Emissions of carbon dioxide and other greenhouse gases (GHGs) occur throughout the process of producing and distributing transportation fuels, as well as from fuel combustion itself. By reducing the volume of fuel consumed by passenger cars and light trucks, higher CAFE standards will thus reduce GHG emissions generated by fuel use, as well as throughout the fuel supply cycle. Lowering these emissions is likely to slow the projected pace and reduce the ultimate extent of future changes in the global climate, thus reducing future economic damages that changes in the global climate are otherwise expected to cause. Further, by reducing the probability that climate changes with potentially catastrophic economic or environmental impacts will occur, lowering GHG emissions may also result in economic benefits that exceed the resulting reduction in the expected future economic costs caused by gradual changes in the earth's climatic systems.

Quantifying and monetizing benefits from reducing GHG emissions is thus an important step in estimating the total economic benefits likely to result from establishing higher CAFE standards. Since direct estimates of the economic benefits from reducing GHG emissions are generally not reported in published literature on 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. That is, the benefits from reducing emissions are usually measured by the savings in estimated economic damages that an equivalent increase in emissions would otherwise have caused.

Researchers usually estimate the economic costs of increased GHG emissions in several steps. The first is to project future changes in the global climate and the resulting economic damages that are expected to result under a baseline projection of net global GHG emissions. These projections are usually developed using models that relate concentrations of GHGs in the earth's atmosphere to changes in summary measures of the global climate such as temperature and sea levels, and in turn estimate the reductions in global economic output that are expected to result from changes in climate. Since the effects of GHG emissions on the global climate occur decades or even centuries later, and there is considerable inertia in the earth's climate systems, changes in the global climate and the resulting economic impacts must be estimated over a comparably long future period.

Next, this same process is used to project future climate changes and resulting economic damages under the assumption that GHG emissions increase by some increment during a stated future year. The increase in projected global economic damages resulting from the assumed

[266] This figure is calculated as 0.50 + 0.50*0.9 = 0.50 + 0.45 = 0.95.

increase in future GHG emissions, which also occurs over a prolonged period extending into the distant future, represents the added economic costs resulting from the assumed increase in emissions. Discounted to its current value as of the year when the increase in emissions are expected to occur and expressed per unit of GHG emissions (usually per ton of carbon emissions, with non-CO_2 GHGs converted to their equivalents in terms of carbon emissions), the resulting value represents the global economic cost of increasing GHG emissions by one unit – usually a metric ton of carbon – in a stated future year. This value is often referred to in published research and debates over climate policy as the Social Cost of Carbon (SCC), and applies specifically to increased emissions during that year.

This process involves multiple sources of uncertainty, including those in scientific knowledge about the effects of varying levels of GHG emissions on the magnitude and timing of changes in the functioning of regional and global climatic and ecological systems. In addition, significant uncertainty surrounds the anticipated extent, geographic distribution, and timing of the resulting impacts on the economies of nations located in different regions of the globe. Because the climatic and economic impacts of GHG emissions are projected to occur over the distant future, uncertainty about the correct rate at which to discount these future impacts also significantly affects the estimated economic benefits of reducing GHG emissions.

Researchers have not yet been able to quantify many of the potentially significant effects of GHG emissions and their continued accumulation in the earth's atmosphere on the global climate. Nor have they developed complete models to represent the anticipated impacts of changes in the global climate on economic resources and the productivity with which they are used to generate economic output. As a consequence, the estimates of economic damages resulting from increased GHG emissions that are generated using integrated models of climate and economic activity exclude some potentially significant sources of costs that are likely to result from increased emissions. As a result, estimates of economic benefits derived from these models' estimates of the likely future climate-related economic damages caused by increased GHG emissions may underestimate the true economic value of reducing emissions, although the extent to which they are likely to do so remains unknown.

In the NPRM, NHTSA explained how it accounted for the economic benefits of reducing CO_2 emissions in this rulemaking, both in developing the proposed CAFE standards and in assessing the economic benefits of each alternative that was considered. The agency noted that the Ninth Circuit found in *CBD v. NHTSA* that NHTSA had been arbitrary and capricious in deciding not to monetize the benefit of reducing CO_2 emissions, stating that the agency had not substantiated the conclusion in its April 2006 final rule that the appropriate course was not to monetize (*i.e.*, quantify the value of) carbon emissions reduction at all. NHTSA's discussion in the NPRM of how it estimated the economic value of reductions in CO_2 emissions received a great deal of attention from commenters, so for the reader's benefit, it is largely reproduced below.

To that end, NHTSA reviewed published estimates of the "social cost of carbon" (SCC) emissions. As noted above, the SCC refers to the marginal cost of additional damages caused by the increase in expected climate impacts resulting from the emission of each additional metric ton of carbon, which is emitted in the form of CO_2.[267] It is typically estimated as the net present value of the impact over some extended time period (100 years or longer) of one additional ton of carbon emitted into the atmosphere. Because atmospheric concentrations of greenhouse gases are increasing over time, and the potential damages from global climate are believed to increase with higher atmospheric GHG concentrations, the economic damages resulting from an additional ton of CO_2 emissions are expected to increase over time. Thus, estimates of the SCC are typically reported for a specific year, and these estimates are generally larger for emissions in more distant future years.

NHTSA found substantial variation among different authors' estimates of the SCC, much of which can be traced to differences in their underlying assumptions about several variables. These variables include the sensitivity of global temperatures and other climate attributes to increasing atmospheric concentrations of GHGs, discount rates applied to future economic damages from climate change, whether damages sustained by developing regions of the world should be weighted more heavily than damages to developed nations, how long climate changes persist once they occur, and the economic valuation of specific climate impacts.[268]

NHTSA explained that, taken as a whole, recent estimates of the SCC may underestimate the true damage costs of carbon emissions because they often exclude damages caused by extreme weather events or climate response scenarios with low probabilities but potentially extreme impacts, and may underestimate the climate impacts and damages that could result from multiple stresses on the global climatic system. At the same time, however, many studies do not consider potentially beneficial impacts of climate change, and do not adequately account for how future technological innovations, development patterns, and adaptations could reduce potential impacts from climate change or the economic damages they cause.

Given the uncertainty surrounding estimates of the SCC, NHTSA suggested that the use of any single study may not be advisable, since its estimate of the SCC will depend on many assumptions made by its authors. NHTSA cited the Working Group II's contribution to the Fourth Assessment Report of the United Nations Intergovernmental Panel on Climate Change (IPCC) as noting that:

> The large ranges of SCC are due in large part to differences in assumptions regarding climate sensitivity, response lags, the treatment of risk and equity, economic and non-economic impacts, the inclusion of potentially catastrophic losses, and discount rates.[269]

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[267] Carbon itself accounts for 12/44, or about 27 percent, of the mass of carbon dioxide (12/44 is the ratio of the molecular weight of carbon to that of carbon dioxide). Thus, each ton of carbon emitted is associated with 44/12, or 3.67, tons of carbon dioxide emissions. Estimates of the SCC are typically reported in dollars per ton of carbon, and must be divided by 3.67 to determine their equivalent value per ton of carbon dioxide emissions.

[268] For a discussion of these factors, *see* Yohe, G.W., R.D. Lasco, Q.K. Ahmad, N.W. Arnell, S.J. Cohen, C. Hope, A.C. Janetos, and R.T. Perez, "Perspectives on climate change and sustainability," 2007, in Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, M.L. Parry, O.F. Canziani, L.P. Palutikof, P.J. van der Linden and C.E. Hanson, eds., Cambridge University Press, 2007, at 821-824. *Available at* http://www.ipcc.ch/ipccreports/ar4-wg2.htm (last accessed March 23, 2009).

[269] Climate Change 2007: Impacts, Adaptation and Vulnerability, Contribution of Working Group II to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, at 17. *Available at* http://www.ipcc.ch/ipccreports/ar4-wg2.htm (last accessed March 23, 2009).

Although the IPCC is considered authoritative on the topic of the SCC, it did not recommend a single estimate. However, the IPCC did cite the Tol (2005) study on four separate occasions as the only available survey of the peer-reviewed literature that has itself been subjected to peer review.[270] Tol developed a probability function using the SCC estimates of the peer-reviewed literature, which ranged from less than zero to over $200 per metric ton of carbon. In an effort to resolve some of the uncertainty in reported estimates of climate damage costs from carbon emissions, Tol (2005) reviewed and summarized 103 estimates of the SCC from 28 published studies. He concluded that when only peer-reviewed studies published in recognized journals are considered, "…climate change impacts may be very uncertain but it is unlikely that the marginal damage costs of carbon dioxide emissions exceed $50 per [metric] ton carbon,"[271] which is about $14 per metric ton of CO_2. In the NPRM, NHTSA assumed that the summary SCC estimates reported by Tol were denominated in U.S. dollars of the year of his article's publication, 2005.

NHTSA stated that because of the number of assumptions required by each study, the wide range of uncertainty surrounding these assumptions, and their critical influence on the resulting estimates of climate damage costs, some studies have undoubtedly produced estimates of the SCC that are unrealistically high, while others are likely to have estimated values that are improbably low. Using a value for the SCC that reflects the central tendency of estimates drawn from many studies reduces the chances of relying on a single estimate that subsequently proves to be biased.

It is important to note that the published estimates of the SCC almost invariably include the value of worldwide damages from potential climate impacts caused by carbon dioxide emissions, and are not confined to damages likely to be suffered within the U.S. In contrast, the other estimates of costs and benefits of raising fuel economy standards included in this proposal include only the economic values of impacts that occur within the U.S. For example, the economic value of reducing criteria air pollutant emissions from overseas oil refineries is not counted as a benefit resulting from this rule, because any reduction in damages to health and property caused by overseas emissions are unlikely to be experienced within the U.S.

In contrast, the reduced value of transfer payments from U.S. oil purchasers to foreign oil suppliers that results when lower U.S. oil demand reduces the world price of petroleum (the reduced "monopsony effect") is counted as a benefit of reducing fuel use.[272] The agency state that if its analysis were conducted from a worldwide rather than a U.S. perspective, however, the benefit from reducing air pollution overseas would be included, while reduced payments from U.S. oil consumers to foreign suppliers would not.

In the NPRM, NHTSA tentatively concluded that in the interest of analytical consistency, *i.e.*, in order to be consistent with the agency's use of exclusively domestic costs and benefits in prior CAFE rulemakings, the appropriate value to be placed on climate damages caused by carbon emissions should be the one that reflects the change in damages to the U.S. alone. Accordingly,

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[270] *Id.*, at 17, 65, 813, and 822.
[271] Tol, Richard S.J., "The marginal damage costs of carbon dioxide emissions: an assessment of the uncertainties," Energy Policy 33 (2005), 2064-2074, at 2072.
[272] The reduction in payments from U.S. oil purchasers to domestic petroleum producers is not included as a benefit, however, since it represents a transfer that occurs entirely within the U.S. economy.

NHTSA noted that the value for the benefits of reducing CO_2 emissions might be restricted to the fraction of those benefits that are likely to be experienced within the U.S.

Although no estimates are currently available for the benefits to the U.S. itself that are likely to result from reducing CO_2 emissions, NHTSA explained that it expected that if such values were developed, the agency would employ those, rather than global benefit estimates, in its analysis. NHTSA also stated that it anticipated that if such values were developed, they would be lower than comparable global values, since the U.S. is likely to sustain only a fraction of total global damages resulting from climate change.

In the meantime, NHTSA explained that it elected to use the mean value of peer-reviewed estimated global value reported by Tol (2005), which was $43 per metric ton of carbon, as an upper bound on the global benefits resulting from reducing each metric ton of U.S. emissions.[273] This value corresponds to approximately $12 per metric ton of CO_2 when expressed in 2006 dollars. The Tol (2005) study is cited repeatedly as an authoritative survey in various IPCC reports, which are widely accepted as representing the general consensus in the scientific community on climate change science.

Since Tol's estimate includes the *worldwide* costs of potential damages from carbon dioxide emissions, NHTSA elected to employ it as an upper bound on the estimate value of the reduction in *U.S. domestic* damage costs that is likely to result from lower CO_2 emissions.[274] NHTSA noted that Tol had a more recent (2007) and inclusive survey published online with peer-review comments. NHTSA stated that it had elected not to rely on this study, but that it would consider doing so in its analysis for the final rule if the survey had been published, and would also consider any other newly-published evidence.

NHTSA noted that the IPCC Working Group II Fourth Assessment Report (2007, at 822) further suggests that the SCC is growing at an annual rate of 2.4 percent, based on estimated increases in damages from future emissions reported in published studies. NHTSA also elected to apply this growth rate to Tol's original 2005 estimate. Thus, by 2011, NHTSA estimated that the upper bound on the benefits of reducing CO_2 emissions will have reached about $14 per metric ton of CO_2, and will continue to increase by 2.4 percent annually thereafter.

In setting a lower bound, the agency agreed with the IPCC Working Group II report (2007) that "significant warming across the globe and the locations of significant observed changes in many systems consistent with warming is very unlikely to be due solely to natural variability of temperatures or natural variability of the systems." (p. 9) Although this finding suggests that the *global* value of economic benefits from reducing carbon dioxide emissions is unlikely to be zero,

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[273] $43 per ton of carbon emissions was reported by Tol (at 2070) as the mean of the "best" estimates reported in peer-reviewed studies (at the time). It thus differs from the mean of *all* estimates reported in the peer-reviewed studies surveyed by Tol. The $43 per ton value was also attributed to Tol by IPCC Working Group II (2007), at 822.

[274] For purposes of comparison, NHTSA noted that in the rulemaking to establish CAFE standards for MY 2008-11 light trucks, NRDC recommended a value of $10-$25 per ton of CO_2 emissions reduced by fuel savings, and both EDF and UCS recommended a value of $50 per ton of carbon, which is equivalent to about $14 per ton of CO_2 emissions.

NHTSA stated that it does not necessarily rule out low or zero values for the benefit to the U.S. itself from reducing emissions.

In some of the analysis it performed to develop the CAFE standards, NHTSA employed a point estimate for the value of reducing CO_2 emissions. For this estimate, the agency used the midpoint of the range from $0 to $14, or $7.00, per metric ton of CO_2 as the initial value for the year 2011, and assumed that this value would grow at 2.4 percent annually thereafter. This estimate was employed for the analyses conducted using the Volpe model to support development of the proposed standards. The agency also conducted sensitivity analyses of the benefits from reducing CO_2 emissions using both the upper ($14/metric ton) and lower ($0/metric ton) bounds of this range.

NHTSA sought comment on its tentative conclusion for the value of the SCC, the use of a domestic versus a global value for the economic benefit of reducing CO_2 emissions, the rate at which the value of the SCC grows over time, the desirability of and procedures for incorporating benefits from reducing emissions of GHGs other than CO_2, and any other aspects of developing a reliable SCC value for purposes of establishing CAFE standards.

NHTSA received many comments on its assumptions in the NPRM about the SCC. The comment summaries are presented below and grouped by topic:

(1) NHTSA's proposal of a single value for the SCC;

(2) NHTSA's proposal of $7 as the value for the SCC;

(3) NHTSA's proposal of $0 as the lower bound estimate for the domestic U.S. value for the SCC;

(4) NHTSA's proposal of $14 as the upper bound estimate for the domestic U.S. value for the SCC;

(5) other values that NHTSA could have proposed for the SCC;

(6) NHTSA's use of a domestic versus a global value for the economic benefit of reducing CO_2 emissions;

(7) the rate at which the SCC grows over time;

(8) the discount rate that should be used for SCC estimates; and

(9) other issues raised by commenters.

(1) NHTSA's proposal of a single value for the SCC

NHTSA received a comment on its proposal of a single value for the SCC from Prof. Gary Yohe, an economist who has considered the SCC extensively and whom NHTSA cited in the NPRM. Prof. Yohe commented that the NPRM had stated that "Using a value for the SCC that reflects the central tendency of estimates drawn from many studies reduces the chances of relying on a single estimate that subsequently proves to be biased."[275] Prof. Yohe argued that proposing a single value for the SCC inherently creates bias, because "Any value is based on presumptions about pure rate of time preference, risk and/or inequity aversion, and climate sensitivity."

(2) NHTSA's proposal of $7 as the value for the SCC

NHTSA received comments from 3 individuals, CARB, the Attorneys General, 10 U.S. Senators, 10 environmental and consumer groups, and the Alliance. Prof. Tol, whose 2005 paper provided

[275] 73 FR 24414 (May 2, 2008).

the basis for NHTSA's proposal of an SCC number, commented that contrary to NHTSA's belief that the dollars used in Tol (2005) were 2005 dollars, they were in fact 1995 dollars. Prof. Tol also commented that NHTSA should "alert the reader" that although Tol (2007) was only "conditionally accepted," as NHTSA had noted in the NPRM, the newer study "finds larger estimates than the 2005 paper." Sierra Club *et al.*, in its comments, also stated that Prof. Tol had commented on the NPRM, arguing that using 1995 instead of 2005 dollars "would make his 1995 value of $14 closer to a 2005 value of $19.26."

Several commenters disputed NHTSA's proposal of $7 as the midpoint between $0 and $14. UCS argued that proposing $7 puts as much weight on $0 as on $14, even though failing to assign a value was declared by the Ninth Circuit to be arbitrary and capricious. CBD commented that "NHTSA's methodology for the selection of an estimate of the value of reducing greenhouse gas emissions is arbitrary and designed to minimize the estimate." CBD argued that "…simply splitting the difference between two points is not a defensible methodology, particularly when the low point of the range is not part of a valid range but simply an arbitrary selection of zero as an endpoint."

EDF also commented NHTSA's decision to propose $7 because it is the midpoint between $0 and $14 also "lacks a reasoned basis," for which "NHTSA fails to provide any justification."

The Sierra Club *et al.* commented that NHTSA is wrong to place "equal weighting and probability" on $0 and $14 and pick the median, and that $7 is "far below current carbon estimates," citing the 2006 Stern Review which found an SCC of "on the order of" $85/tonne CO_2. The Sierra Club argued that this shows how "misguided and unrealistic NHTSA's carbon pricing really is."

The Attorneys General commented that NHTSA's decision to simply halve Tol's estimate was "not a reasoned judgment."

Public Citizen argued that there is no justification for using the midpoint, and that NHTSA should instead "weight the credibility of each estimate," by making "apples to apples" comparisons between the studies by "looking at studies based on their assumptions." Public Citizen argued that this will help NHTSA avoid skewing the result of averaging estimates from multiple studies. NRDC similarly argued that proposing $7 as "a simple average of its proposed upper and lower bounds….assumes a normal distribution of damages, which is decidedly *not* the distribution of social cost of carbon estimates." NRDC further argued that "…most social cost of carbon estimates are biased downwards, for the simple reason that almost all models assume perfect substitutability between normal consumption goods and environmental goods." NRDC cited 2007 research by Sterner and Persson disaggregating "goods" into "environmental goods" and "consumption goods," which found that the price of an environmental good like carbon reductions increased at a faster rate as damage progressed than consumption goods would increase. Accordingly, NRDC argued, "NHTSA's social cost of carbon is much too low."

Prof. Hanemann also commented that NHTSA did not justify its decision to pick the midpoint (between $0 and $14) and then project it to 2011, although he focused more particularly on

NHTSA's not having applied "the escalation factor of a 2.4 percent increase in real terms beginning in 2005."

The Alliance commented that proposing $7 as the midpoint between $0 and $14 is incorrect. The Alliance argued that NHTSA must try harder to estimate the purely domestic effects of CO_2 emissions reductions, and stated that NERA had found that the U.S. portion of world gross product "is a much better means of allocating the United States' share of any benefits in reduced CO2 emissions" than picking the midpoint of a range of global SCC estimates. NERA assumed that the U.S. portion is 20 percent, which "reduces NHTSA's estimate of CO2 benefits with the 'optimized standard' for MY2015 from $869 million to $348 million." NERA also argued that this was conservative, since the U.S., as a developed country, should be better able to adapt to negative global warming consequences.

Several commenters also criticized Tol (2005) as being out of date. Prof. Hanemann made this point, and commented that "more recent analyses show higher damage estimates." The Attorneys General similarly commented that "It seems likely that there are better estimates" than Tol's, "Since [that] article is now three years old, and it itself explains in detail the many deficiencies in the economic literature at that time." The Attorneys General stated that "NHTSA should consult with EPA on this issue, and conduct a review of the current scientific and economics literature."

Several commenters simply argued that $7/ton is too low a value for the SCC. CARB argued that "NHTSA's assumed social cost of carbon in the future is also unreasonably low, and if set at defensible levels that also properly value cumulative impacts, could affect the stringency of the standards." Carin Skoog, an individual, similarly commented that "The arbitrary decision to use $7/ton underestimates the economic, social, and environmental consequences of the impacts of global warming." ACEEE similarly commented that NHTSA's use of $7/ton is both "inconsistent with current estimates" and "fails to take into account the potentially high probability of a catastrophic climate change situation." The 10 U.S. Senators who commented stated that NHTSA's value of $7 per ton is "underestimated," and "likely to be found arbitrary and capricious."

(3) NHTSA's proposal of $0 as the lower bound estimate for the domestic U.S. value for the SCC

No commenters supported NHTSA's use of $0/ton as the lower bound estimate for the U.S. domestic SCC. Several commenters, including UCS, EDF, and Prof. Hanemann cited the IPCC Fourth Assessment Report as evidence that, as Prof. Hanemann stated, "there is no credible evidence of any significant net benefit to the U.S. from the climate change scenarios developed for the Fourth IPCC Report." The U.S. Senators who commented also stated that in citing the IPCC as not precluding low or zero values to the U.S., NHTSA had "fail[ed] to recognize that IPCC was looking at global estimates which are not disaggregated."

Commenters also mentioned other reports as providing evidence that there would be some net adverse impact on the U.S. from climate change, and thus a lower bound value of $0 was untenable. Prof. Hanemann cited the recent USCCSP report "conclusively eliminates the notion that climate change is likely to have no net adverse impact on the United States."

UCS argued that proposing $0 as the lower bound "implies the possibility that climate change won't have any negative consequences," which "stands in stark contrast to recent government study findings on U.S. climate change effects and findings from … the Academies of Science for the G8+5."

EDF commented that "A recent review of economic studies on the predicted impacts of climate change on different economic sectors in the U.S. by the Center for Integrative Environmental Research at the University of Maryland, 'The US Economic Impacts of Climate Change and the Costs of Inaction: A Review and Assessment,' also demonstrates the range and scope of adverse impacts that climate change will have on different sectors and regions of the U.S. economy." EDF stated that "The study concluded that 'Scientific evidence is mounting that climate change will directly or indirectly affect all economic sectors and regions of the country, though not all equally. Although there may be temporary benefits from a changing climate, the costs of climate change rapidly exceed benefits and place major strains on public sector budgets, personal income and job security.'"

Sierra Club *et al.* commented that "several government reports [that] have clearly stated that CO_2 emissions do have a significant impact on our economy." NHTSA's conclusion that "it does not necessarily rule out low or zero carbon values for the benefit to the U.S. itself from reducing emissions" is arbitrary given agency's admission that "the global value of economic benefits from reducing carbon dioxide emissions is unlikely to be zero."

NRDC cited a U.S. government report that "documents that many of the projected impacts have already begun," as well as the Stern Review which "estimated that impacts could result in a loss of 5-20 percent of world GDP by 2100," and its own May 2008 report which "found U.S. damages from four impacts alone would cost 1.8 percent of GDP by 2100."

Several commenters instead raised objections to studies that may show a positive net benefit to the U.S. from climate change, such that a domestic SCC value could be $0. CBD stated that NHTSA offered "absolutely no evidence to support" proposing $0 as the lower bound, and argued that "only one study surveyed in Tol (2005) included central estimates below $0.00; and that was a non-peer-reviewed article, also authored by Tol." CBD further argued that Tol (2005) never found, nor included as a consideration in developing SCC estimates, as NHTSA suggested in the NPRM, that any studies failed "to consider potentially beneficial impacts of climate change," or to account adequately "for how future development patterns and adaptations could reduce potential impacts from climate change or the economic damages they cause."

Prof. Hanemann also argued that studies suggesting any possible positive net benefit to U.S. from global warming "have serious flaws and cannot withstand serious scrutiny," and concluded that a value of $0 per ton is "wildly unrealistic" "even [for] a sensitivity analysis."

NRDC commented that "NHTSA's lower bound seems to be based upon the fact that some estimates exist that are zero and even negative." However, NRDC argued that "These lower bound estimates are likely based on outdated science." NRDC "urge[d] NHTSA to do a rigorous re-examination of Tol's work, eliminating outdated zero estimates and adjusting for fat tailed upper distributions."

Several commenters also focused on the *CBD* decision to argue that NHTSA may not use $0 as the lower bound estimate, because as UCS stated, "the Ninth Circuit found a value of $0 to be arbitrary and capricious." EDF also commented that NHTSA's decision to pick $0 as the lower bound "lacks a reasoned basis," given the Ninth Circuit decision. Sierra Club *et al.* and the U.S. Senators similarly commented that $0 as the lower bound is contrary to *CBD*. The comment by the U.S. Senators stated that "…we can only conclude that the purpose of this 'low bound' estimate is to cut the more accurate value in half in an arbitrary manner. We recommend NHTSA remove or justify this low bound estimate in its final CAFE regulation."

(4) NHTSA's proposal of $14 as the upper bound estimate for the domestic U.S. value for the SCC

No commenters supported NHTSA's proposal of $14/ton, based on Tol (2005), as the upper bound estimate for the domestic U.S. value for the SCC. ACEEE argued that "NHTSA's decision to use Tol's estimate of $14 as the upper bound based on the argument that this value includes the worldwide costs CO_2 is flawed," although the commenter did not explain why.

Some commenters argued that NHTSA should not have picked the median from Tol (2005) as its upper bound estimate.

The U.S. Senators who commented stated that NHTSA is wrong to use $14 as the upper bound because Tol's median is an average of multiple estimates, and averages should be used as averages and not as maximums. The Senators stated further that "NHTSA selected the lower of Tol's two estimates without explanation." The U.S. Senators also commented that Tol (2007) updates the previous study and finds a median of over $19/ton. NRDC also cited Tol (2007) as reflecting an increase in the median from $14 to $20 dollars per ton of CO_2.

Sierra Club *et al.* commented that $14 is an incorrect "maximum," because the maximum that Tol "states that the maximum carbon value is in the range of $55-$95 per metric ton CO2." The commenter further argued that if NHTSA could justify $0 as the lower bound, "then it should not be able to rule out the high value of $95 per ton CO_2 in the study, and the average value would be much higher."

NRDC commented that NHTSA should not have used Tol's median value of $14 as its upper bound for two reasons. First, a median value is not properly reflective of climate change damage estimate distributions, which are "asymmetric" with "fat" upper tails. And second, because of the unique aspects of climate change damage estimates, such as "nonlinearities, abrupt change, and thresholds," "a full probability density function should be estimated, using the *full range* of all [SCC] estimates from the studies, *not* simply a collection of their 'best-guesses.'" [Emphasis in original.] NRDC argued that research has shown that "When the same traditional social cost of carbon analyses are rerun incorporating the potential for nonlinear change, the resulting policy conclusions are changed considerably to greater mitigation," and that "Another recent study has shown that incorporating the potential for low-probability, high-damage events can increase the social cost of carbon by a factor of 20."

NRDC also cited Prof. Weitzman to argue that the complications of climate change damage estimates require any analysis to weigh more heavily the "low probability/high catastrophic risks," because these will otherwise be insufficiently accounted for. In discussing the uncertainties associated with climate change, NRDC cited Weitzman as stating that

> The result of this immense cascading of huge uncertainties is a "reduced form" of truly stupendous uncertainty about the aggregate-utility impacts of catastrophic climate change, which mathematically is represented by a very-spread-out very-fat-tailed PDF [probability density function] of what might be called (present discounted) "welfare sensitivity"…[T]he value of "welfare sensitivity" is effectively bounded only by some *very* big number representing something like the value of statistical civilization as we know it or maybe even the value of statistical life on earth as we know it.

Thus, NRDC argued, using an upper bound of $14 cannot possibly account for the uncertainties and risk of climate change. Like Sierra Club *et al*., NRDC further argued that "…for consistency with the rationale used for proposing the lower bound, NHTSA's upper bound should be based upon some function of the highest estimates in the Tol 2005 study (the very highest was $1,666)."

Some commenters argued that NHTSA had overlooked particular aspects of the Tol (2005) study, and thus arrived at $14 incorrectly.

CBD argued that NHTSA overlooked key aspects of the Tol (2005) analysis in proposing $14 per ton, including the fact that Tol included significantly higher estimates in his analysis. EDF similarly commented that NHTSA had failed to "discuss the significant gaps in the existing research reviewed in [Tol (2005)] and focuse[d] on a specific estimate of the SCC that is biased toward lower value estimates." EDF stated that NHTSA's decision to use only peer-reviewed studies from Tol (2005) introduced particular bias, because those studies "systematically used higher discount rates…which may have biased their results downward" compared to averaging all the studies together.

Some commenters argued that Tol (2005) was flawed to the point that it could not provide a reliable basis for NHTSA to use its median estimate as the upper bound.

CBD commented that "the studies cited in the Tol (2005) survey dated back as much as 18 years, to 1991, and 25 of the 28 studies cited were published more than five years ago," so given that climate change science is progressing very rapidly, these studies are probably outdated.

EDF also argued that "Most of the 28 studies surveyed by Tol" are outdated and "consider only a limited number of potential impacts from climate change," as Tol recognizes by cautioning that the estimates analyzed "may understate the true cost of climate change." EDF stated that the IPCC's "most recent compilation of SCC research" agrees. EDF also commented that Tol's meta-analysis "compares studies with widely different methodologies and assumptions," particularly discount rates, which EDF stated NHTSA should have controlled for because it "can have a considerable impact on SCC estimates."

NRDC criticized Tol (2005) extensively in its comments. NRDC stated that Tol's estimate was based on studies which exclude (1) "non-market costs, such as damage to and loss of entire ecosystems and species;" and (2) "studies of national security costs caused by conflicts over stressed resources and increased migration from heavily impacted areas," which "describe global warming as a 'threat multiplier.'" NRDC recognized that Tol acknowledged that "costs such as those described above are poorly accounted for in current social cost of carbon estimates," but insisted that NHTSA must nonetheless account for them.

NRDC also argued that Tol's estimate is based on outdated studies, because "there are smaller natural sinks for carbon than Tol assumed, higher emissions than he assumed, a higher temperature response to emissions than he assumed, and faster changes in observed impacts than he assumed." NRDC commented that recent events like Hurricane Katrina are evidence that the U.S. cannot adapt to climate change-related disasters as fast as previously thought. NRDC further commented that it was unclear whether Tol's estimate "included any valuation for lost lives," suggesting that including this valuation could raise SCC considerably, and arguing that EPA accounts for it in Clean Air Act rulemakings.

(5) Other values that NHTSA could have chosen for the SCC
Many commenters suggested other SCC values that they thought NHTSA should use instead of a value based on Tol (2005).

Several commenters mentioned SCC values produced by EPA. In March 2008, EPA produced an analysis for the Senate Committee on Environment and Public Works for S. 2191, "America's Climate Security Act," also known as the Lieberman-Warner bill.[276] Public Citizen commented that NHTSA's upper bound estimate should be at least as high as EPA's estimates for the Lieberman-Warner bill, which Public Citizen said "are more recent than the Tol estimate cited in NHTSA's notice." Public Citizen commented that EPA "estimated the value of CO_2 in 2015 between $22 and $40 per metric ton of CO_2, and cited two other analyses with higher estimates of $48 and $50 per metric ton CO_2." Sierra Club *et al.* also commented that NHTSA must use a higher SCC value, and stated that "EPA's recent analysis of America's Climate Security Act of 2007 noted that the value of a ton of CO2 could be as high as $22-$40.28." An individual, Carin Skoog, also commented that "The US EPA recently suggested the value of a ton of CO2 could be as high as $22-35." ACEEE appeared to refer obliquely to the EPA estimates, recommending that NHTSA use a higher CO_2 estimate. ACEEE argued that "legislative efforts to implement a carbon regime in which the projected market cost of CO_2 is expected to lie between $20 and $30 – significantly higher than the average damage cost assumed by NHTSA – serves as evidence that the U.S. is now beginning to contemplate the high risk of rising greenhouse gas emissions."

NRDC commented that NHTSA cited "compliance cost estimates provided by NRDC and others in the 2006 light truck rulemaking" in describing its proposal of the upper bound estimate. NRDC argued that NHTSA should instead consider damage costs and not rely on compliance cost estimates. NRDC stated that "If NHTSA were to consider compliance costs it must consider current analyses, such as EPA's analysis of S.2191, which finds that CO_2 allowances would cost

[276] *Available at* http://www.epa.gov/climatechange/downloads/s2191_EPA_Analysis.pdf (last accessed March 23, 2009).

19 to 67 (2005) dollars per ton of CO_2-equivalent in 2012 rising at 5 percent per year real (the range for EPA's Core Scenario is $19 to $35 in 2012, rising at 5 percent per year real)."

EPA also recently released a "Technical Support Document on the Benefits of Reducing GHG Emissions,"[277] (TSD) to accompany an Advance Notice of Proposed Rulemaking (ANPRM) on regulating GHG emissions under the Clean Air Act.[278] EDF commented in its original comments that "The higher SCC estimates contained in EPA's draft ANPR, and EPA's accompanying discussion of the remaining omissions and weaknesses in state-of-the-art SCC research, further demonstrates that NHTSA's estimates are underestimating the benefits of reducing carbon dioxide emissions, and therefore setting CAFE standards below optimal levels." After the TSD was released, EDF submitted it to NHTSA's NPRM docket, and submitted late additional comments arguing that NHTSA must "adjust its final rulemaking action in accordance with EPA's assessment and findings," because "EPA's assessment is far more rigorous than NHTSA's proposal, and EPA's determinations are supported by a considerable and well-reasoned volume of information." EDF stated that EPA did its own meta-analysis "building on" Tol (2005) and (2007), but including "only recent peer reviewed studies that met a range of quality criteria in its evaluation." EDF further stated that EPA arrived at an estimate of $40/t$CO_2$ (using a 3 percent discount rate), or $60/t$CO_2$ (using a 2 percent discount rate). EDF commented that EPA concluded that estimates "likely underestimate costs of carbon dioxide emissions," because they do not account for all the climate change impacts identified by the IPCC, like "non-market damages, the effects of climate variability, risks of potential extreme weather, socially contingent events [(such as violent conflict)], and potential long-term catastrophic events."

The U.S. Senators who commented argued that NHTSA's use of $14/ton based on Tol (2005) as the "high bound" estimate was incorrect because EPA had been working since 2007 "to develop more accurate, 'state-of-the-art' estimates of the benefits of reducing greenhouse gas pollution." The Senators stated that "Although EPA's estimates have not been finalized, the Agency used $40 per ton as the value of reducing carbon dioxide emissions." The Senators further stated that "NHTSA's draft rule inexplicably makes no mention of EPA's extensive research and analysis in this area."

Other commenters argued that NHTSA should have used or considered the value at which CO_2 allowances are currently trading in the EU regulatory system. UCS stated that using $14 as the upper end is "unacceptably low," given that "The European Climate Exchange, which provides a futures market value for global warming pollution in Europe's carbon constrained market, indicates 2011 contracts for carbon dioxide at approximately $45 (U.S.) per metric ton—well above the figure cited by NHTSA." UCS argued that "This value represents a predicted marginal abatement cost (the cost of avoiding global warming pollution), and is likely a conservative estimate of the benefit of reducing global warming since the cost of avoiding climate change is lower than the cost of fixing the damage after it occurs." UCS further argued that this number is also "generally consistent with other recent allowance price estimates, such as the EPA's assessment of GHG allowance prices under Lieberman-Warner: $22-$40 in 2015 and $28-$51 in 2020 (EPA figures are in 2005 dollars per ton of CO_2-equivalent.)"

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[277] *Available at* Docket No. NHTSA-2008-0089-0456.2.
[278] EPA's ANPRM was signed July 11, 2008, after NHTSA's NPRM was published. *See* 73 FR 44353 (July 30, 2008).

Sierra Club *et al.*, Public Citizen, and CARB all also commented that NHTSA's value for the SCC is too low, and that NHTSA should instead use a CO_2 damage value based on the market value in the European Trading System, either the current value (which Public Citizen stated was "recently… around €30 per allowance (one metric ton CO_2 equivalent)," and CARB stated was "currently trading around $42 per ton"), or some future value. Sierra Club *et al*. argued that "the futures market value for a metric ton of CO_2 in 2011 is already up to $45," while CARB went on to argue that "…Germany Deutsche Bank [is] forecasting EUA prices of $60 for 2008 and EUA prices as high as $100 by 2020 [citation removed]."

Other commenters suggested other SCC values different from any discussed so far. For example, Prof. Hanemann argued that, based on his own research, NHTSA use a value of "about $25 per metric ton [of CO_2] in 2005$," and should apply a real growth rate of 2.4 percent per year to determine the value of reducing emissions in future years. CARB, in contrast, commented that "NHTSA should also consider using substantially higher estimates." CARB stated that "the International Energy Agency (IEA) recently estimated that to limit global CO_2 emissions by the 50 percent GHG reduction that the IPCC concluded is needed to keep global temperatures from rising more than two degrees Celsius by 2050, CO_2 offset prices will need to rise to up to $200 per ton…." CARB further argued that "…even this higher market price for carbon may not incorporate the true cost of all natural resources damages, an externality."

Mr. Montgomery commented that NHTSA should use an SCC value of $0, because he argued that "If a comprehensive cap on [CO_2] emissions is put in place, as many commentators and policymakers predict, then the <u>choice</u> of policy instrument will have no effect on the overall level of emissions," such that "Tightening a CAFE standard will only result in greater mitigation in emissions from [motor vehicles] and less mitigation in parts of the economy where decisions are made in response to carbon prices without specific regulatory mandates." Thus, Mr. Montgomery concluded that "the damages from global warming will be the same no matter what the level of the CAFE standard, so that the SCC used should be zero."

Mr. Montgomery also commented that an SCC based on Tol's estimates will be too high if the "global policy objective toward greenhouse gas emissions…is a lower concentration than that on which the Tol estimates are based." Mr. Montgomery argued that "Marginal damages depend on the level of GHG concentrations at which they are measured," so that "If the goal for global concentrations is set at a high level (*e.g.*, 750 ppm) then damages from an additional ton of CO_2 (due to higher concentrations during the period of its residence in the atmosphere) will be higher than if the goal is set at a low level (350 ppm) at which point most of the damaging consequences have been eliminated."

Ford redacted much of its discussion of the SCC based on confidentiality concerns, but seemed to argue generally that reducing CO_2 emissions from motor vehicles is expensive compared to reducing emissions in other sectors, and commented that "All sectors must contribute" to reducing emissions. Ford "recommended that NHTSA consider using CO_2 mitigation cost in their analysis in lieu of emission damage cost."

NADA commented that "NHTSA should consider incorporating into its analysis the $2.97 per metric ton recently paid by the U.S. House of Representatives for carbon offsets."[279]

The Alliance was the only commenter to suggest that NHTSA not quantify the SCC at all. The Alliance argued that "…given the fact that no published studies of which we are aware address the SCC apportionment issue, NHTSA would be well within its rights to decide that SCC will be considered purely in a qualitative balancing fashion and not quantified." The Alliance cited *Transmission Access Policy Study Group v. FERC*, 225 F.3d 667, 736 (D.C. Cir. 2000) ("Given that FERC's comparison of the frozen efficiency case to its base case yielded little difference, the agency had no reason to conduct further analysis. By rigorously examining the frozen efficiency case, even though it believed the case to be unreasonable, FERC ensured that its decision was 'fully informed' and 'well-considered.'").

(6) NHTSA's use of a domestic versus a global value for the economic benefit of reducing CO_2 emissions

NHTSA received a number of comments on its tentative decision to employ a domestic value for the SCC instead of a global value. Several commenters supported a domestic value, while other commenters supported a global value.

The Alliance argued that NHTSA must consider only domestic impacts both because of EPCA, which refers to "the need of the *United States* to conserve energy," and because of the "extraterritoriality" or "*Aramco* canon," *see EEOC v. Arabian American Oil Co.*, 499 U.S. 244, 260 (1991) ("It is a longstanding principle of American law 'that legislation of Congress, unless a contrary intent appears, is meant to apply only within the territorial jurisdiction of the United States.') (quoting *Foley Bros. v. Filardo*, 336 U.S. 281, 285 (1949)). The Alliance further argued that because NHTSA must consider only domestic impacts, it must "develop some mechanism for scaling down the global SCC estimates produced in the published literature," besides NHTSA's proposal which just took the midpoint between $0 and $14 as the domestic SCC value. The Alliance argued that it would be inappropriate to use land mass to determine the domestic portion, since so much of the land mass on the planet is uninhabited; and also argued that it would be inappropriate to use population, since "not all human beings live in areas that are expected to be equally impacted by climate change." As discussed above, the Alliance cited to the NERA Report that it included with its comments as having found that an SCC value based on the U.S. share of world gross product was more appropriate.

NADA similarly commented that "NHTSA should account only for any *domestic* impacts of reducing the social costs of motor vehicle CO_2, given that EPCA focuses on U.S. energy security and all other costs and benefits evaluated with respect to the proposed CAFE standards are domestic only."

Mr. Delucchi agreed with NHTSA's discussion that "consistency requires" that only U.S. domestic "global warming damages" be considered if NHTSA also accounts for the monopsony effect in the reduced value of transfer payments from U.S. oil purchasers to foreign oil suppliers.

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[279] NADA cited the "Statement of Daniel P. Beard, Chief Administrative Officer, U.S. House of Representatives, Concerning the Purchase of Carbon Offsets," which does not list the specific price paid for the offsets described. *Available at* http://cao.house.gov/press/cao-20080205.shtml (last accessed March 23, 2009).

Mr. Delucchi suggested that NHTSA use a procedure described in his previous research to estimate the fraction of global damages from climate change that would be borne within the U.S., and apply this fraction to the estimated global SCC to determine the value of U.S. domestic benefits from reducing emissions. This procedure adjusts the fraction of global GDP accounted for by the U.S. by the relative sensitivity of the U.S. to climate damages compared to the remainder of the world, which Delucchi measures by the ratio of U.S. dollar damages from climate change per dollar of U.S. GDP to global economic damages from climate change per dollar of global GDP. Using this method, he estimates that U.S. damages from climate change are likely to represent 0-14 percent of total global damages, and thus that the value to the U.S. of reducing carbon emissions is equal to that same percentage of the estimated global value of the SCC.[280]

Mr. Montgomery argued that a domestic SCC value was appropriate, commenting that "U.S. policy should be based on marginal damages to the U.S. from CO_2 emissions in the U.S., as stated in relevant OMB circulars on cost-benefit analysis and suggested in the draft." Mr. Montgomery further stated that "The consensus appears to be that richer countries are less vulnerable than poorer, and that temperature increases will be least in temperate regions like the U.S." Thus, Mr. Montgomery argued that a conservative estimate of U.S. damages would be a calculation "based on the ration of U.S. GDP to world GDP."

Other commenters argued that NHTSA should use a global SCC value. NRDC commented that because "Carbon dioxide is a global pollutant, and much of the damages other countries will experience *are a result* of U.S. emissions," and because "emissions in other countries will cause damages in the U.S.," that "It is fundamentally inconsistent with the global circulation of these pollutants to arbitrarily limit assessment of the benefits of reducing U.S. emissions to those accruing in our own territory." NRDC also commented that national security studies show that the global social costs of carbon will "spill over" to the U.S. and other wealthy countries. EDF also commented that NHTSA should use a global SCC number rather than a domestic one, because "Climate change is clearly a global issue," so EDF "recommend[s] that benefits of reducing CO_2 concentrations should reflect benefits to society as a whole."

EDF and the U.S. Senators commented that use of a global SCC value would be consistent with OMB guidance that international impacts of regulations may be considered if appropriate. The Senators also commented that the U.S. must consider the global climate change effects of its regulations because it ratified the United Nations Framework Convention on Climate Change in 1992. If every nation considers only domestic effects of climate change, the Senators argued, emissions reduction policies will fall "far short of the socially optimized level."

CBD similarly commented that NHTSA should use a global value for CO_2, arguing that using $7 "fails to incorporate the full economic costs of global climate change, values that are difficult to monetize, and costs to the world outside the boundaries of the United States." CBD stated that "In general, the estimate of the social costs of climate change fails to incorporate the loss of

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[280] Mark A. Delucchi, Summary of the Non-Monetary Externalities of Motor Vehicle Use, UCD-ITS-RR-96-3 (9) rev.1, Institute of Transportation Studies, University of California, Davis, originally published September 1998, revised October 2004. Available at http://www.its.ucdavis.edu/publications/2004/UCD-ITS-RR-96-03(09)_rev1.pdf (last accessed March 23, 2009).

biodiversity, complex and large-scale ecosystem services, and the disproportionate impacts of global climate change on the developing world." CBD also stated that NHTSA's use of $0 as the lower bound estimate is "[p]resumably … meant to imply that the United States might benefit economically by letting other countries bear the costs of unabated American greenhouse gas emissions. Setting aside the tremendous ethical implications of such a position, NHTSA provides absolutely no evidence to support the claim."

In its late comments accompanying its submission of EPA's TSD, EDF argued that EPA's TSD concluded that a global number is correct, for several reasons. Because GHGs are global pollutants and affect everyone, using "domestic only" estimates would "omit potential impacts on the United States (*e.g.*, economic or national security impacts) resulting from climate change impacts in other countries." Consequently, a global number must be used to avoid missing any benefits and to maximize global net benefits (*i.e.*, "countries would need to mitigate up to the point where their domestic marginal cost equals the global marginal benefit." EDF stated that EPA's TSD cites Nordhaus (2006), and says that "Net present value estimates of global marginal benefits internalize the global and intergenerational externalities of reducing a unit of emissions and can therefore help guide policies towards an efficient level of provision of the public good."

(7) The rate at which the SCC grows over time

Several commenters cited the IPCC Fourth Assessment Report with regard to the rate at which the SCC should increase over time. CBD commented that as part of the Fourth Assessment Report, the IPCC "…states that 'It is virtually certain that the real social cost of carbon and other greenhouse gases will increase over time; it is very likely that the rate of increase will be 2% to 4% per year.'" The U.S. Senators commented that the 2.4 percent per year increase that NHTSA used in the NPRM is incorrect, because "the IPCC report states that 'it is very likely that the rate of increase will be 2% to 4% per year.'"

EDF stated that IPCC's recommendation of a 2.4 percent growth rate was meant to be used in combination with a low, intergenerational discount rate. EDF further argued that after the Fourth Assessment Report was released, one of the lead authors recommended using a growth rate of 3 percent, but that "The OMB equivalent guidance for the UK … recommend using a 2 percent yearly increase." EDF thus concluded that the 2.4 percent growth rate could be used, but only with a maximum 3 percent discount rate, and argued that a range of growth rates should be run in the sensitivity analysis "because of considerable uncertainty."

(8) The discount rate that should be used for SCC estimates

Commenters urged NHTSA to consider a low or even negative discount rate in choosing an estimate for the SCC. CBD, for example, stated that Stern found that "'If consumption falls along a path, the discount rate can be negative. If inequality rises over time, this would work to reduce the discount rate, for the social welfare functions typically used. If uncertainty rises as outcomes further into the future are contemplated, this would work to reduce the discount rate, with the welfare functions typically used.'" CBD then argued that "A negative discount rate would dramatically increase the cost of climate change in the cost-benefit analyses in the proposed rule."

NRDC commented that NHTSA should use a discount rate of no more than 3 percent for the entire rulemaking, and returned to this argument in its SCC discussion, criticizing Tol's estimate for relying "primarily upon estimates that did not use current accepted climate change discounting procedures of a declining discount rate over time."

In its initial comments, EDF stated that NHTSA should only consider recent studies that use a 3 percent discount rate for estimating SCC. In its late comments, EDF stated that EPA's TSD concluded that "a low discount rate is most appropriate for SCC estimation," for several reasons. First, because OMB Circular A-4 allows agencies to use a lower discount rate when there are inter-generational benefits associated with a rulemaking. Second, because "In this inter-generational context, a three percent discount rate is consistent with observed interest rates from long-term intra-generational investments (net of risk premiums) as well as interest rates relevant for monetary estimates of the impacts of climate change that are primarily consumption effects." Third, because EPA had found that the scientific literature supports the use of a discount rate of 3 percent or lower, as being "…more consistent with conditions associated with long-run uncertainty in economic growth and interest rates, intergenerational considerations, and the risk of high impact climate damages (which could reduce or reverse economic growth)."

(9) Other issues raised by commenters

The remaining issues raised by commenters with regard to NHTSA's proposal regarding the value for the SCC were as follows:

Public Citizen commented that NHTSA should also have considered "the costs of inaction on reducing greenhouse gas emissions and the resultant consequences of global warming," including other environmental and health consequences such as those analyzed in NHTSA's DEIS. Public Citizen cited EPA's denial of California's waiver request and "a recent report from the University of Maryland" as evidence of some of these costs, and argued that NHTSA needed to estimate "the costs of inaction" in making its final decision.

NRDC commented that emissions reductions may be "greater than what CAFE accomplishes," such that the U.S. would "get…a larger social cost of carbon benefits stream," if the U.S. actions in "taking a lead in reducing emissions… [helps to] induce other countries, especially China and India, to also reduce." NRDC also argued that "Carbon dioxide has a very slow decay rate in the atmosphere, lasting hundreds of years into the future," which means that "the social costs of carbon extend well past the life time of the vehicle." Thus, "Any sensible benefits stream would extend them at *least* several decades past the lifetime of a vehicle."

In its original comments, EDF argued that NHTSA should have considered using a risk-management framework in developing an SCC estimate, because cost-benefit analysis "cannot capture the range of uncertainty and risk that characterizes climate change." EDF cited Prof. Weitzman's work as highlighting "that the expected damages of climate change may be dominated by the existence of consequences which have very low probability but very high damages (such as double-digit increases in mean global temperature), or a 'fat tail' in the distribution of possible outcomes." In its late comments, EDF added that EPA's TSD also suggested that a risk assessment framework may be more appropriate than cost-benefit analysis "in light of the ethical implications of climate change and the difficulty in valuing catastrophic risks to future generations." The TSD went on to say that "Economics alone cannot answer the questions, policy, legal, ethical considerations are relevant too, and many cannot be quantified. When there is much uncertainty, economics recommends a risk management framework for guiding policy."

Agency response:
In determining its responses to the public comments on the value of reducing CO_2 emissions, the agency was mindful that the 9th Circuit remanded rulemaking to NHTSA "for it to include a monetized value for this benefit [the reduced risk of global warming as a result of reducing CO_2 emissions] in its analysis of the proper CAFE standards."[281] (Emphasis added.) NHTSA understands this directive to require the agency to include within its modeling, with at least some level of specificity, actual values for the SCC. Further, as in the case of other public comments, the agency is required by the Administrative Procedure Act to respond to the relevant and significant public comments, including those central to the agency's decision on standards under EPCA, in a manner reflecting consideration of the relevant factors.

As noted above, in the NPRM, we tentatively selected the mean value ($14) in Tol (2005) as a global value, and announced plans to attempt to develop and possibly use a domestic value for the final rule. For most of the analysis it performed to develop the proposed standards using the Volpe CAFE model, NHTSA used a single estimate for a domestic value of reducing CO_2 emissions. The agency thus elected to use the midpoint of the range from $0 to $14 (or $7.00) per metric ton of CO_2 as the initial value for the year 2011, and assumed that this value would grow at 2.4 percent annually thereafter. This estimate was employed for the analyses conducted using the Volpe CAFE model to support development of the proposed standards. The agency also conducted sensitivity analyses of the benefits from reducing CO_2 emissions using both the upper ($14 per metric ton, since the domestic value could not exceed the global one) and lower ($0 per metric ton) bounds of this range.

After considering comments on the approach it employed in the NPRM and more recent estimates of the SCC, NHTSA has decided to employ a range of estimates for the value of reducing GHG emissions in the analysis it performed to support this Final Rule for MY 2011 as discussed in further detail below. To do so, the agency identified a range of estimates from current peer-reviewed estimates of the value of the SCC, and then tested the sensitivity of alternative CAFE standards to this range of uncertainty while holding the other economic parameters used in its analysis fixed at their estimated values. The range of estimates, which the agency believes fairly represents the uncertainty surrounding the value of the SCC, consists of a domestic value ($2) at the lower end, a global value ($33) equal to the mean value in Tol (2008) and a global value ($80) one standard deviation above the mean value. NHTSA believes that, based on currently available information and analysis, $2 is a reasonable domestic value and $33 is a reasonable global value, but notes the uncertainty regarding both values. The agency tested the sensitivity of alternative CAFE standards to this range of uncertainty while holding the other economic parameters used in its analysis fixed at their estimated values.

On the basis of this analysis, the agency has concluded that its adopted standards for MY 2011 are not sensitive to the alternative estimates of the value of reducing CO_2 emissions, so although

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281 CBD, 508 F.3d 508, 535.

it has selected global and domestic values for the SCC for use in analyzing the effects of different SCC values on the standards in this one-year rulemaking, NHTSA believes that is *not* necessary for purposes of this rulemaking to make definitive, long term choices about the most appropriate global or domestic value or to choose between using a global versus domestic value. This approach is sufficient for this rulemaking and will allow efforts to make more specific choices to be deferred until additional scientific and economic evidence can be accumulated, and the participation of other federal agencies in those efforts can enable the development of a consistent estimate for use in those agencies' respective regulatory and policy-making activities, including the next CAFE rulemaking.

The agency is well aware that scientific and economic knowledge about the contribution of GHG emissions to changes in the future global climate and the potential resulting damages to the world economy continues to evolve rapidly. Thus, any value placed in this rulemaking on reducing CO_2 emissions is subject to likely change. NHTSA recognizes the importance of continuing to monitor current research on the potential economic damages resulting from climate change, and of periodically updating estimates of the value of reducing CO_2 emissions to reflect continuing advances in scientific and economic knowledge about the nature and extent of climate change and the threat it poses to world economic development. NHTSA recognizes the interest and expertise of other federal agencies, particularly EPA and DOE, in the issue of valuing the reductions in climate damages that are likely to result from those agencies' own efforts to reduce GHG emissions. NHTSA will continue to work closely with those and other federal agencies in the development and review of the economic values of reducing GHG emissions that it plans to employ in its next CAFE rulemaking.

Global value of reducing CO_2 emissions

To develop a range of estimates that accurately reflects the uncertainty surrounding the value of reducing emissions, NHTSA relied on Tol's (2008) expanded and updated survey of 211 estimates of the global SCC, which was published after the agency completed the analysis it conducted to develop its proposed CAFE standards.[282] Tol's 2008 survey encompasses a larger number of estimates for the global value of reducing carbon emissions than its previously-published counterpart, Tol (2005), and continues to represent the only recent, publicly-available compendium of peer-reviewed estimates of the SCC that has itself been peer-reviewed and published. The wide range of estimates it includes reflects their authors' varying assumptions about critical parameters that affect the SCC, including the sensitivity of the global climate system to increasing atmospheric concentrations of CO_2 and other GHGs, the extent of economic damages likely to result from climate change, the rate at which to discount future damages, the relative valuation of climate damages likely to be sustained by nations with different income levels, and the degree of collective aversion to the risk of extreme climate change and the resulting potential for equally extreme economic damages. NHTSA believes that Tol's updated survey provides a reliable and consistent current basis for establishing a range of plausible values for reducing CO_2 emissions from fuel production and use.

Tol's updated survey includes 125 estimates of the SCC published in peer-reviewed journals through the year 2006. Each of these represents an independent estimate of the world-wide value

[282] Richard S.J. Tol (2008), The social cost of carbon: trends, outliers, and catastrophes, *Economics -- the Open-Access, Open-Assessment E-Journal*, 2 (25), 1-24.

of increased economic damages from global climate change that would be likely to result from a small increase in carbon emissions, and by implication, the global value of the reduction in future economic damages from climate change that would result from an incremental decline in GHG emissions. Tol reports that the mean value of these estimates is $71 per ton of carbon emissions, and that the standard deviation of this estimate – a measure of how much a typical estimate differs from their average value – is $98 per ton; the fact that this latter measure is significantly larger than the mean value indicates the broad range spanned by the estimates.

NHTSA staff confirmed in conversations with the author that these values apply to carbon emissions occurring during the mid-1990s time frame, and are expressed in approximately 1995 dollars.[283] The $71 mean value of the social cost of increased carbon emissions reported by Tol corresponds to a global value of $19 per metric ton of CO_2 emissions reduced or avoided when expressed in 1995 dollars, while the $98 standard deviation for carbon emissions corresponds to $27 per ton of CO_2.[284] Adjusted to reflect increases since the mid-1990s in the marginal damage costs of emissions at now-higher atmospheric concentrations of GHGs, and expressed in 2007 dollars, Tol's mean value corresponds to a global damage cost of $33 per ton of CO_2 emitted during the year 2007, with a standard deviation of nearly $47 per ton. Thus, the value that is one standard deviation above the $33 figure is $80 per ton of CO_2.

Many commenters noted that some recent estimates of the SCC are significantly higher that those reported by Tol (2005), and suggested that NHTSA employ these higher estimates of the SCC to determine the value of reducing CO_2 emissions. Specifically, commenters highlighted the widely-cited *Stern Review's* estimate that the current SCC is likely to be in excess of $300 per metric ton of carbon, or approximately $80 per ton of CO_2.[285] Some commenters argued that Stern's estimate should be given substantial weight in determining the value of reducing CO_2 emissions used to develop the agency's final CAFE standards. Although Stern's estimate is reported in Tol's 2008 survey, it is not included in the estimates that form the basis for NHTSA's revised range of values, because Stern's study has not yet been subjected to formal peer review.

NHTSA notes that the Stern Report's estimate of the SCC employs a low value for the discount rate it applies to future economic damages from climate change, and that this assumption is largely responsible for its high estimate of the SCC. Hope and Newbury demonstrate that substituting a more conventional discount rate would reduce Stern's estimate of the benefits from reducing emissions to the range of $20-25 per ton of CO_2, which is well within the range of other

[283] Tol (2008), Table 1, p. 16.

[284] As noted in an earlier footnote, carbon itself accounts for 12/44, or about 27 percent, of the mass of carbon dioxide (12/44 is the ratio of the molecular weight of carbon to that of carbon dioxide). Thus, each ton of carbon emitted is associated with 44/12, or 3.67, tons of carbon dioxide emissions. Estimates of the SCC are typically reported in dollars per ton of carbon, and must be divided by 3.67 to determine their equivalent value per ton of carbon dioxide emissions.

[285] Stern, N.H., S.Peters, V.Bakhshi, A.Bowen, C.Cameron, S.Catovsky, D.Crane, S.Cruickshank, S.Dietz, N.Edmonson, S.-L.Garbett, L.Hamid, G.Hoffman, D.Ingram, B.Jones, N.Patmore, H.Radcliffe, R.Sathiyarajah, M.Stock, C.Taylor, T.Vernon, H.Wanjie, and D.Zenghelis (2006), *Stern Review: The Economics of Climate Change* Cambridge University Press, Cambridge, England.

estimates summarized in Tol's 2008 survey, and significantly *below* the $33 equivalent of the mean of peer-reviewed estimates Tol reports.[286]

Other commenters noted that EPA has recently developed preliminary estimates of the value of reducing CO_2 emissions, and recommended that NHTSA employ these values in its analysis of alternative CAFE standards. EPA's estimates are reported in that agency's Technical Support Document on Benefits of Reducing GHG Emissions (GHG Benefits TSD) accompanying its Advance Notice of Proposed Rulemaking on motor vehicle CO_2 emissions.[287] In that document, EPA derives estimates of the SCC using the subset of estimates included in Tol's 2008 survey drawn from peer-reviewed studies published after 1995 that do not employ so-called equity weighting.[288] Updated from their original mid-1990s values to reflect increases in the marginal damage costs of emissions at growing atmospheric concentrations of CO_2 and expressed in 2006 dollars, EPA reports average values of $40 per ton of CO_2 for studies using a 3 percent discount rate, and $68 per ton for studies using a 2 percent discount rate.[289] (The discount rates employed in developing the 125 peer-reviewed estimates surveyed by Tol ranged from 1 to 10 percent.[290])

NHTSA recognizes that in a recent rulemaking, DOE used a range of values from $0 to $20 (in 2007 dollars) per ton to estimate the benefits of reductions in CO_2 emissions resulting from new energy conservation standards for commercial air conditioning equipment.[291] DOE derived the upper bound of this range from the mean of published estimates of the SCC reported in the same earlier survey by Tol (2005) that NHTSA relied upon for the value it used to analyze the CAFE standards proposed in the NPRM, and the lower bound from the assumption that reducing CO_2 emissions would produce no economic benefit. However, NHTSA believes that the estimates of the mean and standard deviation derived from Tol's more recent (2008) and comprehensive survey of published estimates of the SCC provides a more up-to-date range of values for reductions in CO_2 emissions resulting from higher CAFE standards, primarily because Tol's 2008 survey includes a larger number of estimates of the SCC, as well as more recently-published estimates.

The agency is aware that rapid advances in modeling climate change and its potential economic damages have occurred over the past decade, and that the choice of discount rates has an

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[286] See Hope, Chris, and David Newbery, "Calculating the Social Cost of Carbon," unpublished paper, Cambridge University, May 2006, p. 15.

[287] U.S. EPA, Technical Support Document on Benefits of Reducing GHG Emissions, EPA-HQ-OAR-2008-318-0078.pdf, June 12, 2008.

[288] Equity weighting assigns higher weights per dollar of economic damage from climate change that are expected to be borne by lower-income regions of the globe, in an attempt to make the welfare changes corresponding to those damages more comparable to the damages expected to be sustained by higher-income world regions.

[289] These values are reported in EPA, Table 1. p. 12. Using the original estimates included in Tol's 2008 survey, which were supplied to NHTSA by the author, the agency calculates these values at $38 per ton and $62 per ton for 3% and 2% discount rates, slightly below the estimates reported by EPA. These differences may be attributable to the two agencies' use of different measures of inflation to update the original estimates from mid-1990s to 2007 price levels (NHTSA employs the Implicit Price Deflator for U.S. GDP, generally considered to be an accurate index of economy-wide price inflation).

[290] Tol (2008), Table A1.

[291] Department of Energy, 10 CFR Part 431, Energy Conservation Program for Commercial and Industrial Equipment: Packaged Terminal Air Conditioner and Packaged Terminal Heat Pump Energy Conservation Standards: Final Rule, *Federal Register*, October 7, 2008, pp. 58813-58814.

important influence on estimates of the SCC. In its next CAFE rulemaking, NHTSA will be working closely with EPA and other federal agencies to review the arguments for more selective use of published estimates of the SCC advocated by the EPA. However, based on the information gathered and analysis performed by the agency through last fall, and in view of the fact that this is a one model year rulemaking and the agency will review matters in considerable detail for the post MY 2011 proposal to be issued later this year, NHTSA is not now taking that step. Thus, for the purposes of this final rule, NHTSA has elected to use all 125 SCC estimates from peer-reviewed studies reported by Tol, instead of the more limited subset of these estimates relied upon by EPA. Including the full array of studies provides a reasonable basis for valuing reductions in CO_2 emissions. Specifically, NHTSA believes that there is still value at this time in considering pre-1995 studies and those that employ equity weighting (which account for 58 of the 125 peer-reviewed estimates included in Tol's survey), particularly recognizing that those studies have been published in peer-reviewed journals.[292]

For the purpose of this rulemaking, NHTSA has also elected not to base its estimates of the value of reducing CO_2 emissions solely on estimates that utilize a single discount rate. NHTSA acknowledges that the varying discount rates employed by different researchers are an important source of the significant differences in their resulting estimates of the SCC. However, the agency believes that the appropriate rate at which to discount economic damages occurring in the distant future is an economic parameter whose correct value for the purpose of analyzing future climate change and the resulting economic damages is subject to significant uncertainty, analogous to that surrounding other critical scientific and economic parameters in climate analysis. In the agency's view, it is reasonable to consider estimates based on different discount rates at the present time instead of attempting to resolve this uncertainty in the time left to complete this one-year rulemaking by limiting the sample of estimates to those that employ the single discount rate it regards as most appropriate. In its next CAFE rulemaking, NHTSA will work with EPA, DOE and other federal agencies to consider anew the issue of whether to rely exclusively on values of the SCC that are developed using discount rates that are consistent with the rate the agency uses to discount the value of reductions in future GHG emissions reductions to their present values.[293]

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[292] Again using the original estimates from Tol's 2008 survey supplied by the author, NHTSA estimates that excluding the 18 pre-1995 estimates from the 125 used to develop the $33 per ton mean estimate would increase it to $36 per ton, while excluding the 40 estimates that employ equity weighting would *reduce* the mean estimate to $23 per ton. Excluding both pre-1995 estimates and those that employ equity weighting would eliminate a total of 58 of the 125 peer-reviewed estimates, and reduce their mean value to $20 per ton.

[293] Climate economic studies report estimates of the SCC for specific future years, often in the form of a value for some stated base year and an estimate of the annual rate at which it will grow, as total atmospheric concentrations of GHGs are assumed to increase. These studies use some assumed rate to discount economic damages that are projected to occur over a very long span of future years to their present values as of the future year when emissions increases are assumed to occur. These estimates of the SCC during specific future years are used to value the reductions in GHG emissions that would result each year over the lifetimes of vehicles affected by CAFE standards; for example, higher CAFE standards for model year 2011 cars and light trucks would reduce GHG emissions each year from 2011 through approximately 2047, and the value of reducing those emissions by one ton will rise each year over that span. The estimated economic values of the reductions in GHG emissions during each of those future years must in turn be discounted to their present values as of today, so that they can be compared with the present values of other benefits and with vehicle manufacturers' costs for meeting higher CAFE standards. The rate used to perform this latter discounting must be selected by NHTSA, and the choice of its value is discussed in detail in Section V.B.14

As some commenters pointed out, another approach NHTSA could rely on to estimate the value of reducing GHG emissions would be to use actual or projected prices for CO_2 emission permits in nations that have adopted or proposed GHG emission cap and trade systems. In theory, permit prices would reflect the incremental costs for achieving the last emissions reductions necessary to comply with the overall emissions cap. If this cap were based on an estimate of the level of global emissions required to prevent an unacceptable degree of climate change, permit prices could provide an estimate of the benefits of reducing GHG emissions to a level that forestalls unacceptable climate change. A related approach would be to use estimates of the cost of reducing emissions from specific sources *other than* passenger cars or light trucks to estimate the value of reducing CO_2 emissions via higher CAFE standards, under the reasoning that requiring higher fuel economy for cars and light trucks would allow these costs to be avoided or saved.

NHTSA considered the use of CO_2 permit prices to measure the benefits from reducing emissions via higher CAFE standards, but did not select this approach primarily because of the current difficulty in deciding what is considered an "acceptable" degree of climate change. The answer to that question cannot be provided by environmental, technological or economic analyses alone or even in combination; answering that question also involves policy judgment. The agency also notes that there would also be considerable scientific uncertainty in determining the level of emissions reduction that would be necessary to limit climate change to any degree that was deemed acceptable, even if agreement on the latter could be achieved. Since permit prices would depend on the level of emission reduction that is required, they are likely to reflect this uncertainty. Additionally, as a general matter, permit prices reflect avoided costs of emission reductions and there is no direct or necessary relationship between avoided costs and benefits.

Finally, still other commenters urged the agency to take into account the economic value of any reduction in the risk of catastrophic climate events resulting from lower GHG emissions when estimating the benefits from reducing emissions. Most of the estimates of the SCC that are included in Tol's updated review treat the risks and potential damages from catastrophic events using conventional probabilistic methods to compute the "expected" value of a wide range of potential changes in climate and associated economic damages. However, few studies of the SCC attempt to include explicit premiums that measure the population's aversion to accepting the risks of catastrophic climate damages.[294] Further, most published studies of climate damages report insufficiently detailed results to allow the calculation of appropriate risk premiums.

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[294] Under the conventional assumption that successive increases in consumption produce progressively smaller improvements in economic welfare, the welfare level associated with the mean of a range of possible consumption levels is higher than the mean of the welfare levels associated with each possible level of consumption. Moreover, the difference between these welfare levels increases as the span of possible consumption levels is broadened, as would occur if increased GHG emissions have the potential to cause drastic climate changes and result in similarly drastic economic damages. In this situation, the true economic costs of increased emissions include not only the resulting increase in the probabilistic expected value of climate-related economic damages, but also the compensation that those suffering these damages would require in order to willingly accept the increased risk of catastrophic damages, even if that risk is extremely small. Conversely, the value of reducing GHG emissions should include not only the resulting reduction in the expected value of future climate-related economic damages, but also the added amount people would be willing to pay for the associated reduction in the risk that such catastrophic damage might occur.

NHTSA acknowledges that including an appropriate premium to reflect the value of reducing the risks of catastrophic climate events could significantly increase its estimate of the value of reducing CO_2 emissions, but it has not attempted to do so at this time.[295] (For discussion of NHTSA's consideration of abrupt climate change, see § 3.4.3.2.4 of the FEIS.) However, the agency is aware of recent research suggesting that including an appropriate risk premium can significantly increase estimates of the SCC, and by implication increase the estimated value of reducing CO_2 emissions.[296] In working with EPA, DOE and other federal agencies in the development of revised estimates of the benefits from reducing CO_2 emissions that could be used in the next CAFE rulemaking, NHTSA will carefully consider any new research that explicitly estimates risk premiums, and evaluate their applicability to the issue of estimating economic benefits from reductions in CO_2 emissions resulting from future CAFE standards. The agency will also work with those agencies and departments in exploring the possibility of calculating an appropriate risk premium using results reported in published studies of the SCC together with any necessary assumptions about the underlying economic behavior, such as the response of welfare to successive increases in consumption levels.

Domestic value of reducing CO_2 emissions

The agency was able to develop a domestic value by using the mean estimate of the global value of reduced economic damages from climate change resulting from reducing CO_2 emissions as a starting point; estimating the fraction of the reduction in global damages that is likely to be experienced within the U.S.; and applying this fraction to the mean estimate of global benefits from reducing emissions to obtain an estimate of the U.S. domestic benefits from lower GHG emissions.

The agency constructed an estimate of the U.S. domestic benefits from reducing CO_2 emissions using estimates of U.S. domestic and global benefits from reducing greenhouse gas emissions developed by EPA and reported in that agency's Technical Support Document accompanying its advance notice of proposed rulemaking on motor vehicle CO_2 emissions.[297] Specifically, NHTSA calculated the ratio of domestic to global values of reducing CO_2 emissions estimated by EPA using the Climate Framework for Uncertainty, Negotiation, and Distribution (FUND) integrated assessment model.

EPA's central estimates of domestic and global values for reducing GHG emissions during 2007 using the FUND model using a 3 percent discount rate were \$1 and \$17 per metric ton (in 2006\$), which suggests that benefits to the U.S. from reducing CO_2 emissions are likely to represent about 6 percent of their global total. The comparable figures derived using a 2 percent discount rate are \$4 and \$88 for 2007, suggesting that U.S. domestic benefits from reductions in CO_2 emissions would amount to less than 5 percent of their global total. EPA's results also suggest that these fractions are likely to remain roughly constant over future decades.[298]

[295] Tol estimates that including an appropriate risk premium would increase the mean estimate of the SCC included in his more recent survey by 15-27%; see Tol (2008), Table 2.
[296] Hope, Chris, and David Newbery (2006), Calculating the social cost of carbon, University of Cambridge, May 2, 2006.
[297] U.S. EPA, Technical Support Document on Benefits of Reducing GHG Emissions, June 12, 2008.
[298] These values are reported in EPA, Table 1. p. 12.

Applying the 5-6 percent figure to the $33 per metric ton mean estimate of the global value of reducing CO_2 emissions derived previously yields an estimate of approximately $2 per metric ton for the domestic benefit from reducing U.S. CO_2 emissions in 2007.

NHTSA also constructed a second estimate of the fraction of global economic damages from climate change likely to be borne by the U.S., using the procedure described by Delucchi in his comments on the NPRM.[299] Delucchi noted that the fraction of global damages from climate change borne within the U.S. can be estimated by adjusting the U.S. share of world economic output, measured by the ratio of U.S. GDP to gross world product, by the relative sensitivity of U.S. and world economic output to damages resulting from climate change. Using data on the U.S. share of world economic output (which ranges from 20-28 percent) and published estimates of the relative sensitivity of the U.S. economy to climate damages compared to the world economy as a whole, Delucchi estimated that the U.S. fraction of global economic damages from climate change is likely to range from 0-14 percent. Applying the midpoint of this range (7 percent) to the $33 per ton mean estimate of the global value of reducing CO_2 emissions also yields an estimate of approximately $2 per metric ton for the domestic benefit from reducing U.S. CO_2 emissions in 2007.

Choosing between a global value and a domestic value, and estimating the global values
As the IPCC has noted, CO_2 and other GHGs are chemically stable, and thus remain in the atmosphere for periods of a decade to centuries or even longer, becoming well-mixed throughout the earth's atmosphere. As a consequence, emissions of these gases have extremely long-term effects on the global climate. Further, emissions from any particular geographic area (for example, the U.S.), are expected to contribute to changes in the global climate that will affect many other countries around the world. Similarly, emissions occurring in other countries will contribute to changes in the earth's future climate that are expected to affect the well-being of the U.S. The long-lived nature of atmospheric GHGs means that emissions of these gases from any location or source can affect the global climate over a prolonged period, and can thus result in economic damages to many other nations as well as over subsequent generations.

In view of the global effects of GHG emissions, reducing those emissions to an economically efficient level, *i.e.*, one that maximizes the difference between the total benefits from limiting the extent of climate change and the total costs of achieving the reduction in emissions necessary to do so, would require each individual nation to limit its own domestic emissions to the point where its *domestic* costs for further reducing emissions within its borders equal the *global* value of reduced economic damages that result from limiting climate change. NHTSA believes that this argument has considerable merit from the standpoint of economic theory.

If individual nations were instead to consider only the domestic benefits they receive from limiting the pace or extent of climate change, each nation would reduce emissions only to the point where its costs for achieving further reductions equal the benefits to its domestic economy from limiting the impacts of climate change. As a result, the combined global reduction in

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[299] Mark A. Delucchi, Summary of the Non-Monetary Externalities of Motor Vehicle Use, UCD-ITS-RR-96-3 (9) rev.1, Institute of Transportation Studies, University of California, Davis, originally published September 1998, revised October 2004, pp. 49-51. Available at http://www.its.ucdavis.edu/publications/2004/UCD-ITS-RR-96-03(09)_rev1.pdf (last accessed March 23, 2009).

emissions resulting from individual nations' comparisons of their domestic benefits from limiting climate change to their domestic costs for reducing emissions might be inadequate to slow or limit climate change.

At the same time, however, the agency must also consider the economic, environmental and other effects on the U.S. that a choice of a global value in this rulemaking might have, given the current stage of ongoing domestic legislative activity and negotiations regarding effective international cooperation and coordination. NHTSA notes that there might be risks to nations that unilaterally attempt to reduce their emissions by adopting policies or regulations whose domestic marginal costs equal the global marginal benefits from reducing the threat of climate change. Such actions could induce economic activity within their borders – particularly production by emissions-intensive industries – to shift to nations that adopt less stringent regulations or lower economic penalties on emissions within their respective borders. Such a shift would cause emissions abroad to increase, offsetting at least some of the benefits of domestic emissions reductions.

The agency recognizes that the arguments for using global versus domestic values of reducing GHG emissions are complex, and cannot be resolved satisfactorily by the unilateral actions of any single federal agency. Instead, resolution of whether to use a domestic or global value for reducing emissions, and developing reliable estimates of those values, as relevant, will require active participation by all federal agencies whose regulatory and policy-making activities will be affected by this decision, as well as leadership from the Administration. In reaching such a consensus, participants will need to assess not only the economic arguments favoring global versus domestic values of reducing emissions, but also the prospects for effective international cooperation to reduce global GHG emissions, the likelihood that leadership by the U.S. in seeking emissions reductions would spur international efforts to reduce emissions, and the precedents established by federal agencies that have previously evaluated benefits from regulations that lower GHG emissions. They will also need to consider arguments that U.S. citizens may attach some value to reductions in the threat of climate impacts occurring in other regions of the globe, and that reducing the impacts of climate change on other nations may have important "spillover" benefits to the U.S. itself. A position has not been adopted by the relevant entities.

In these circumstances, NHTSA decided to take a pragmatic approach to estimating the value of reducing GHG emissions for the immediate and limited purpose of this rulemaking. As noted above, we used the mean value in Tol (2008). To develop a reasonable upper-bound estimate of that value for purposes of this rule, the agency used a value one standard deviation above the $33 mean value.[300] As also noted above, the standard deviation of peer-reviewed estimates from Tol's 2008 survey is $47 per ton when expressed in comparable terms, which yields an upper-bound estimate of $80 per ton (equal to $33 plus $47) of CO_2 emissions avoided.[301] Because the

[300] A two-standard deviation range around the agency's $33 per ton central estimate would extend from minus $59 to $126 per ton of CO_2 emissions. The agency notes that the lower end of this range implies economic *benefits* of $59 for each additional ton of CO_2 emissions during 2007, while its upper end significantly exceeds all but two of the 125 peer-reviewed estimates included in Tol's 2008 survey.
[301] A value one standard deviation below the $33 mean would be -$14 per ton, which implies economic benefits of $14 for each additional ton of emissions. Because of this implication, NHTSA regards the $2 per ton estimate of the

$80 per ton value is higher than those corresponding to nearly 90% of the 125 peer-reviewed estimates of the SCC included in the survey, the agency views it as a reasonable upper bound on the likely global value of reducing CO_2 emissions.[302] For the purposes of this rulemaking, NHTSA believes that the range extending from the $2 per ton estimate of the domestic value of reducing CO_2 emissions to the $80 per ton estimate of the global value is sufficiently broad to illustrate the sensitivity of alternative MY 2011 CAFE standards and the resulting fuel savings and emissions reductions to plausible differences in the SCC.

Rate of growth of SCC

The marginal cost per ton of additional CO_2 emissions is generally expected to rise over time, because the increased pace and degree of climate change – and thus the resulting economic damages – caused by additional emissions are both expected to rise in proportion to the *existing* concentration of CO_2 in the earth's atmosphere. The IPCC Fourth Assessment Report variously reported that the climate-related economic damages resulting from an additional ton of carbon emissions are likely to grow at a rate of 2.4 percent annually, and at a rate of 2-4 percent annually.[303] Virtually all commenters who addressed this issue indicated that the IPCC intended the 2.4 percent growth rate it reported for the SCC in one passage to instead read "2-4 percent," and many urged NHTSA to apply a 3 percent or higher growth rate to determine the future value of the SCC.

NHTSA staff reviewed the underlying references from which the disputed figure was derived, and those sources clearly report the growth rate implied by their estimates of the future value of the SCC for different future years as 2.4 percent, instead of the 2-4 percent asserted by commenters.[304] Although most studies that estimate economic damages caused by increased GHG emissions in future years produce an implied growth rate in the SCC, neither the rate itself nor the information necessary to derive its implied value is commonly reported. NHTSA has been unable to locate other published research that reports the likely future rate of growth in damage costs from CO_2 emissions or the information required to derive it. NHTSA understands that other researchers may be using alternative growth rates. The agency may revise the estimated rate of growth it uses in its future analyses based on emerging estimates in the literature and on interagency coordination with the EPA, DOE and other federal agencies.

For the purposes of this rulemaking, NHTSA used the 2.4 percent annual growth rate to calculate the future increases in its estimates of both the domestic ($2/metric ton in 2007) and global ($33/metric ton and $80/metric ton in 2007) values of reducing CO_2 emissions. Over the lifetimes of cars and light trucks subject to the CAFE standards it is establishing for model year 2011, these values average nearly $4, $61, and $157 per ton of CO_2 emissions, approximately

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domestic value of reducing emissions as a more plausible lower bound on the value of reducing emissions than the $-14 per ton figure.

302 Tol reports that the 90% confidence limit of the distribution of peer-reviewed values is $170 per ton, while adding one standard deviation to his reported mean yields a value of $169; see Tol (2008), Table 1.

303 Yohe et al. (2007), p. 13 reports that "…it is very likely that the rate of increase [in the social cost of carbon] will be 2% to 4% per year." However, p. 822 states that "…the SCC will increase over time; current knowledge suggests a 2.4% per year rate of growth."

304 Hope, C.W. (2006), The Marginal Impact of CO2 from PAGE2002: An Integrated Assessment Model Incorporating the IPCC's Five Reasons for Concern, *Integrated Assessment Journal*, 6, (1), 19-56; and Hope, Chris, and David Newbery (2006), Calculating the social cost of carbon, University of Cambridge, May 2, 2006.

twice their estimated values during 2007. The agency is unaware of the basis for EDF's assertion that the 2.4 percent growth rate is to be used only in conjunction with an intergenerational discount rate with a maximum of 3 percent. Although the agency's analysis did follow EDF's suggestion in any case, NHTSA selected the growth rate in the future value of reducing CO_2 emissions and the discount rate applied to these benefits for separate reasons, as discussed in detail previously.

Insensitivity of MY 2011 standards to different values of SCC

NHTSA examined the sensitivity of alternative CAFE standards for MY 2011 to the choice among three different estimates of the value of reducing CO_2 emissions from fuel production and use: (1) the mean estimate of the global value of reducing emissions derived as discussed previously from Tol's 2008 survey--$33 per ton; (2) a value one standard deviation above this mean estimate--$80 per ton; and (3) the estimate of the value of U.S. domestic benefits from lower emissions derived as discussed above--$2 per ton.[305]

The agency tested the sensitivity of its "optimized" CAFE standards for MY 2011 passenger cars and light trucks to the choice among those three alternative values for reducing CO_2 emissions. The agency's analysis revealed that the optimized CAFE standards for MY 2011 cars and light trucks were unaffected by the choice among those values for reducing CO_2 emissions from fuel production and use. The detailed results of this analysis are reported in the agency's previously-released Final Environmental Impact Statement for MY 2011-15 CAFE standards.

There are several reasons for the insensitivity of the MY 2011 standards to the different values of the SCC. First, not more than 15 percent of all models are being redesigned for MY 2011, thus limiting the changes that can be made. Second, in any year, the value of gasoline has a far greater effect on the potential level of the CAFE standards than the SCC. Third, in the analyses that employ the $33 or $80 per ton global values of the benefits from reducing CO_2 emissions, NHTSA reduces the savings in monopsony costs from lower U.S. petroleum consumption and imports to zero.[306] This is done in order to be consistent with the fact that monopsony payments are a transfer rather than a real economic benefit when viewed from the same global perspective. This reduction partly offsets the effect of the higher CO_2 value on the optimized CAFE standards and resulting benefits. It does not do so completely, however, because the value of reducing CO_2 emissions continues to grow at the assumed 2.4 percent rate over the period spanned by the analysis, nearly doubling over the lifetimes of MY 2011 vehicles.

Decision regarding the value of SCC

Given the insensitivity of the potential standards to the various values of SCC used in the above analysis, NHTSA concludes that it is unnecessary for the agency to select a single estimate of the

[305] In all analyses that employ its estimated value of the global benefits from reducing CO_2 emissions, NHTSA reduces the value of the savings in monopsony costs from lower U.S. petroleum consumption and imports to zero. This is consistent with the fact that when viewed from the same global perspective that justifies the use of a global value for reducing emissions, these monopsony payments represent a transfer of economic resources from consumers of petroleum products to petroleum producers, rather than an actual savings in economic resources, and thus do not constitute a real economic benefit.

[306] As noted above earlier in the discussion of SCC, NHTSA plans to review this practice in the next CAFE rulemaking.

value of reducing CO_2 emissions for inclusion in its analysis as part of this rulemaking. For that reason and in view of the significance that announcing the selection of either a domestic or global value in this rulemaking might have in the context of ongoing legislative activities and international negotiations, we are deferring the choice between a domestic SCC and a global SCC and, for the appropriate choice, the monetized value for the benefit of reduction, until the next CAFE rulemaking. This will provide the time necessary for more refined analysis and for the various affected federal agencies to work together and identify a consistent value for use in their respective regulatory and policy-making activities. NHTSA expects to participate actively in the process of developing an appropriate range of estimates for that value. By the time we issue a proposal this summer for MY 2012 and beyond, we anticipate those activities and efforts will have progressed sufficiently to enable the federal agencies to make an informed choice that we can use as a basis for that rulemaking. NHTSA expects that the economic value of reducing CO_2 emissions will play an important role in developing and analyzing standards in the next CAFE rulemaking which, unlike this rulemaking, we expect to be a five-year rulemaking.

Consumer 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 are at least as large as drivers' added costs for the fuel it consumes (measured at the improved level of fuel economy resulting from stricter CAFE standards).[307] The benefits from additional rebound effect travel also include the consumer surplus received by vehicle buyers who value the opportunities that increased travel makes available to them at more than the fuel cost of the additional driving. Because it depends on the improvement in fuel economy, the value of benefits from increased vehicle use changes by model year and alternative CAFE standard, and is shown in Tables VIII-6 through VIII-10.

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, any 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.

[307] These benefits are included in the value of fuel savings reported in Tables VIII-5 through VIII-9.

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 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 increased external costs from the rebound effect.

Our analysis uses estimates of the congestion costs, crash costs, and noise costs for pickup trucks and vans developed by the Federal Highway Administration to estimate the increased external costs caused by added light truck use from the rebound effect.[308] 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 light trucks that are borne by persons other than their drivers. FHWA's "Middle" estimates for congestion, crash, and noise costs imposed by passenger cars are 5.22 cents, 2.26 cents and 0.07 cents per vehicle mile when expressed in 2006 dollars.[309] For pickup trucks and vans these costs are 4.66 cents, 2.51 cents, and 0.07 cents per vehicle-mile. These costs are multiplied by the estimated increases in passenger car and light truck use from the rebound effect during each year of the affected model years' lifetimes in the fleet to yield the estimated increases in congestion, crash, and noise externality costs during that year. The resulting estimates are discounted to their present values as of the date each model year is sold and summed to obtain their total values.

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

[308] These estimates were developed by FHWA for use in its 1997 *Federal Highway Cost Allocation Study*.

[309] 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. 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.

in the U.S. to be 3.9 and 3.4 cents per vehicle-mile when converted to 2006 dollars.[310] 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.

Costs from Increased Air Pollutant Emissions

Finally, as noted previously under Emissions Reductions Resulting from Fuel Savings, additional passenger car and light truck use associated with the rebound effect will increase emissions of air pollutants that occur as motor vehicles are driven. Predominant air pollutants emitted by motor vehicles include hydrocarbon compounds (usually referred to as "volatile organic compounds," or VOC), nitrogen oxides (NOx), fine particulate matter (PM), and sulfur dioxide (SO_2). The increased use of passenger cars and light trucks that occurs through the rebound effect causes higher emissions of these "criteria" pollutants, since Federal standards limit their permissible emissions by motor vehicles on a per-mile basis. The increase in emissions of these pollutants from additional vehicle use is estimated by multiplying the increase in total miles driven by vehicles of each model year and age during a calendar year by age-specific emission rates per vehicle-mile developed using the U.S. Environmental Protection Agency's MOBILE6.2 motor vehicle emissions factor model[311]. The monetized value of changes in criteria pollutant emissions (fine PM, NOx, SO2, VOCs andCO) are derived from EPA estimates of the value of health and welfare-related damages (incurred or avoided). These estimates, expressed as dollars per ton, are based on the benefits associated with recently-adopted regulations that limit emissions of air pollutants from mobile sources, a category that includes passenger cars, light trucks, and other highway vehicles.[312]

The Value of Increased Driving Range

Improving the fuel economy of passenger cars and light-duty trucks may also increase their driving range before they require refueling. By reducing the frequency with which drivers typically refuel their vehicles, and by extending the upper limit of the range they can travel before requiring refueling, improving fuel economy thus provides some additional benefits to their owners. (Alternatively, if manufacturers respond to improved fuel economy by reducing the size of fuel tanks to maintain a constant driving range, the resulting cost saving will presumably be reflected in lower vehicle sales prices.)

No direct estimates of the value of extended vehicle range are readily available, so the agency's analysis calculates the reduction in the annual number of required refueling cycles that results from improved fuel economy, and applies DOT-recommended values of travel time savings to convert the resulting time savings to their economic value.[313] As an illustration of how the value

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[310] 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.

[311] U.S. Environmental Protection Agency, MOBILE6 Vehicle Emission Modeling Software, http://www.epa.gov/otaq/m6.htm#m60

[312] EPA, "Mobile Source $ per Ton Estimates," document provided to NHTSA by EPA Office of Transportation and Air Quality staff, June 26, 2007.

[313] See http://ostpxweb.dot.gov/policy/Data/VOT97guid.pdf and http://ostpxweb.dot.gov/policy/Data/VOTrevision1_2-11-03.pdf

of extended refueling range is estimated, a typical small light truck model has an average fuel tank size of approximately 20 gallons. Assuming that drivers typically refuel when their tanks are 20 percent full (i.e., 4 gallons in reserve), increasing this model's actual on-road fuel economy from 24 to 25 mpg would extend its driving range from 384 miles (= 16 gallons x 24 mpg) to 400 miles (= 16 gallons x 25 mpg). Assuming that it is driven 12,000 miles/year, this reduces the number of times it needs to be refueled each year from 31.3 (= 12,000 miles per year / 384 miles per refueling) to 30.0 (= 12,000 miles per year / 400 miles per refueling), or by 1.3 refuelings per year.

Weighted by the nationwide mix of urban (about 2/3) and rural (about 1/3) driving and average vehicle occupancy for all driving trips (1.6 persons), the DOT-recommended value of travel time per vehicle-hour is $24.00 (in 2006 dollars).[314] Assuming that locating a station and filling up requires ten minutes, the annual value of time saved as a result of less frequent refueling amounts to $5.20 (calculated as 10/60 x 1.3 x $24.00). This calculation is repeated for each future calendar year that light trucks of each model year affected by the alternative CAFE standards considered in this rule would remain in service. Like fuel savings and other benefits, however, the value of this benefit declines over a model year's lifetime, because a smaller number of vehicles originally produced during that model year remain in service each year, and those remaining in service are driven fewer miles.

Table VIII-5 summarizes the values used to calculate the impacts of each scenario.

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[314] The hourly wage rate during 2006 is estimated to be $24.00. Personal travel (94.4% of urban travel) is valued at 50 percent of the hourly wage rate. Business travel (5.6% or urban travel) is valued at 100 percent of the hourly wage rate. For intercity travel, personal travel (87%) is valued at 70 percent of the wage rate, while business travel (13%) is valued at 100 percent of the wage rate. The resulting values of travel time are $12.67 for urban travel and $17.66 for intercity travel, and must be multiplied by vehicle occupancy (1.6) to obtain the estimate value of time per vehicle hour.

Table VIII-5
Economic Values for Benefits Computations (2007$)

Fuel Prices (average retail gasoline price per gallon, 2011-30)	$3.33
Rebound Effect (VMT Elasticity)	-0.15
Discount Rates Applied to Future Benefits	
Reductions in CO_2 Emissions	3%
Other Benefits	7%
Payback Period (years)	5.0
"Gap" between Test and On-Road MPG	20%
Value of Travel Time per Vehicle ($/hour)	$24.64
Economic Costs of Oil Imports ($/gallon)	
"Monopsony" Component	$0.266
Price Shock Component	$0.116
Military Security Component	-
Total Economic Costs ($/gallon)	$0.381
External Costs from Additional Automobile Use Due to "Rebound" Effect ($/vehicle-mile)	
Congestion	$0.054
Accidents	$0.023
Noise	$0.001
Total External Costs	$0.078
External Costs from Additional Light Truck Use Due to "Rebound" Effect ($/vehicle-mile)	
Congestion	$0.048
Accidents	$0.026
Noise	$0.001
Total External Costs	$0.075
Emission Damage Costs	
Carbon Monoxide ($/ton)	$ -
Volatile Organic Compounds ($/ton)	$1,700
Nitrogen Oxides ($/ton)	$4,000
Particulate Matter ($/ton)	$168,000
Sulfur Dioxide ($/ton)	$16,000
Carbon Dioxide ($/metric ton)	$ 2.00
Carbon Dioxide ($/metric ton)	
(U.S. domestic value)	$2.00
(Mean global value from Tol (2008)	$33.00
(One standard deviation above mean global value	$80.00
Annual Increase in CO2 Damage Cost	2.4%

Summary of Benefits

Benefits were calculated separately for passenger cars and light trucks under each alternative CAFE requirement for each model year covered by this proposal. In Tables VIII-6 through VIII-7, the societal impacts for passenger car and light truck CAFE standards under the proposed Optimized Net Benefits alternative is shown for model year 2011. These tables include undiscounted values as well as present value calculations at 7 percent. They also show changes in the physical units of measure that produced these values. Negative values in these tables reflect net reductions in fuel consumption or emissions and their resulting economic impacts, which represent benefits from the proposal, while positive 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 proposed standards for passenger cars would save approximately 463 million gallons of fuel and prevent 4 million metric tons of tailpipe CO_2 emissions over the lifetime of the passenger cars sold during those model years, compared to the fuel savings and emissions reductions that would occur if the standards remained at the adjusted baseline (i.e., the higher of manufacturer's plans or the manufacturer's required level of average fuel economy for MY 2010).

The total value of societal benefits of the proposed passenger car standards would be $1billion[315] over the lifetime of the MY 2011fleet. 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. Direct benefits to consumers, including fuel savings, consumer surplus from additional driving, and reduced refueling time, account for 87.7 percent of the <u>gross</u> consumer benefits[316] resulting from increased passenger car CAFE. Petroleum market externalities account for 10 percent. Environmental externalities, i.e., reduction of air pollutants accounts for 2.3 percent.

The proposed standards for light trucks would save approximately 424 million gallons of fuel and prevent 4 million metric tons of tailpipe CO_2 emissions over the lifetime 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 (i.e., the higher of manufacturer's plans or the manufacturer's required level of average fuel economy for MY 2010).

The total value of societal benefits of the proposed light truck standards would be $920 million[317]. 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. Direct benefits to consumers, including fuel savings, consumer surplus from additional driving, and reduced refueling time, account for 87.6 percent of the <u>gross</u> consumer

[315] The $1 billion estimate is based on a 7% discount rate for valuing future impacts. Undiscounted, these benefits are valued at almost $1.6 billion.

[316] Gross consumer benefits are benefits measured prior to accounting for the negative impacts of the rebound effect. They include fuel savings, consumer surplus from additional driving, reduced refueling time, petroleum market externalities, reduced criteria pollutants, and reduced greenhouse gas production. Negative impacts from the rebound effect include added congestion, noise, and crash costs due to additional driving.

[317] The $920 million estimate is based on a 7% discount rate for valuing future impacts. Undiscounted, these benefits are valued at about $1.5 billion

benefits resulting from increased light truck CAFE. Petroleum market externalities account for 10 percent. Environmental externalities, i.e., reduction of air pollutants accounts for 2.4 percent.

Table VIII-8 summarizes the fuel savings from all alternatives for passenger cars and light trucks. As would be expected, benefit levels parallel the increasing stringency of the various alternatives that were examined. The two Optimized scenarios pushes technology up to the point where is ceases to be cost effective, but the 3% based scenario produces more benefits than the 7% based scenario because it places a higher value on benefits experienced in the future. The TC=TB scenario produces benefits that exceed the Optimized scenarios because it allows benefits that accrue from cost-beneficial technologies to offset costs that accrue from technologies that are not cost-beneficial. As might be expected, the High Technology scenario, which assumes the maximum use of all available technologies in all vehicles regardless of cost, produces higher savings than any of the 6 other scenarios. The 25% Below Optimized, 25% Above Optimized, and 50% Above Optimized scenarios were designed to produce results relative to the Optimized scenario, and their benefits accordingly reflect this.

Tables VIII-9 summarizes the total social benefits from all alternatives for passenger cars and light trucks. These tables summarize the value of net consumer benefits over the lifetime of the vehicles manufactured. The value of societal benefits mirrors the trends in stringency across alternative scenarios.

Table VIII-6

Lifetime Monetized Societal Impacts, Optimized 7%, MY 2011,
Passenger Cars

Societal Effect	Physical Units	Undiscounted Value (2007$ millions)	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-462,739(kgal)	1,296	842
Consumer Surplus from Additional Driving	1,827,193(kmiles)	158	103
Refueling Time Value	2,291,110(hours)	56	38
Petroleum Market Externalities	-462,739(kgal)	168	112
Congestion Costs	1,827,193(kmiles)	-98	-65
Noise Costs	1,827,193(kmiles)	-1	-1
Crash Costs	1,827,193(kmiles)	-42	-28
CO2	-4(mmT)	14	8
CO	-44,493(tons)	0	0
VOC	-2,171(tons)	4	2
NOX	-1,547(tons)	6	4
PM	-56(tons)	9	6
SOX	-616(tons)	10	7
Total		1,580	1,027

Table VIII-7

Lifetime Monetized Societal Impacts,
Optimized 7%, MY 2011, Light Trucks

Societal Effect	Physical Units	Undiscounted Value (2007$ millions)	Present Discounted Value @ 7%
Lifetime Fuel Expenditures	-424,238(kgal)	1,206	747
Consumer Surplus from Additional Driving	1,370,561(kmiles)	147	92
Refueling Time Value	1,613,123(hours)	40	25
Petroleum Market Externalities	-424,238(kgal)	154	98
Congestion Costs	1,370,561(kmiles)	-66	-42
Noise Costs	1,370,561(kmiles)	-1	-1
Crash Costs	1,370,561(kmiles)	-35	-22
CO2	-4(mmT)	15	8
CO	5,409(tons)	0	0
VOC	-1,047(tons)	2	1
NOX	-737(tons)	3	2
PM	-69(tons)	12	7
SOX	-554(tons)	9	6
Total		1,484	921

Table VIII-8
Savings in Millions of Gallons of Fuel
Undiscounted, over the Lifetime of the Model Year 2011 Fleet

	Passenger Cars	Light Trucks	Passenger Cars and Light Trucks Combined
25% Below Optimized (7%)	352	424	776
Optimized (7%)	463	424	887
25% Above Optimized (7%)	598	456	1,054
50% Above Optimized (7%)	794	456	1,250
Optimized (3%)	946	424	1,371
TC = TB (7%)	1,121	567	1,687
Technology Exhaustion (7%)	2,982	1,420	4,402

Table VIII-9
Present Value of Lifetime Social Benefits
(Millions of 2007 Dollars)

	Passenger Cars	Light Trucks	Passenger Cars and Light Trucks Combined
25% Below Optimized (7%)	786	921	1,707
Optimized (7%)	1,027	921	1,948
25% Above Optimized (7%)	1,332	989	2,321
50% Above Optimized (7%)	1,773	989	2,763
Optimized (3%)	2,647	1,176	3,824
TC = TB (7%)	2,487	1,189	3,676
Technology Exhaustion (7%)	6,406	2,950	9,356

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IX. NET BENEFITS AND SENSITIVITY ANALYSES

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 fines, 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 manufacturers' plans. Sensitivity analyses are also performed on some of the assumptions made in this analysis. Finally, a payback period is calculated, from the consumer's perspective.

Table IX-1 provides the total incremental costs (in millions of dollars) from a societal perspective. Table IX-2 provides the total benefits from a societal perspective for all vehicles produced. Table IX-3 shows the total net benefits in millions of dollars for the projected fleet of sales for model year 2011.

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 the exception of the Optimized (3%) alternative for light trucks. For the combined fleet, total compliance costs for the Total Cost = Total Benefit alternative is roughly 3.5 times those for the Optimized (7%) alternative. Relative to the proposed Optimized (7%) alternative, Technology Exhaustion produces costs that are 15.8 times the Optimized cost levels.

From Table IX-2, 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 1.9 times as high as the Optimized (7%) alternative, and the Technology Exhaustion alternative produces gross benefits that are 4.8 times the Optimized (7%) alternative.

While the pattern for benefits is directionally similar to the pattern for costs, the more aggressive technology scenarios do not increase benefits by as high a ratio as they do for costs. For example, the TC=TB alternative increases total benefits, but it also increases total costs, resulting in a net loss to society of $334 million. This is a function of the more aggressive alternatives relatively unrestrained functions. While the Optimized (7%) alternative adds technology until the marginal cost to society begins to exceed the marginal benefit, the TC=TB scenario and the Technology exhaustion scenario allow for continued investment in technology despite its negative net return. Thus, while both costs and benefits continue to rise with more aggressive technologies, the costs rapidly begin to exceed the benefits that society derives from the added investment.

The impact of the relatively unrestricted technology application that is enabled by the more aggressive scenarios is apparent from Table IX-3, which shows net total lifetime societal benefits under each alternative. The Optimized (7%) or the Optimized (3%) alternative produces the highest net total benefits to society, as would be expected. The TC=TB and Technology Exhaustion alternatives produce a net loss to society.

Table IX-1
Incremental Total Cost – Societal Perspective
(Millions of 2007 Dollars)

	Passenger Cars	Light Trucks	Passenger Cars and Light Trucks Combined
25% Below Optimized (7%)	291	649	940
Optimized (7%)	496	649	1,145
25% Above Optimized (7%)	1,003	915	1,918
50% Above Optimized (7%)	1,630	915	2,545
Optimized (3%)	1,820	649	2,469
TC = TB (7%)	2,619	1,391	4,009
Technology Exhaustion (7%)	11,907	6,214	18,120

Table IX-2
Present Value of Lifetime Societal Benefits by Alternative
(Millions of 2007 Dollars)

	Passenger Cars	Light Trucks	Passenger Cars and Light Trucks Combined
25% Below Optimized (7%)	786	921	1,707
Optimized (7%)	1,027	921	1,948
25% Above Optimized (7%)	1,332	989	2,321
50% Above Optimized (7%)	1,773	989	2,763
Optimized (3%)	2,647	1,176	3,824
TC = TB (7%)	2,487	1,189	3,676
Technology Exhaustion (7%)	6,406	2,950	9,356

Table IX-3
Net Total Benefits
Over the Vehicle's Lifetime – Present Value
(Millions of 2007 Dollars)

	Passenger Cars	Light Trucks	Passenger Cars and Light Trucks Combined
25% Below Optimized (7%)	496	272	767
Optimized (7%)	531	272	802
25% Above Optimized (7%)	329	75	403
50% Above Optimized (7%)	143	75	218
Optimized (3%)	828	527	1,355
TC = TB (7%)	(132)	(202)	(334)
Technology Exhaustion (7%)	(5,501)	(3,264)	(8,765)

Sensitivity Analyses
The agency has performed several sensitivity analyses to examine important assumptions. The analyses include:

1) The value of CO_2. We examined $2 per metric ton as a domestic value, $33 per metric ton as a global value and $80 per metric ton as a global value. These values can be translated into cents per gallon by multiplying by 0.0089[318], as shown below:

   $2 per ton CO_2 = $2*0.0089 = $0.0178 per gallon
   $33.00 per ton CO_2 = $33*0.0089 = $0.2937 per gallon
   $80.00 per ton CO_2 = $80*0.0089 = $0.712 per gallon

2) The value of monopsony costs. For domestic values of CO_2, the main analysis uses $0.27 per gallon for monopsony costs. At the low end of the range for domestic values, the sensitivity analysis examines $0.21. For global values of CO_2, a $0 value of monopsony cost is appropriate.

3) The price of gasoline. The main analysis uses the AEO 2008 high cost case estimate for the price of gasoline (see Table VIII-3). In this sensitivity analysis we also examine the reference case estimate of the price of gasoline from AEO 2008 estimate.

[318] 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. One ton of C = 44/12 tons CO_2 = 3.67 tons CO_2. 1 gallon of gas weighs 2,819 grams, of that 2,433 grams are carbon. $1.00 CO_2 = $3.67 C and
$3.67/ton * ton/1000kg * kg/1000g * 2433g/gallon = (3.67 * 2433) / 1000 * 1000 = $0.0089/gallon

4) Military security. For one of the scenarios, we added a $0.05 per gallon military security cost.

Sensitivity analyses were performed on just the optimized (7%) alternative. Presented are information on the average mpg expected to be achieved by the manufacturers, the price per vehicle increase, total benefits, the total cost increase, the total lifetime fuel saved and the total CO_2 emissions reduction.

Table IX-4
Sensitivity Analyses

	Fuel Prices	CO2 Value	Monopsony	Military Security
Final Rule	High	$2	$0.27	0
Low Global Carbon	High	$33	0	0
High Global Carbon	High	$80	0	0
Low Fuel	Low	$2	$0.21	0
Low Fuel High Military	Low	$2	$0.21	$.05

In the PRIA, we examined the sensitivity of the price of gasoline (low, reference, and high case), values of CO2 ($0 to $14 per ton), combined externalities ($0.120 and $0.504 per gallon), and the rebound effect (10 to 20 percent). Only the price of gasoline had a significant impact on the results. We repeated the rebound effect sensitivity analysis for the Final Environmental Impact Statement (FEIS). The results of these sensitivity analyses are shown in the FEIS at Section 3.4.4.2. Reducing the rebound effect from the 15 percent to 10 percent would have only a slight effect on fuel savings and reductions in CO_2 emissions. In contrast, increasing the rebound effect from the 15 percent value to 20 percent would lower the combined passenger car and light truck fuel savings by 0.5 to 1.5 mpg for the scenarios examined in Tables 3.4-3 and 3.4-4 of the FEIS.

The results of the sensitivity analyses indicate that the much wider values of CO_2 examined have almost no impact on the achieved mpg levels for passenger cars and a small impact on the light truck levels. The low fuel price has an impact on the light truck levels of 0.3 mpg. The high military cost (only $0.05 per gallon) has no impact on the level of the standards.

Note that there are some slight inconsistencies in the relationships one would expect when comparing the required mpg levels for corresponding model years in the various sensitivity analyses to those under the final rule CAFE standards. For example, the level of the standard should increase when CO_2 is assigned a higher value, because this increases the benefit of each gallon of fuel saved, but the optimized standards are actually *lower* with the high CO_2 value than under the final rule. Problems such as this arise when making slight changes in parameter values used by the CAFE model, since the model derives a relationship between net benefits and the stringency level of standards, and minor changes in parameter values can affect the exact shapes and positions of those curves. In any case, the seemingly anomalous results are mostly small (0.1 mpg or less). When larger variations are made to the model's parameters or other inputs, such as substituting the Reference Case gasoline price forecast, the sensitivity analysis invariable produces the anticipated result.

Table IX-5
Passenger Car Sensitivity Analyses
(mpg)

	MY 2011
Final Rule	30.7
Low Global Carbon	30.7
High Global Carbon	30.7
Low Fuel	30.7
Low Fuel, High Military	30.7

	MY 2011 Per Vehicle Cost ($)	MY 2011 Total Benefits ($Mill.)	MY 2011 Total Cost $(Mill.)	Total Fuel Saved (Bill. Gal.)	Total CO_2 Emissions (mmt)
Final Rule	64	1,027	496	463	4.3
Low Global Carbon	48	935	354	392	3.6
High Global Carbon	48	1,121	354	392	3.6
Low Fuel	45	662	317	404	3.7
Low Fuel High Military	45	662	317	404	3.7

Table IX-6
Light Truck Sensitivity Analyses
(mpg)

	MY 2011
Final Rule	23.2
Low Global Carbon	23.1
High Global Carbon	23.1
Low Fuel	22.9
Low Fuel, High Military	22.9

	MY 2011 Per Vehicle Cost ($)	MY 2011 Total Benefits ($Mill.)	MY 2011 Total Cost $(Mill.)	Total Fuel Saved (Bill. Gal.)	Total CO_2 Emissions (mmt)
Final Rule	126	921	649	424	3.9
Low Global Carbon	121	944	613	408	3.8
High Global Carbon	316	3,774	1,794	1,372	12.6
Low Fuel	95	297	560	220	2.0
Low Fuel High Military	95	297	560	220	2.0

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 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 and future savings are not discounted to present value, since consumers generally only consider and respond to what they pay at the pump. The payback periods are estimated as an average for all manufacturers for the different alternatives. The payback periods for MY 2011 are shown in Table IX-7.

Table IX-7
Payback Period for MY 2011 Average Vehicles
(in years)

	Passenger Cars	Light Trucks
25% Below Optimized	3.7	7.7
Optimized (7%)	4.4	7.7
25% Above Optimized	5.2	10.0
50% Above Optimized	8.2	10.0
Optimized (3%)	7.7	7.7
TC = TB	9.2	Never
Technology Exhaustion	Never	Never

X. PROBABILISTIC UNCERTAINTY ANALYSIS

OMB Circular A-4 requires 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 preliminary regulatory impact analysis and estimates the probability distribution of the benefits, costs, and net benefits of the compliance options selected for the proposed rule for MY 2011 passenger car and light truck CAFE 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. 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 imbedded 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 their probability distributions. These newly defined values are then randomly selected and fed back into the model to determine the net benefits using the Monte Carlo statistical simulation technique.[319] The simulation technique induces the probabilistic outcomes accompanied with degrees of probability or plausibility. This facilitates a more informed decision-making process.

The analysis is based on the actual processes used to derive net benefits as described in the previous chapters. Each variable (e.g., cost of technology) in the mathematical model represents an uncertainty factor that would potentially alter the modeling outcomes if its value was changed. We assume that these variables are independent of each other. 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. By contrast, there is reason to believe that monopsony costs may be dependent on fuel prices. However, monopsony costs are only one of several oil import externalities, and the range of monopsony costs is quite narrow. The potential for significant error due to an assumption of independence for monopsony costs is thus quite low. Given this, the agency has elected to treat monopsony costs as an independent variable.

The uncertainties of these variables are described by appropriate probability distribution functions based on available data. If data are not sufficient or not available, professional judgments are used to estimate the probability distributions of these uncertainty factors. A complete description of the formulas and methods used in the CAFE model is available in the public docket.[320]

[319] 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.

[320] CAFE Compliance and Effects Modeling System Documentation, Volpe Center, U.S. Dept. of Transportation, July 2005, pp. 27-46 and C-22 to C-35. Docket No. NHTSA 21974-2.

After defining and quantifying the major uncertainty factors, the next step is to simulate the model to obtain probabilistic results rather than single-value estimates. In the uncertainty analysis, CAFE levels were kept constant; in other words, we did not change the CAFE standards for each run based on net benefits. The simulation process was run repeatedly for 20,000 trials under each discount rate scenario. Each complete run is a trial. For each trial, the simulation first randomly selects a value for each of the uncertainty factors based on their probability distributions. The selected values are then fit into the models to forecast results. In addition to the simulation results, the program also estimates the degree of certainty (or confidence, credibility). The degree of certainty provides the decision-maker with an additional piece of important information with which to evaluate the forecast results.

A. 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 focus of the simulation model was variation around the chosen uncertainty parameters and their resulting impact on the key output parameters, fuel savings, and net benefits. Net benefits measure the difference between (1) the total dollar value that would be saved in fuel 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. Five factors were identified as contributing the most uncertainty to the estimated impacts of higher CAFE standards:

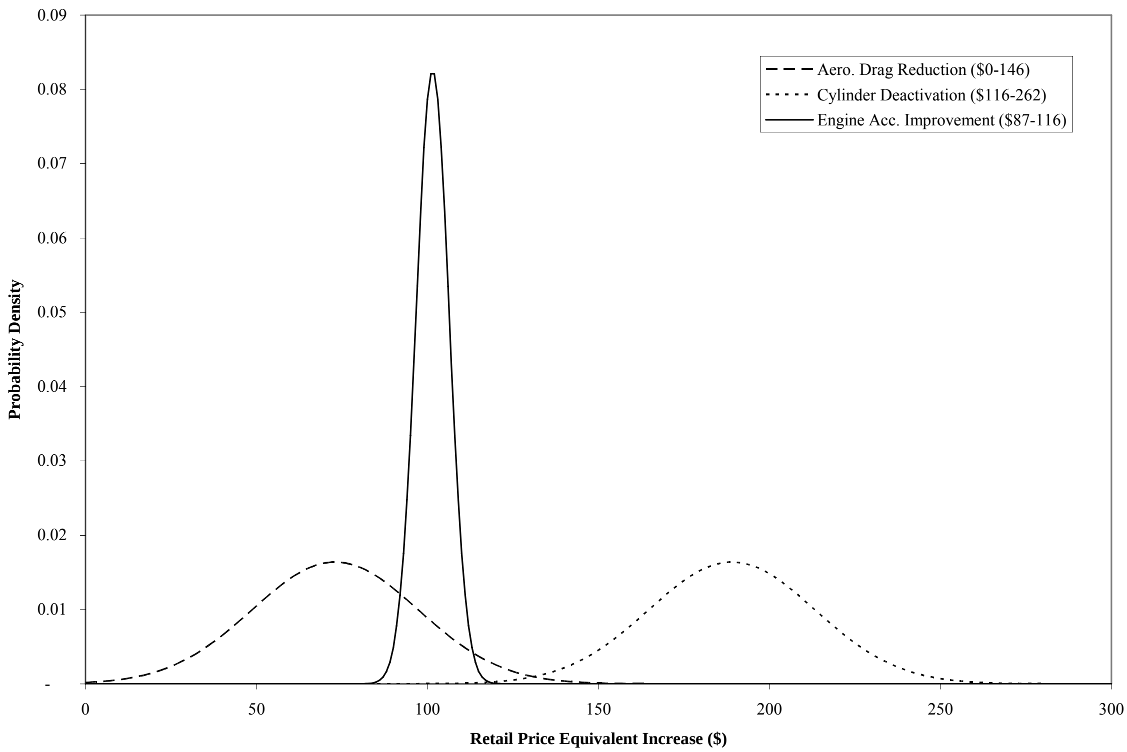
(1) Technology costs;
(2) Technology effectiveness;
(3) Fuel prices;
(4) The value of oil consumption externalities; and
(5) The rebound effect.
(6) Greenhouse gas values

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.

Forty different technologies were examined as possible methods to comply with higher CAFE standards. These technologies were summarized in Chapter V earlier in this analysis. Chapter V also summarizes the estimated range of costs for these technologies. The expected values (mid-range values) were used in the main analysis. For the uncertainty analysis, the full range of NAS cost estimates is used. The uncertainty model assumes a normal distribution for these costs, with each end of the range being three standard deviations from the mean (or expected) value. Since only 9 of the 40 technologies had range estimates for costs, the range across the remaining 31 technologies was estimated based on the average range found in the 9 technologies with range estimates (+-29%) Figure X-1 graphically demonstrates the distributions of a hypothetical sample of three of the technologies.

Figure X-1
Normal Distributions for 3 Different Technologies



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, forty different technologies were examined as possible methods to comply with higher CAFE standards. These technologies were summarized in Chapter V earlier in this analysis. Chapter V also summarizes the estimated range of effectiveness for these technologies. The expected values (mid-range values) were used in the main analysis. For the uncertainty analysis, the full range of effectiveness estimates is used. The uncertainties model assumes a normal distribution for these values, with each end of the range being three standard deviations from the mean (or expected) value. Since only 30 of the 40 technologies had range estimates for effectiveness, the range across the remaining 10 technologies was estimated based on the average range found in the 30 technologies with range estimates (+-31%)

Fuel Prices

Higher CAFE standards will result in reduced gasoline consumption, which will translate into lower vehicle operating costs for consumers. The value of this reduced fuel consumption 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.

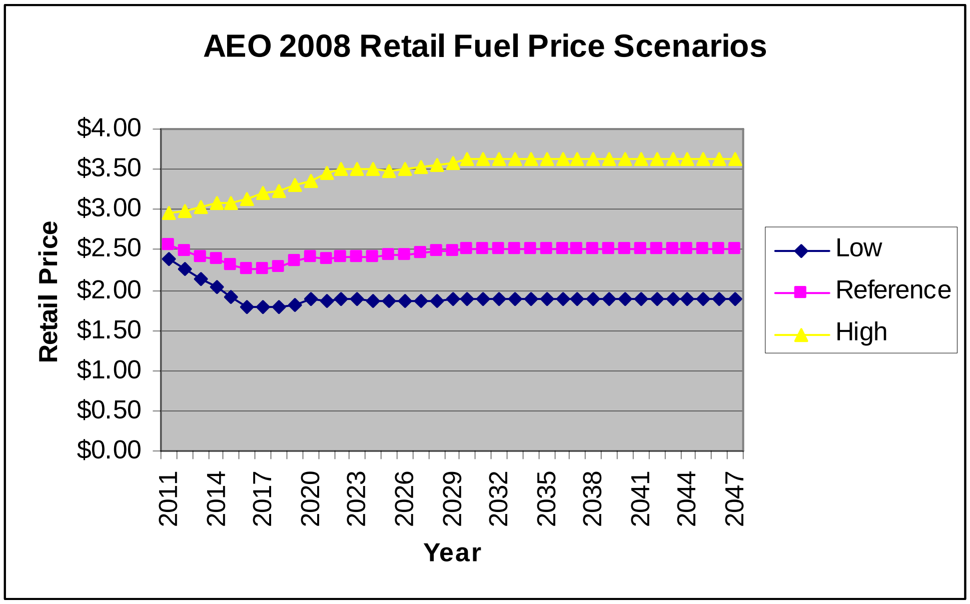
The analysis attempts to measure impacts that occur as much as 40 years in the future and estimating gasoline prices this far in advance is an uncertain process. In the main analysis, the agency utilized predicted fuel prices from the Energy Information Administration's (EIA) publication Annual Energy Outlook 2008 (AEO). For reasons discussed previously, the main analysis is based on the AEO High Case scenario, which represents the Agency's best estimate of future fuel prices. For the uncertainty analysis, the Agency examined two other AEO scenarios, the Low Oil Price scenario (LOP) and the Reference Oil Price scenario (ROP). Both scenarios were also derived from the AEO 2008.   These 2 alternate scenarios were chosen to allow for the possibility that the EIA's High Case predictions could overestimate the price of gasoline in the future. Oil prices have been extremely volatile over the past year, climbing to record highs and then most recently dropping to levels consistent with a year ago.

Each of these scenarios was applied as a discrete input (i.e., draws were not made from among the three scenarios separately for each future year). Rather, for each draw, one of the three scenarios was chosen and applied across the full vehicle life for each model year. The probability of selection for each of the three scenarios was modeled using discrete weights of 60 percent for the High Case, and 35 percent for the Reference Case and 5 percent for the LOP Case. Table X-1 lists the AEO gasoline price forecasts under each scenario. These same prices are demonstrated graphically (in 2007 economics) in Figure X-2. Note that these prices include Federal, State, and local fuel taxes. For the uncertainty analysis, taxes were removed because they are viewed as transfer payments (see discussion in Chapter VIII). Estimated retail prices are shown here because they are a better reference point for most readers.

Table X-1
AEO 2008 Gasoline Price Scenarios
(2007 dollars)

Year	Low	Reference	High
2011	$2.397	$2.551	$2.949
2012	$2.263	$2.475	$2.974
2013	$2.141	$2.404	$3.023
2014	$2.032	$2.388	$3.077
2015	$1.906	$2.315	$3.093
2016	$1.791	$2.254	$3.138
2017	$1.791	$2.266	$3.200
2018	$1.791	$2.292	$3.241
2019	$1.815	$2.360	$3.301
2020	$1.890	$2.419	$3.363
2021	$1.866	$2.384	$3.451
2022	$1.883	$2.404	$3.491
2023	$1.879	$2.412	$3.492
2024	$1.862	$2.407	$3.510
2025	$1.858	$2.423	$3.485
2026	$1.851	$2.436	$3.494
2027	$1.853	$2.449	$3.518
2028	$1.858	$2.472	$3.545
2029	$1.877	$2.496	$3.576
2030	$1.892	$2.512	$3.618
2031	$1.892	$2.512	$3.618
2032	$1.892	$2.512	$3.618
2033	$1.892	$2.512	$3.618
2034	$1.892	$2.512	$3.618
2035	$1.892	$2.512	$3.618
2036	$1.892	$2.512	$3.618
2037	$1.892	$2.512	$3.618
2038	$1.892	$2.512	$3.618
2039	$1.892	$2.512	$3.618
2040	$1.892	$2.512	$3.618
2041	$1.892	$2.512	$3.618
2042	$1.892	$2.512	$3.618
2043	$1.892	$2.512	$3.618
2044	$1.892	$2.512	$3.618
2045	$1.892	$2.512	$3.618
2046	$1.892	$2.512	$3.618
2047	$1.892	$2.512	$3.618

Figure X-2



Oil Consumption Externalities

Reduced fuel consumption can benefit society by lowering the world market price for oil, reducing the threat of petroleum supply disruptions, and reducing the cost of maintaining military security in oil producing regions and operating 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. For this reason, they were examined in the uncertainty analysis.

Table X-3 lists the range of values that were examined for oil consumption externalities. The expected values were used in the main analysis. Both the value of reducing U.S. demand on the world market price for oil and the value of reduced threat of supply disruptions were derived from a study by Leiby (2008) (see Chapter VIII). For reasons noted in Chapter VIII, military security is not specifically valued in this analysis. A normal distribution was assumed for the range of values for oil consumption externalities with the low and high values assumed to be two standard deviations from the mean, based on the Leiby estimates.

Table X-2
Uncertainty Ranges for Oil Consumption Externalities ($/gallon)

	Low	Expected	High
For reducing U.S. demand on world market price	$0.008	$0.266	$0.524
For reducing the threat of supply disruptions	$0.034	$0.116	$0.198

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 portion of the gasoline savings that results from more fuel-efficient vehicles. Although consumers derive some value from this extra driving, it also leads to increases in crash, congestion, noise, and pollution costs associated with driving. Most recent estimates of the magnitude of the rebound effect for light duty vehicles fall in the range of 10-20 percent (i.e., increasing vehicle use will offset 10-20 percent of the fuel savings resulting from an improvement in fuel economy). A more complete discussion of the rebound effect is included in Chapter VIII. The agency employed a rebound effect of 15 percent in the main analysis. For the uncertainty analysis, a range of 10 to 20 percent is used and employed in a skewed Beta distribution which produced a mean of approximately 14 percent. The skewed distribution reflects the agency's belief that the more credible studies that differ from the 15 percent value chosen for the main analysis fall below this value and differ by more substantial margins than the upper range of credible values.

Greenhouse Gas Emissions

Emissions of carbon dioxide (CO_2) and other greenhouse gases (GHG) occur throughout the process of producing and distributing transportation fuels, as well as from fuel combustion itself. By reducing the volume of fuel consumed by passenger cars and light trucks, higher CAFE standards will thus reduce GHG emissions generated by fuel use, as well as throughout the fuel supply cycle. Lowering these emissions is likely to slow the projected pace and reduce the ultimate extent of future changes in the global climate, thus reducing future economic damages that changes in the global climate would otherwise cause. By reducing the probability that climate changes with potentially catastrophic economic or environmental impacts will occur, lowering GHG emissions may also result in economic benefits that exceed the resulting reduction in the expected future economic costs caused by gradual changes in the earth's climatic systems. In Chapter VIII a full discussion of this issue, including alternate estimates of values for Greenhouse gases is presented. We had to pick a number for the uncertainty analysis. We could have chosen any of the numbers discussed in Chapter VIII. We chose $2 per metric ton of CO_2 emissions with a standard deviation of $1.00 per metric ton.

Table X-3 Summarizes the economic parameters used in the uncertainty analysis.

Table X-3

Monte-Carlo Specific Parameters

Rebound Randomization Parameters	
Rebound Alpha Shape	15.0
Rebound Beta Shape	6.6
Rebound Scale	-0.20
Rebound Base	-0.05
Monopsony Randomization Parameters	
Monopsony Mean	$0.266
Monopsony Standard Deviation	$0.129
Price Shock Randomization Parameters	
Price Shock Mean	$0.116
Price Shock Standard Deviation	$0.041
Military Security Randomization Parameters	
Military Security Mean	$0.000
Military Security Standard Deviation	$0.000
Carbon Dioxide Randomization Parameters	
CO-2 Mean	$2.00
CO-2 Standard Deviation	$1.00
Default Cost and Effectiveness Variations	
Cost Variation %	29%
Effectiveness Variation %	31%
Fuel Path Randomization Parameters	
Low	5%
Reference	35%
High	60%

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 40,000 trials (20,000 for each discount rate) Figures X- 3 through X-14 graphically illustrate the draw results for a sample of the 84 variables (40 technology effectiveness rates, 40 technology costs, the fuel price scenario, oil import externalities, the rebound effect, and CO2.) that were examined. Tables X-4 through X-8 list the draw results for each economic input, technology cost, and technology effectiveness.

Figure X-3
Monte Carlo Draw Profile, Passenger Car Costs

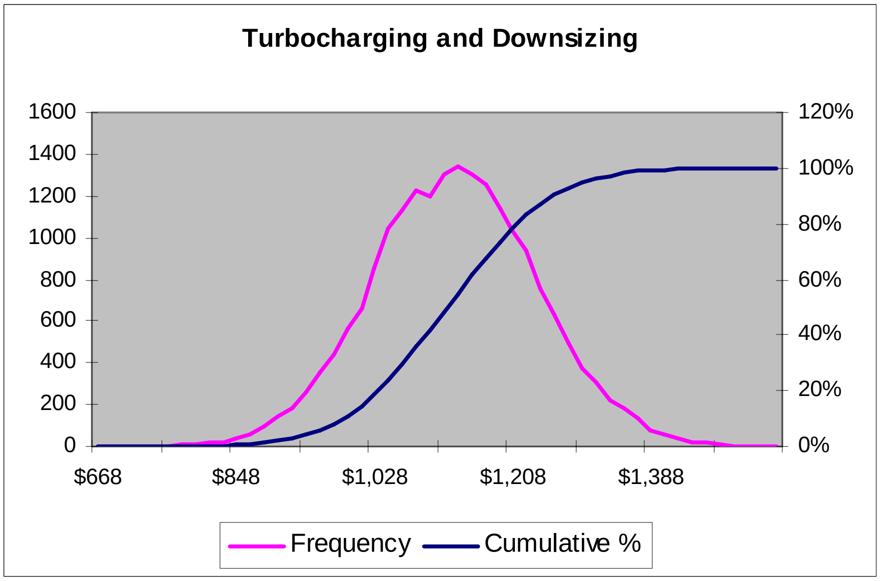


Figure X-4
Monte Carlo Draw Profile, Passenger Car Effectiveness

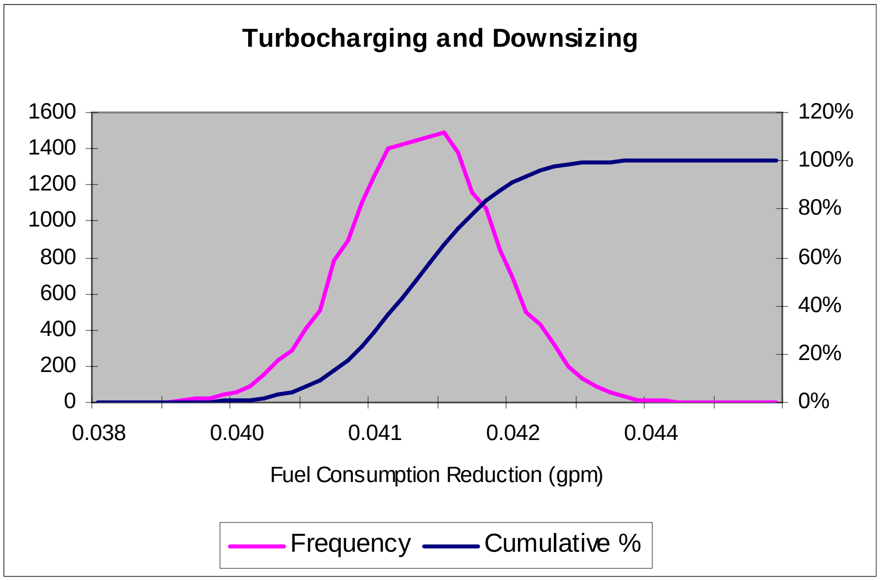


Figure X-5
Monte Carlo Draw Profile, Passenger Cars, Costs

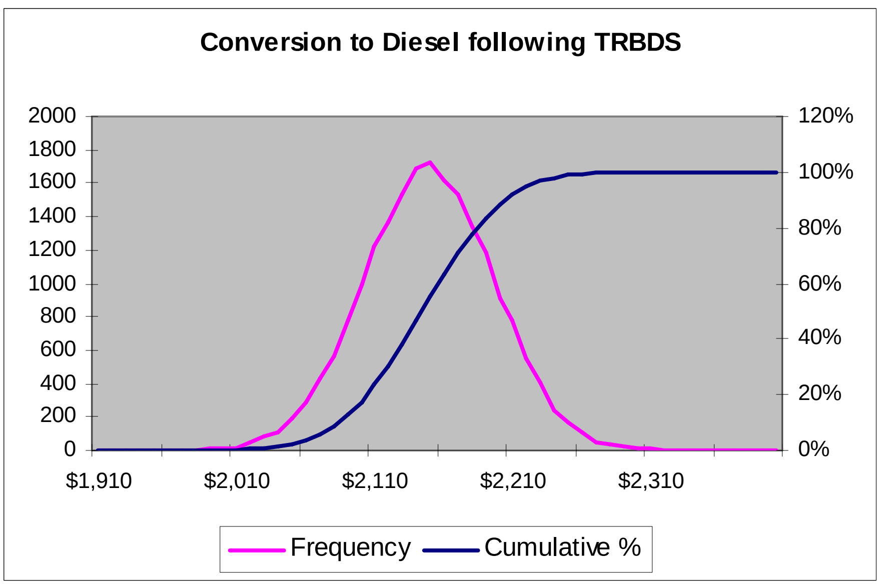


Figure X-6
Monte Carlo Draw Profile, Passenger Cars, Effectiveness

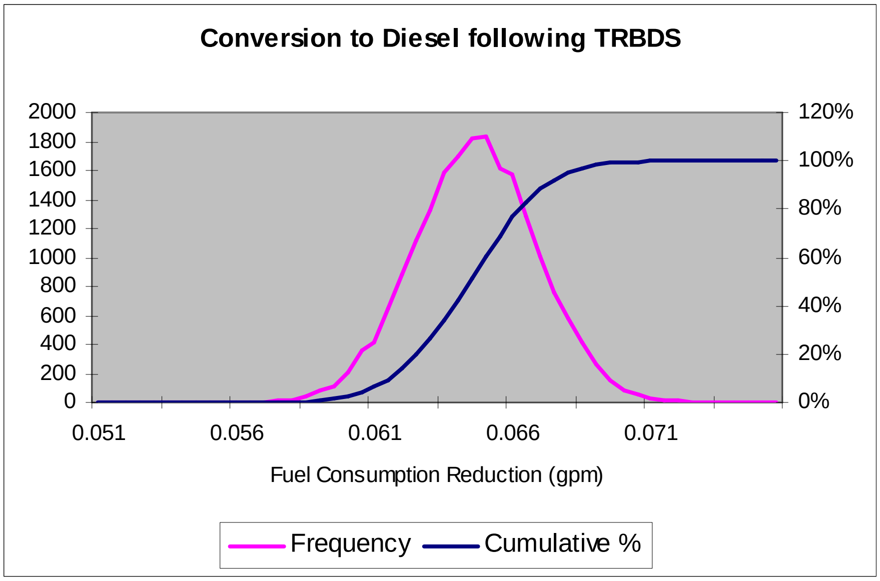


Figure X-7
Monte Carlo Draw Profile, Passenger Cars, Costs

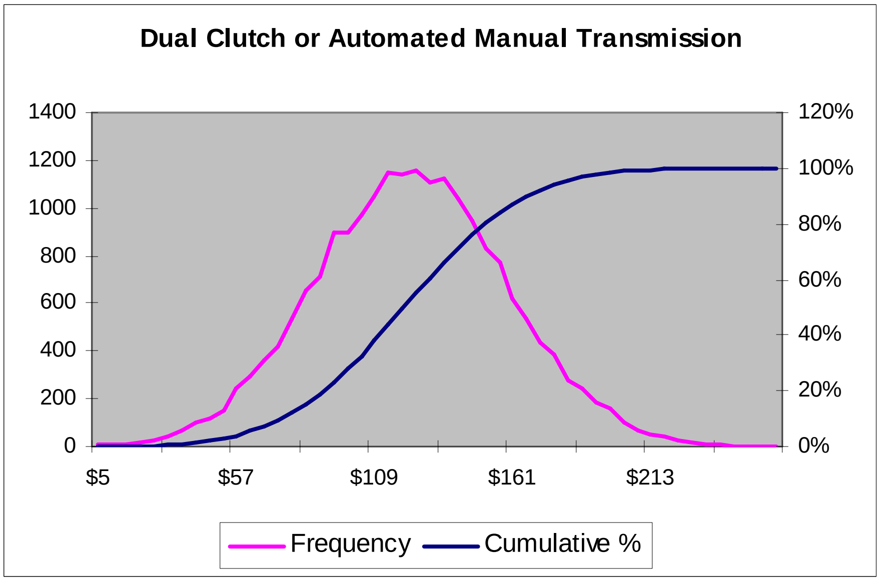


Figure X-8
Monte Carlo Draw Profile, Passenger Cars, Effectiveness

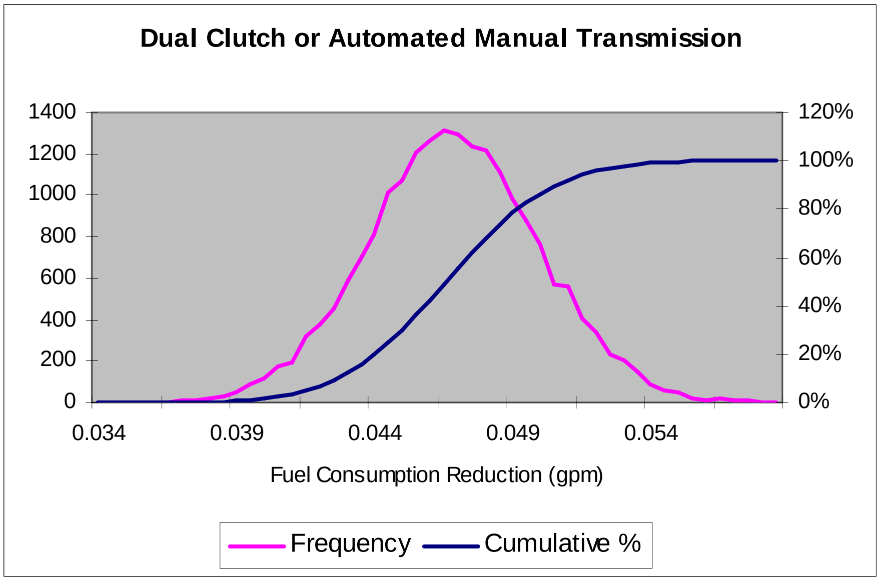


Figure X-9
Monte Carlo Draw Profile
Pretax Fuel Price Path

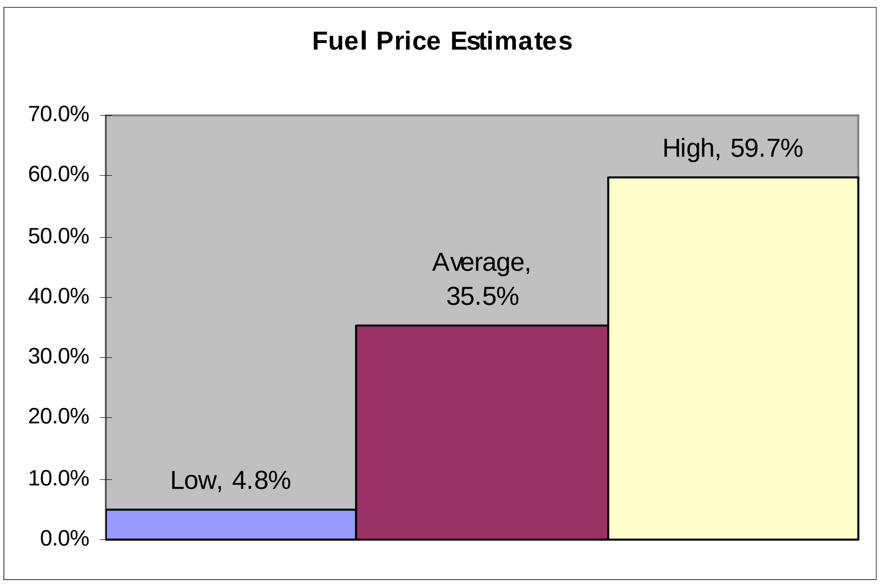


Figure X-10
Monte Carlo Draw Profile

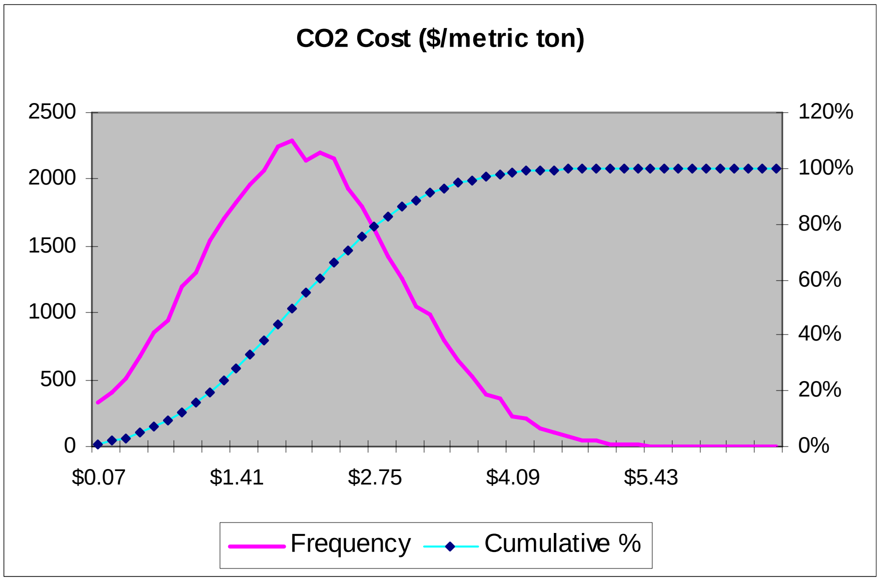


Figure X-11
Monte Carlo Draw Profile

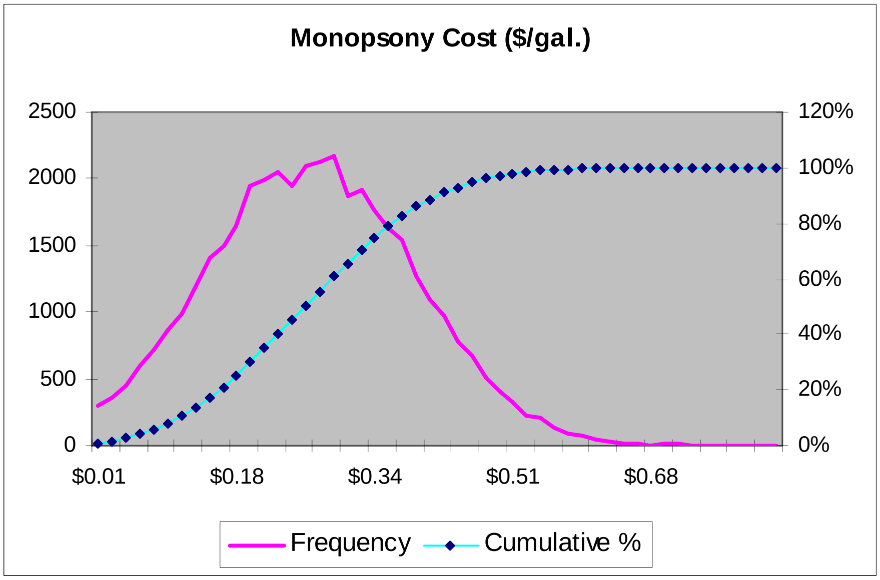


Figure X-12
Monte Carlo Draw Profile

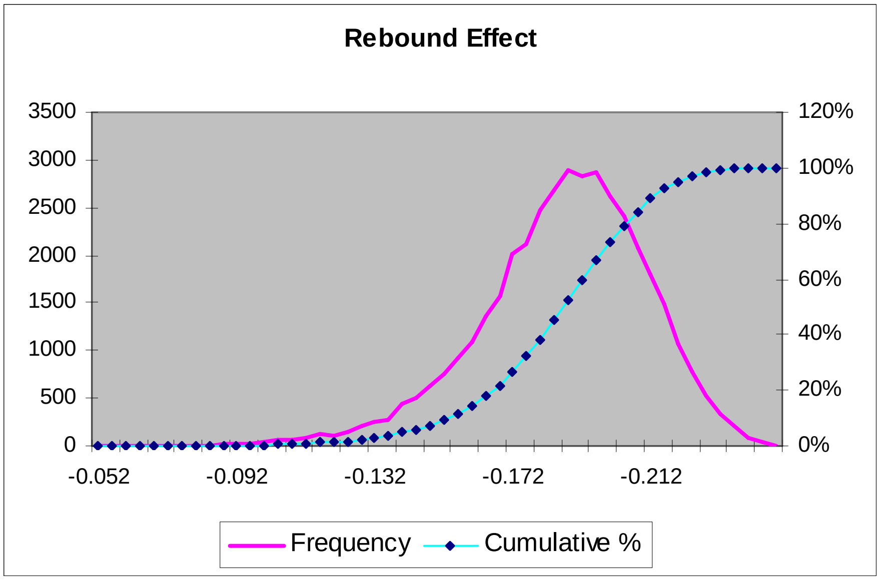


Figure X-13
Monte Carlo Draw Profile

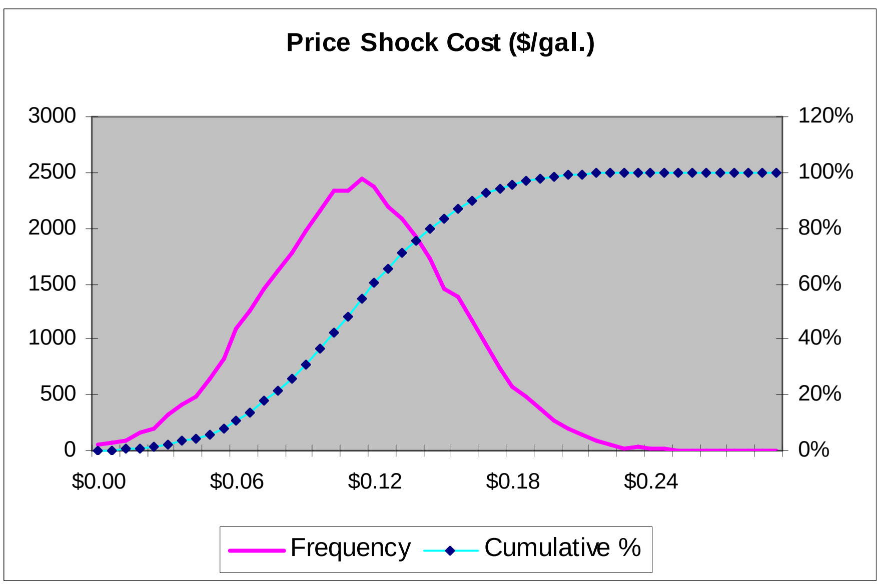


Figure X-14
Monte Carlo Draw Profile

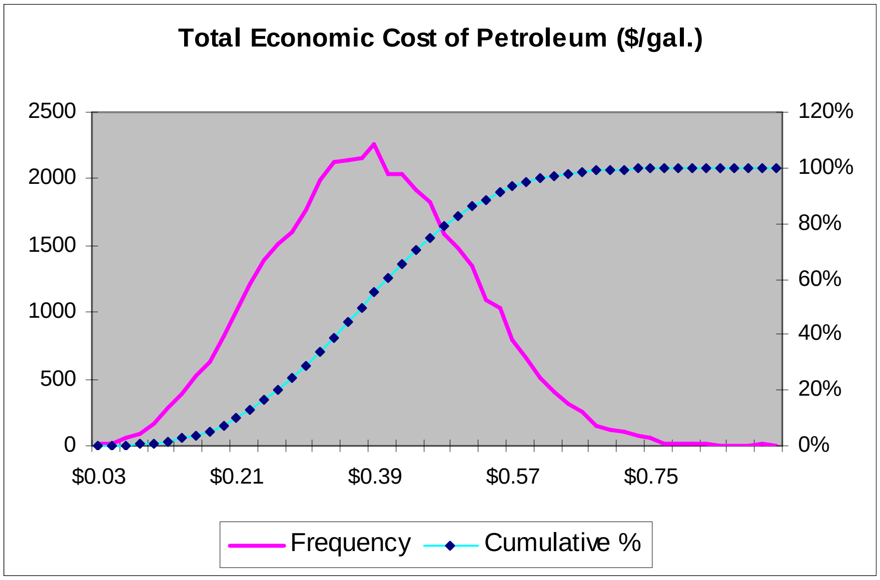


Table X-4
Monte Carlo Draw Results, Economic Inputs

Economic Inputs	**Minimum**	**Maximum**	**Mean**	**StdDev**
Rebound Effect	-0.247363	-0.058833	-0.186533	0.024108
Monopsony Cost	2.112E-05	0.8328859	0.270747	0.1210186
Price Cost Shock	1.944E-05	0.2958011	0.1160486	0.0402068
Total Economic Costs	0.0262398	0.9144824	0.3867956	0.1273687
CO2 Costs	0.000961	6.6922461	2.0517406	0.9371776

Table X-5
Monte Carlo Draw Results, Passenger Car Technology Costs

Passenger Car Technology Costs	**Minimum**	**Maximum**	**Mean**	**StdDev**
Low Friction Lubricants	$3.19	$7.28	$5.00	$0.48
Engine Friction Reduction	$6.31	$58.79	$31.01	$6.03
VVT - Coupled Cam Phasing (CCP) on SOHC	$37.89	$87.04	$60.99	$5.87
Discrete Variable Valve Lift (DVVL) on SOHC	$118.51	$275.63	$188.81	$18.18
Cylinder Deactivation on SOHC	$43.49	$101.67	$70.80	$6.82
VVT - Intake Cam Phasing (ICP)	$36.84	$88.25	$60.99	$5.89
VVT - Dual Cam Phasing (DCP)	$36.97	$89.25	$61.03	$5.84
Discrete Variable Valve Lift (DVVL) on DOHC	$115.55	$257.50	$188.57	$18.29
Continuously Variable Valve Lift (CVVL)	$172.36	$407.52	$283.34	$27.43
Cylinder Deactivation on DOHC	$46.30	$97.20	$70.80	$6.83
Cylinder Deactivation on OHV	$31.61	$71.54	$50.94	$4.93
VVT - Coupled Cam Phasing (CCP) on OHV	$37.65	$88.45	$60.95	$5.90
Discrete Variable Valve Lift (DVVL) on OHV	$97.77	$224.79	$157.90	$15.45
Conversion to DOHC with DCP	$222.89	$478.16	$353.58	$34.17
Stoichiometric Gasoline Direct Injection (GDI)	$65.53	$111.74	$88.14	$5.64
Combustion Restart	$84.90	$199.86	$141.17	$13.54
Turbocharging and Downsizing	$681.50	$1,597.47	$1,122.99	$108.04
Exhaust Gas Recirculation (EGR) Boost	$111.02	$237.59	$172.83	$16.67
Conversion to Diesel following TRBDS	$1,950.09	$2,351.85	$2,143.92	$47.08
Conversion to Diesel following CBRST	$3,238.68	$3,675.06	$3,440.37	$52.49
6-Speed Manual/Improved Internals	$208.46	$457.04	$337.99	$32.85
Improved Auto. Trans. Controls/Externals	$36.11	$85.05	$58.99	$5.70
Continuously Variable Transmission	$186.55	$438.16	$300.16	$28.97
6/7/8-Speed Auto. Trans with Improved Internals	$251.70	$474.10	$360.39	$26.52
Dual Clutch or Automated Manual Transmission	$0.08	$259.88	$120.22	$35.88
Electric Power Steering	$102.88	$122.11	$112.49	$2.49
Improved Accessories	$166.76	$214.06	$192.02	$6.31
12V Micro-Hybrid	$268.05	$587.90	$436.94	$41.89
Higher Voltage/Improved Alternator	$51.12	$119.34	$84.00	$8.12
Belt mounted Integrated Starter Generator	$1,263.54	$2,822.47	$2,091.42	$200.61
Power Split Hybrid	$2,195.51	$2,253.54	$2,225.28	$7.33
2-Mode Hybrid	$7,451.27	$7,830.93	$7,645.98	$48.93
Plug-in Hybrid	$15,563.84	$32,715.96	$24,095.03	$2,313.54
Material Substitution (1%)	$0.84	$2.13	$1.50	$0.17
Material Substitution (2%)	$0.86	$2.10	$1.50	$0.17

Passenger Car Technology Costs	Minimum	Maximum	Mean	StdDev
Material Substitution (5%)	$1.63	$4.45	$3.00	$0.33
Low Rolling Resistance Tires	$5.55	$9.65	$7.50	$0.50
Low Drag Brakes	$53.60	$121.49	$88.91	$8.62
Secondary Axle Disconnect - Ladder Frame	$72.53	$162.54	$116.93	$11.40
Aero Drag Reduction	$51.17	$130.84	$87.99	$9.38

Table X-6
Monte Carlo Draw Results, Passenger Car Fuel Economy Improvement Rates

Passenger Car Fuel Economy Improvement Rates	Minimum	Maximum	Mean	StdDev
Low Friction Lubricants	0.003081	0.006944	0.005004	0.000520
Engine Friction Reduction	0.008423	0.021196	0.015017	0.001680
VVT - Coupled Cam Phasing (CCP) on SOHC	0.006509	0.031585	0.019517	0.003163
Discrete Variable Valve Lift (DVVL) on SOHC	0.006988	0.032878	0.019508	0.003169
Cylinder Deactivation on SOHC	0.024094	0.031399	0.027480	0.000833
VVT - Intake Cam Phasing (ICP)	0.008318	0.021437	0.014987	0.001672
VVT - Dual Cam Phasing (DCP)	0.019176	0.032757	0.025008	0.001668
Discrete Variable Valve Lift (DVVL) on DOHC	0.007146	0.031442	0.019499	0.003197
Continuously Variable Valve Lift (CVVL)	0.011316	0.040263	0.025042	0.003351
Cylinder Deactivation on DOHC	0.000001	0.006360	0.002498	0.000833
Cylinder Deactivation on OHV	0.037523	0.059210	0.047002	0.002660
VVT - Coupled Cam Phasing (CCP) on OHV	0.009449	0.015728	0.012492	0.000833
Discrete Variable Valve Lift (DVVL) on OHV	0.001237	0.029994	0.015507	0.003511
Conversion to DOHC with DCP	0.008036	0.030776	0.018013	0.002669
Stoichiometric Gasoline Direct Injection (GDI)	0.017140	0.032116	0.023978	0.001675
Combustion Restart	0.016894	0.025485	0.020999	0.001014
Turbocharging and Downsizing	0.038320	0.044068	0.041346	0.000737
Exhaust Gas Recirculation (EGR) Boost	0.038821	0.040267	0.039498	0.000167
Conversion to Diesel following TRBDS	0.055095	0.072376	0.063902	0.002208
Conversion to Diesel following CBRST	0.132909	0.144731	0.138004	0.001357
6-Speed Manual/Improved Internals	0.002921	0.006953	0.004999	0.000519
Improved Auto. Trans. Controls/Externals	0.013493	0.027226	0.020011	0.001676
Continuously Variable Transmission	0.005850	0.024451	0.013511	0.002154
6/7/8-Speed Auto. Trans with Improved	0.011587	0.036830	0.024001	0.003343

Passenger Car Fuel Economy Improvement Rates	**Minimum**	**Maximum**	**Mean**	**StdDev**
Internals				
Dual Clutch or Automated Manual Transmission	0.034972	0.057801	0.046578	0.002969
Electric Power Steering	0.008506	0.022496	0.015024	0.001663
Improved Accessories	0.008457	0.021425	0.014979	0.001674
12V Micro-Hybrid	0.021328	0.035888	0.028333	0.001894
Higher Voltage/Improved Alternator	0.001109	0.008370	0.004740	0.000908
Belt mounted Integrated Starter Generator	0.051607	0.063482	0.057622	0.001520
Power Split Hybrid	0.129323	0.137372	0.133660	0.001073
2-Mode Hybrid	0.005196	0.022135	0.013360	0.001993
Plug-in Hybrid	0.599984	0.640456	0.619019	0.004634
Material Substitution (1%)	0.002063	0.005055	0.003499	0.000364
Material Substitution (2%)	0.002151	0.004818	0.003501	0.000362
Material Substitution (5%)	0.005825	0.014986	0.009997	0.001028
Low Rolling Resistance Tires	0.008153	0.021865	0.014995	0.001663
Low Drag Brakes	0.004202	0.010680	0.007507	0.000834
Secondary Axle Disconnect - Ladder Frame	0.009563	0.015715	0.012492	0.000834
Aero Drag Reduction	0.018163	0.031236	0.024991	0.001671

Table X-7
Monte Carlo Draw Results, Light Truck Technology Costs

Light Truck Technology Costs	**Minimum**	**Maximum**	**Mean**	**StdDev**
Low Friction Lubricants	$3.19	$7.28	$5.00	$0.48
Engine Friction Reduction	$6.31	$58.79	$31.01	$6.03
VVT - Coupled Cam Phasing (CCP) on SOHC	$37.89	$87.04	$60.99	$5.87
Discrete Variable Valve Lift (DVVL) on SOHC	$109.97	$255.76	$175.20	$16.87
Cylinder Deactivation on SOHC	$46.07	$107.70	$75.00	$7.22
VVT - Intake Cam Phasing (ICP)	$36.84	$88.25	$60.99	$5.89
VVT - Dual Cam Phasing (DCP)	$36.97	$89.25	$61.03	$5.84
Discrete Variable Valve Lift (DVVL) on DOHC	$107.22	$238.93	$174.97	$16.97
Continuously Variable Valve Lift (CVVL)	$154.68	$365.73	$254.28	$24.61
Cylinder Deactivation on DOHC	$49.04	$102.97	$74.99	$7.24
Cylinder Deactivation on OHV	$31.38	$71.02	$50.56	$4.89

Light Truck Technology Costs	**Minimum**	**Maximum**	**Mean**	**StdDev**
VVT - Coupled Cam Phasing (CCP) on OHV	$37.65	$88.45	$60.95	$5.90
Discrete Variable Valve Lift (DVVL) on OHV	$33.53	$77.09	$54.15	$5.30
Conversion to DOHC with DCP	$210.08	$450.69	$333.27	$32.21
Stoichiometric Gasoline Direct Injection (GDI)	$59.34	$101.19	$79.82	$5.11
Combustion Restart	$84.90	$199.86	$141.17	$13.54
Turbocharging and Downsizing	$619.49	$1,452.12	$1,020.81	$98.21
Exhaust Gas Recirculation (EGR) Boost	$111.02	$237.59	$172.83	$16.67
Conversion to Diesel following TRBDS	$3,095.29	$3,732.99	$3,402.95	$74.73
Conversion to Diesel following CBRST	$4,327.81	$4,910.94	$4,597.32	$70.14
6-Speed Manual/Improved Internals	$208.46	$457.04	$337.99	$32.85
Improved Auto. Trans. Controls/Externals	$36.11	$85.05	$58.99	$5.70
Continuously Variable Transmission	$186.55	$438.16	$300.16	$28.97
6/7/8-Speed Auto. Trans with Improved Internals	$322.56	$607.58	$461.85	$33.98
Dual Clutch or Automated Manual Transmission	$0.05	$172.00	$79.57	$23.75
Electric Power Steering	$102.88	$122.11	$112.49	$2.49
Improved Accessories	$166.76	$214.06	$192.02	$6.31
12V Micro-Hybrid	$299.01	$655.81	$487.41	$46.73
Higher Voltage/Improved Alternator	$51.12	$119.34	$84.00	$8.12
Belt mounted Integrated Starter Generator	$1,432.05	$3,198.90	$2,370.36	$227.37
Power Split Hybrid	$2,819.76	$2,894.29	$2,858.00	$9.42
2-Mode Hybrid	$10,623.90	$11,165.22	$10,901.52	$69.77
Plug-in Hybrid	$15,697.59	$32,997.09	$24,302.08	$2,333.42
Material Substitution (1%)	$0.84	$2.13	$1.50	$0.17
Material Substitution (2%)	$0.86	$2.10	$1.50	$0.17
Material Substitution (5%)	$1.63	$4.45	$3.00	$0.33
Low Rolling Resistance Tires	$5.55	$9.65	$7.50	$0.50
Low Drag Brakes	$53.60	$121.49	$88.91	$8.62
Secondary Axle Disconnect - Ladder Frame	$72.53	$162.54	$116.93	$11.40
Aero Drag Reduction	$51.17	$130.84	$87.99	$9.38

Table X-8
Monte Carlo Draw Results, Light Truck Fuel Economy Improvement Rates

Light Truck Fuel Economy Improvement Rates	Minimum	Maximum	Mean	StdDev
Low Friction Lubricants	0.003081	0.006944	0.005004	0.000520
Engine Friction Reduction	0.008423	0.021196	0.015017	0.001680
VVT - Coupled Cam Phasing (CCP) on SOHC	0.006509	0.031585	0.019517	0.003163
Discrete Variable Valve Lift (DVVL) on SOHC	0.006988	0.032878	0.019508	0.003169
Cylinder Deactivation on SOHC	0.024094	0.031399	0.027480	0.000833
VVT - Intake Cam Phasing (ICP)	0.008318	0.021437	0.014987	0.001672
VVT - Dual Cam Phasing (DCP)	0.019176	0.032757	0.025008	0.001668
Discrete Variable Valve Lift (DVVL) on DOHC	0.007146	0.031442	0.019499	0.003197
Continuously Variable Valve Lift (CVVL)	0.011316	0.040263	0.025042	0.003351
Cylinder Deactivation on DOHC	0.000001	0.006360	0.002498	0.000833
Cylinder Deactivation on OHV	0.037523	0.059210	0.047002	0.002660
VVT - Coupled Cam Phasing (CCP) on OHV	0.009449	0.015728	0.012492	0.000833
Discrete Variable Valve Lift (DVVL) on OHV	0.001237	0.029994	0.015507	0.003511
Conversion to DOHC with DCP	0.008036	0.030776	0.018013	0.002669
Stoichiometric Gasoline Direct Injection (GDI)	0.017140	0.032116	0.023978	0.001675
Combustion Restart	0.016894	0.025485	0.020999	0.001014
Turbocharging and Downsizing	0.022433	0.025799	0.024205	0.000432
Exhaust Gas Recirculation (EGR) Boost	0.038821	0.040267	0.039498	0.000167
Conversion to Diesel following TRBDS	0.044485	0.058439	0.051596	0.001783
Conversion to Diesel following CBRST	0.107210	0.116746	0.111320	0.001094
6-Speed Manual/Improved Internals	0.002921	0.006953	0.004999	0.000519
Improved Auto. Trans. Controls/Externals	0.013493	0.027226	0.020011	0.001676
Continuously Variable Transmission	0.005850	0.024451	0.013511	0.002154
6/7/8-Speed Auto. Trans with Improved Internals	0.011587	0.036830	0.024001	0.003343
Dual Clutch or Automated Manual Transmission	0.025527	0.042190	0.033998	0.002167
Electric Power Steering	0.008506	0.022496	0.015024	0.001663
Improved Accessories	0.008457	0.021425	0.014979	0.001674
12V Micro-Hybrid	0.025690	0.043228	0.034128	0.002282
Higher Voltage/Improved Alternator	0.000993	0.007492	0.004242	0.000813
Belt mounted Integrated Starter Generator	0.054636	0.067207	0.061003	0.001610
Power Split Hybrid	0.136395	0.144884	0.140969	0.001132
2-Mode Hybrid	0.017174	0.073159	0.044157	0.006589
Plug-in Hybrid	0.600961	0.641500	0.620027	0.004641

Light Truck Fuel Economy Improvement Rates	Minimum	Maximum	Mean	StdDev
Material Substitution (1%)	0.002063	0.005055	0.003499	0.000364
Material Substitution (2%)	0.002151	0.004818	0.003501	0.000362
Material Substitution (5%)	0.005825	0.014986	0.009997	0.001028
Low Rolling Resistance Tires	0.008153	0.021865	0.014995	0.001663
Low Drag Brakes	0.004202	0.010680	0.007507	0.000834
Secondary Axle Disconnect - Ladder Frame	0.009563	0.015715	0.012492	0.000834
Aero Drag Reduction	0.018163	0.031236	0.024991	0.001671

Modeling Results – Output

Tables X-9 and X-10 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. These results are also illustrated in Figures X-15 through X-18 for passenger cars under Optimized CAFE at 7 percent. Although not shown here, the general shape of the resulting output distributions are similar for the light trucks. The humped shape that occurs for both social benefits and net benefits reflects the three different gasoline price scenarios. About half of all draws were selected from the AEO Reference Case, while about one quarter were drawn from the Low Oil Price scenario and one quarter were drawn from the High Oil Price scenario. This produces three separate humps which reflect the increasing impact on benefits from the three progressively higher oil price scenarios. The Low Oil scenario is close enough to the Forecast scenario that the 2 humps visually begin to merge. However, the difference between the High Oil Price scenario and the Forecast is typically more than double the difference between the Forecast and the Low Oil price scenario, which results in a separate distribution further up the x axis. The following discussions summarize the range of results presented in these tables for the combined passenger car and light truck across both the 7 percent (typically the lower range) and 3 percent (typically upper range) discount rates[321].

Fuel Savings: The analysis indicates that MY 2011 vehicles (both passenger cars and light trucks) will experience between 732 million and 1,114 million gallons of fuel savings over their useful lifespan.

Total Costs: The analysis indicates that owners of MY 2011 passenger cars and light trucks will pay between $760 million and $2,235 million in higher vehicle prices to purchase vehicles with improved fuel efficiency

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[321] 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.

<u>Societal Benefits:</u> The analysis indicates that changes to MY 2011 passenger cars and light trucks to meet the proposed CAFE standards will produce overall societal benefits valued between $1,003 million and $2,229 million.

<u>Net Benefits</u>: The uncertainty analysis indicates that the net impact of the higher CAFE requirements for MY 2011 passenger cars and light trucks will range from a net loss of $913 million to a net benefit of $1,224 million. There is at least an 80 percent certainty (the lower of the passenger car and light truck certainty levels) that changes made to MY 2011 vehicles to achieve the higher CAFE standards will produce a net benefit.

Table X-9
Uncertainty Analysis Results, Passenger Cars
(7% Discount Rate)

MY 2011	Mean	Low	High
Fuel Saved (mill. gall.)	445	383	566
Total Cost ($mill.)	496	332	776
Societal Benefits ($mill.)	868	512	1,183
Net Benefits ($mill.)	372	(121)	734
% Certainty Net Ben. > 0	100%		

Table X-10
Uncertainty Analysis Results, Light Trucks
(7% Discount Rate)

MY 2011	Mean	Low	High
Fuel Saved (mill. gall.)	407	349	548
Total Cost ($mill.)	673	428	1,459
Societal Benefits ($mill.)	788	491	1,046
Net Benefits ($mill.)	115	(792)	490
% Certainty Net Ben. > 0	80%		

Table X-11
Uncertainty Analysis Results, Passenger Cars and Light Trucks
(7% Discount Rate)

MY 2011	Mean	Low	High
Fuel Saved (mill. gall.)	852	732	1114
Total Cost ($mill.)	1169	760	2235
Societal Benefits ($mill.)	1656	1003	2229
Net Benefits ($mill.)	487	-913	1224

Figure X-15
Model Output Profile

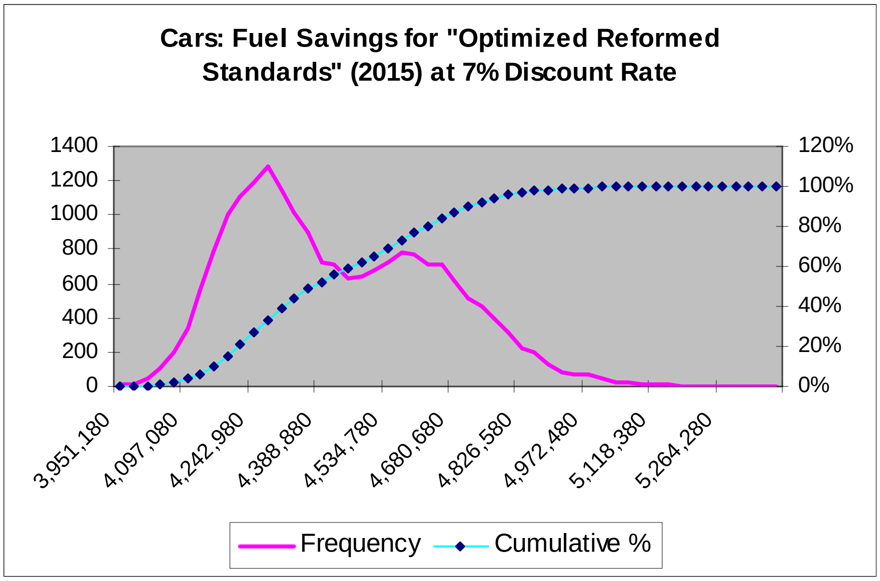


Figure X-16
Model Output Profile

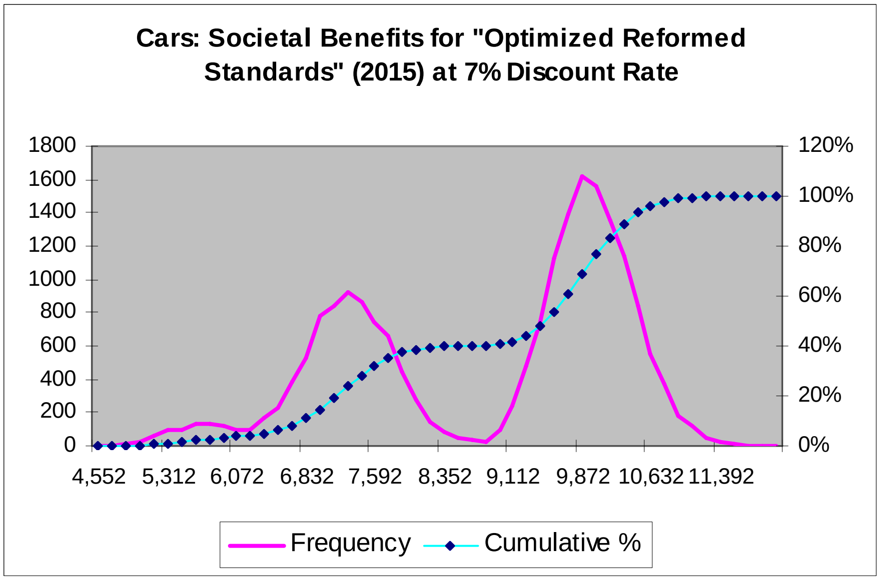


Figure X-17
Model Output Profile

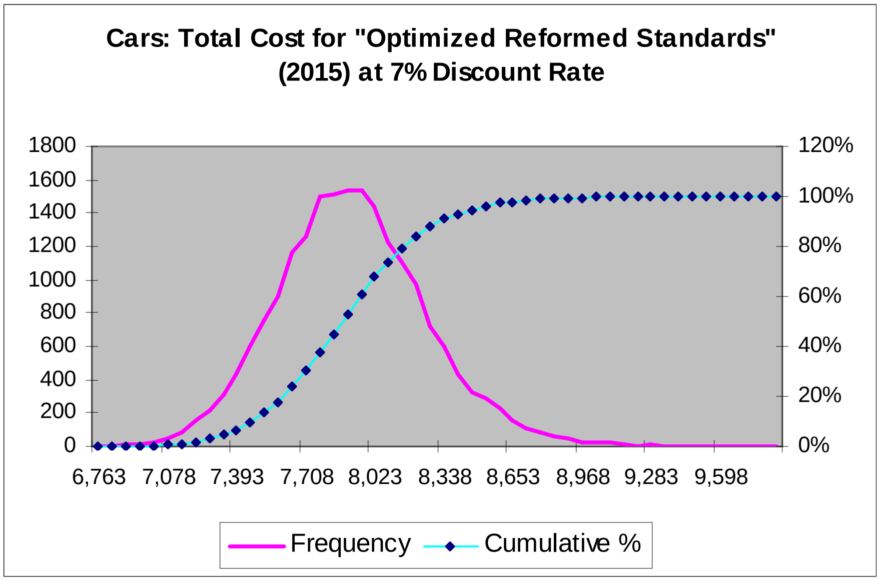
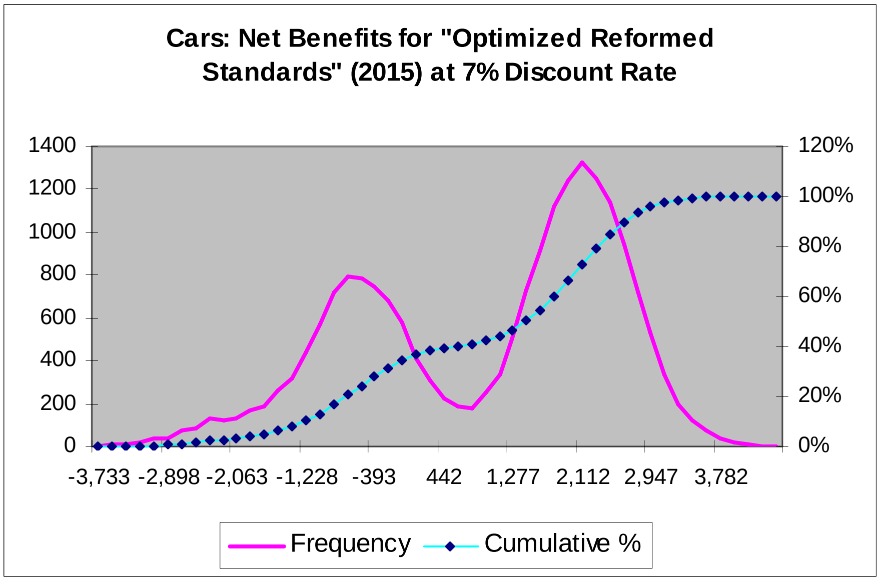


Figure X-18
Model Output Profile



XI. REGULATORY FLEXIBILITY ACT AND UNFUNDED MANDATES REFORM ACT ANALYSIS

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 proposing this action to improve vehicle fuel economy.

2. Objectives of, and legal basis for, the final rule
The Energy Policy and Conservation Act requires the agency to set light truck fuel economy standards every year and allows the agency to update passenger car fuel economy standards. 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 are no light truck manufacturers that are small businesses. However, there are four 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 manufacturer 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 27.5 mpg standard 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 (Tesla and Fisker) make electric vehicles or hybrid vehicles that will pass the final rule.

Currently, there are six small passenger car motor vehicle manufacturers in the United States. Table X1-1 provides information about the 6 small domestic manufacturers in MY 2007. All are small manufacturers, having much less than 1,000 employees.

Table XI-1
Small Vehicle Manufacturers

Manufacturer	Employees	Estimated Sales	Sale Price Range	Est. Revenues*
Fisker Automotive**	N/A	15,000 projected	$80,000	N/A
Mosler Automotive	25	20	$189,000	$2,000,000
Panoz Auto Development Company	50	150	$90,000 to $125,000	$16,125,000
Saleen Inc.	170	1,000#	$39,000 to $59,000	$49,000,000
Saleen Inc.	170	16##	$585,000	$9,000,000
Standard Taxi***	35	N/A	$25,000	$2,000,000
Tesla Motors, Inc.	250	2,000	$65,000 to $100,000	N/A

* Assuming an average sales price from the sales price range.
** Fisker Automotive is a joint venture of Quantum Fuel Systems Technologies Worldwide, Inc. and Fisker Coachbuild, LLC.
*** Standard Taxi is a subsidiary of the Vehicle Production Group LLC. 35 employees is the total for VPG LLC.
# 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.

<u>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.</u>
This final rule includes no new requirements for reporting, record keeping of other compliance requirements.

<u>5. An identification, to the extent practicable, of all relevant Federal rules which may duplicate, overlap, or conflict with the final rule</u>
We know of no 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.

There are no other alternatives that can achieve the stated objectives without installing fuel economy technologies into the vehicle.

A. Unfunded Mandates Reform Act

The Unfunded Mandates Reform Act of 1995 (Public Law 104-4) requires agencies to prepare a written assessment of the costs, benefits, and other effects of proposed or final rules that include a Federal mandate likely to result in the expenditures by States, local or tribal governments, in the aggregate, or by the private sector, of more than $100 million annually (adjusted annually for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for 2007 results in $130 million (119.816/92.106 = 1.30). The assessment may be included in conjunction with other assessments, as it is here.