Preliminary Regulatory Impact Analysis

Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks for Model Years 2027 and Beyond and Fuel Efficiency Standards for Heavy-Duty Pickup Trucks and Vans for Model Years 2030 and Beyond

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U.S. Department of Transportation

National Highway Traffic Safety Administration

NHTSA

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Table of Acronyms and Abbreviations

Abbreviation	Term
AC	Air Conditioning
ACC	Advanced Clean Cars
ACT	Advanced Clean Trucks
ADAS	Advanced Driver Assistance Systems
AEO	Annual Energy Outlook
AFV	Alternative Fuel Vehicle
AMPC	Advanced Manufacturing Production Credit
AT	Automatic transmissions
AWD	All-Wheel Drive
BEV	Battery Electric Vehicle
BISG	Belt Integrated Starter Generator
BMW	BMW of North America, LLC
BTU	British Thermal Unit
BTW	Brake & Tire Wear
CAA	Clean Air Act
CAFE	Corporate Average Fuel Economy
CARB	California Air Resources Board
CH_4	Methane
CI	Compression Ignition
CNG	Compressed Natural Gas Engine
CO_2	Carbon Dioxide
COVID	Coronavirus disease of 2019
CVC	Clean Vehicle Credit
CVT	Continuously Variable Transmission
CY	Calendar Year
DCT	Dual-Clutch Transmission
DEAC	Cylinder Deactivation
DMC	Direct Manufacturing Costs
DOE	U.S. Department of Energy
DOHC	Dual Overhead Cam
DOT	U.S. Department of Transportation
DPC	Domestic Passenger Car
DR	Discount Rate
EIA	U.S. Energy Information Administration
EIS	Environmental Impact Statement
EISA	Energy Independence and Security Act of 2007

Abbreviation	Term
EPA	Environmental Protection Agency
EPCA	Energy Policy and Conservation Act of 1975
EV	Electric Vehicle
FCEV	Fuel Cell Electric Vehicle
FCF	Fuel Content Factor
FCIV	Fuel Consumption Improvement Value
FCPIAA	Federal Civil Penalties Inflation Adjustment Act
FCV	Fuel Cell Vehicle
FE	Fuel Economy
FHWA	Federal Highway Administration
FP	Fuel Price
FR	Federal Register
FWD	Front-Wheel Drive
GCWR	Gross Combined Weight Rating
GDP	Gross Domestic Product
GGE	Gasoline Gallon Equivalent
GHG	Greenhouse Gas
GI	Global Insight
GM	General Motors
GREET	Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation Model
GVWR	Gross Vehicle Weight Rating
GWP	Global Warming Potential
HCR	High Compression Ratio
HD	Heavy-Duty
HDPUV	Heavy-Duty Pickups and Vans
HTF	Highway Trust Fund
IC	Internal Combustion
ICE	Internal Combustion Engine
IFR	Interim Final Rule
IPC	Imported Passenger Car
IRA	Inflation Reduction Act
IWG	Interagency Working Group
LD	Light-Duty
LDT	Light-Duty Trucks
LDV	Light-Duty Vehicle
LT	Light Trucks
MDPCS	Minimum Domestic Passenger Car Standard
MMT	Million Metric Tons

Abbreviation	**Term**
MOVES	Motor Vehicle Emission Simulator
MPG	Miles Per Gallon
MR	Mass Reduction
MSRP	Manufacturer Suggested Retail Price
MY	Model Year
NAS	National Academy of Sciences
NASEM	National Academies of Sciences, Engineering, and Medicine
NEMS	National Energy Modeling System
NEPA	National Environmental Policy Act
NHTSA	National Highway Traffic Safety Administration
NO_X	Nitrogen Oxide
NPRM	Notice of Proposed Rulemaking
NREL	National Renewable Energy Laboratory
OMB	Office of Management and Budget
OPEC	Organization of the Petroleum Exporting Countries
PC	Passenger Car
PDO	Property Damage-Only
PEF	Petroleum Equivalency Factor
PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
$PM_{2.5}$	Particulate matter 2.5 microns or less in diameter
PRIA	Preliminary Regulatory Impact Analysis
RC	Reference Case
RIA	Regulatory Impact Analysis
ROLL	Tire Rolling Resistance
SC	Social Cost
SHEV	Strong Hybrid Electric Vehicle
SI	Spark Ignition
SO2	Sulfur Dioxide
SOHC	Single Overhead Camshaft
SO_X	Sulfur Oxide
SS12V	Stop-Start 12V Hybrid Electric Vehicle
SUV	Sport Utility Vehicle
TCO	Total Cost of Ownership
TS&D	Fuel Transportation, Storage, and Distribution
TSD	Technical Support Document
TWh	Terawatt-hours
UNFCCC	United Nations Framework Convention on Climate Change

Abbreviation	Term
USD	US Dollars
VCR	Variable Compression Ratio Engine
VMT	Vehicle Miles Traveled
VSL	Value of a Statistical Life
VTG	Variable Turbo Geometry
VTGE	Variable Turbo Geometry (Electric)
VVL	Variable Valve Lift
VWA	Volkswagen Group of America
WF	Work Factor
ZEV	Zero Emission Vehicle

1. Executive Summary

Pursuant to Executive Order 12866 and Executive Order 13563, which establish general principles of regulation (including emphasizing the importance of cost-benefit analysis in decision-making) with which Executive branch agencies are encouraged to comply, this Preliminary Regulatory Impact Analysis (PRIA) has been prepared to assess the potential and anticipated consequences of proposed and alternative Corporate Average Fuel Economy (CAFE) standards for passenger cars (PCs) and light trucks (LTs) for model years (MYs) 2027-2032, and fuel efficiency standards for heavy-duty pickup trucks and vans (HDPUVs) for MYs 2030-2035. Regulatory analysis is a tool used to anticipate and evaluate likely consequences of rules. It provides a formal way of organizing the evidence on the key effects, positive and negative, of the various alternatives that are considered in developing regulations. The goal of this PRIA is to consolidate that evidence to help inform decision-makers of the potential consequences of choosing among the considered regulatory paths.

This assessment examines the costs and benefits of proposed and alternative CAFE standards for passenger cars and LTs for MYs 2027 through 2032, and proposed and alternative HDPUV standards levels for HDPUVs for MYs 2030 through 2035. The proposed action is taken under the agency's statutory authority. The MY 2032 standards proposed for passenger cars and LTs are "augural," in that they fall beyond the statutory 5-model-year period set out in 49 U.S.C. 32902, and thus represent what the agency *would* propose, based on the information currently before us, but the National Highway Traffic Safety Administration (NHTSA) will not be finalizing those standards as part of this rulemaking effort. This assessment examines the costs and benefits of setting fuel economy standards for passenger cars and LTs and fuel efficiency standards for HDPUVs that change at a variety of different rates during those model years.[1] It includes a discussion of the technologies that can improve fuel economy/efficiency, as well as an analysis of the potential impacts on vehicle retail prices, lifetime fuel savings and their value to consumers, and other societal effects such as energy security, changes in pollutant emissions levels, and safety.[2] Estimating impacts also involves considering consumers' responses to standards – for example, whether and how changes in vehicle prices as a result of changes in CAFE or HDPUV standards could affect sales of new and used vehicles.

The Energy Independence and Security Act of 2007 (EISA) requires NHTSA to set attribute-based CAFE standards that are based on a mathematical function for passenger cars and LTs and gives NHTSA discretion to set attribute-based standards based on a mathematical function for HDPUVs. For passenger cars and LTs, the mathematical function or "curve" representing the standards is a constrained linear function that provides a separate fuel economy target for each vehicle footprint. There are separate curves for cars and for trucks. Vehicle footprint has been used as the relevant attribute for passenger car and LT curves since MY 2011. For HDPUVs, the mathematical functions representing the standards are unconstrained linear curves. The curves provide a separate fuel consumption target for each vehicle based on a "work factor" (WF) which is a function of payload and towing capabilities. NHTSA sets separate standards for "compression ignition" (i.e., diesel) HDPUVs and "spark ignition" (i.e., gasoline) HDPUVs. WF has been used as the relevant attribute for all HDPUV curves since MY 2014. Generally, the more of the attribute a vehicle has, the less numerically stringent the corresponding fuel economy/efficiency target. With attribute-based standards, the burden of compliance is theoretically distributed across all vehicles and across all manufacturers. Under all of the regulatory alternatives, the standards would become more stringent for each model year covered by the rulemaking, relative to the MY 2026 standards for passenger cars and LTs and the MY 2027 standards for HDPUVs. Each manufacturer is subject to individualized compliance obligations for passenger cars, LTs, and HDPUVs, in each model year, based on the vehicles it produces.

We constructed an analysis fleet representing the entire MY 2022 passenger car and LT fleet and the MY 2022 HDPUV fleet in detail as a starting point to evaluate the costs and benefits of the proposal, against

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[1] Throughout this PRIA, cost and benefit analyses are presented for individual model years as well as the cumulative total for all model years through 2032 for passenger cars and LTs, although some physical effects are presented on a calendar year basis instead, as appropriate. Only calander year cumulative effects for on-the road vehicles for year 2022 thru 2050 are presented for HDPUVs.

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

which we simulate manufacturers' year-by-year response through MY 2050[3] to standards defining each regulatory alternative. The analysis fleet is comprised of the best information available as of August of 2022 regarding the MY 2022 fleet for passenger cars and LTs and the MY 2022 fleet for HDPUVs. For each of 3,527 specific model/configurations the analysis contains information such as production volumes, fuel economy/efficiency ratings, dimensions, curb weight and gross vehicle weight rating (GVWR), engine characteristics, transmission characteristics, and other key engineering information. For the No-Action alternative, we used the CAFE Model to simulate manufacturers' year-by-year application of technology that improves fuel economy/efficiency, assuming that manufacturers would respond not only to the year-by-year standards defining the regulatory alternative, but also to a baseline consisting of the CAFE standards finalized in 2022 and the HDPUV standards finalized in 2016, California's Zero Emission Vehicle (ZEV) program, U.S. Environmental Protection Agency (EPA)'s baseline (i.e., those finalized in 2021 for passenger cars and LTs and those finalized in 2016 for HDPUVs) fleetwide greenhouse gas (GHG) standards, and buyers' willingness to pay for a portion of the fuel savings expected to occur over vehicles' lifetimes.

NHTSA is proposing to set CAFE standards that would increase at 2 percent per year for passenger cars and 4 percent per year for LTs during MYs 2027-2032, and HDPUV standards that would increase at 10 percent per year during MYs 2030-2035, because that is what NHTSA has tentatively concluded would be maximum feasible in those model years, under the Energy Policy and Conservation Act of 1975 (EPCA)/Energy Independence and Security Act (EISA) factors. Although NHTSA and EPA took separate actions in this round of rulemaking for a variety of reasons, NHTSA sought to coordinate its proposal with EPA's to the greatest extent possible given our statutory and programmatic differences.

While NHTSA's and EPA's proposals differ in certain respects, the fact that differences exist is not new in this proposal. Some parts of the programs are harmonized, and others differ, often as a result of statute. Since NHTSA and EPA began regulating concurrently under President Obama, programmatic differences have meant that manufacturers have had (and will have) to plan their compliance strategies considering both the NHTSA standards and the EPA standards and ensure that they are in compliance with both. Auto manufacturers are sophisticated companies accustomed to operating under multiple regulatory regimes simultaneously (both within the United States and beyond), and we remain confident that they will achieve that goal. For purposes of the PRIA, we have only attempted to report costs and benefits attributable to the NHTSA CAFE and HDPUV proposed standards, and not also EPA's proposed standards. We refer readers to EPA's documents for more information about their proposal and its estimated effects,[4] and note (as in the NHTSA rulemakings since 2012) that costs and benefits of the two programs will largely overlap, since manufacturers will take many actions that respond to both programs simultaneously.

EPCA, as amended by EISA, contains a number of provisions governing how NHTSA must set CAFE and HDPUV standards.[5] EPCA requires that CAFE standards be set separately for passenger cars and LTs[6] at the "maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year,"[7] based on the agency's consideration of four statutory factors: 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.[8] EPCA does not define these terms or specify what weight to give each factor in balancing them. Instead, such considerations are left within the discretion of the Secretary of Transportation (delegated to NHTSA) based upon current information. Accordingly, NHTSA interprets these factors and determines the appropriate weighting that leads to the maximum feasible standards given the circumstances present at the time of promulgating each CAFE standard rulemaking. Similarly, HDPUV standards must be set at the level that "achieve[s] the maximum feasible improvement," and in determining that level, NHTSA must consider whether standards are "appropriate, cost-effective, and technologically feasible." As for passenger car and LT CAFE standards, EPCA/EISA does not define these terms or specify what weight to give each factor in balancing them, so this is left to NHTSA's discretion, and

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[3] As in prior analyses, the analysis for this proposal exercises the CAFE Model using inputs that extend the explicit compliance simulation through MY 2050 – many years beyond the last year for which we propose to issue revised standards. This has been done because interactions between the new and used vehicles markets impact benefits and costs over the lives of vehicles produced in the rulemaking time frame.

[4] 88 FR 29184 (May 5, 2023).

[5] See Preamble Section V.A. for a complete discussion of the EPCA and EISA constraints placed on NHTSA's analysis and rulemaking.

[6] 49 U.S.C. 32902(b)(1). EPCA uses the terms "passenger automobile" and "non-passenger automobile" while NHTSA uses the regulatory terms "passenger car" and "LT," but they are intended interchangeably.

[7] 49 U.S.C. 32902(a).

[8] 49 U.S.C. 32902(f).

NHTSA interprets the factors and determines the appropriate weighting based on the information currently before us. Always in making these determinations, NHTSA remains mindful that EPCA's overarching purpose is energy conservation.

As stated above, NHTSA is proposing new standards for passenger cars and LTs that the agency tentatively concludes would represent maximum feasible CAFE standards for MYs 2027-2031 and setting forth proposed augural passenger car and LT standards for MY 2032. NHTSA is also proposing new standards for HDPUVs that the agency tentatively concludes would represent maximum feasible HDPUV standards for MYs 2030-2035. While the actual standards are footprint-based target curves, for passenger cars and LTs, and work-factor-based target curves, for HDPUVs, NHTSA currently estimates that the proposed standards would require, on an average industry fleet-wide basis, roughly 66 mpg for passenger cars in MY 2032, 54 mpg for LTs in MY 2032, and 2.6 gallons per 100 miles for HDPUVs in MY 2035.

NHTSA estimates that the proposed stringency increases in the LD fleet would reduce gasoline consumption through CY 2050 by approximately 88 billion gallons relative to reductions in the No-Action Alternatives. Under the same conditions, NHTSA also estimates an increase in electricity consumption of approximately 312 terawatt-hours (TWh). This increase in electricity consumption represents 0.3 percent of overall energy consumed in the No-Action Alternative. The additional electricity use is attributed to an increase in the number of plug-in hybrid electric vehicles (PHEVs); PHEV fuel economy is only considered in charge-sustaining (i.e., gasoline-only) mode in the compliance analysis, but electricity consumption is computed for the effects analysis. In the HDPUV fleet, gasoline consumption declines by approximately 2.6 billion gallons and electricity consumption increases by 24 TWh through CY 2050. The change in electricity consumption is 0.2 percent of overall energy consumed in the HDPUV No-Action Alternative and is the result of increases in PHEV and Battery Electric Vehicle (BEV) adoption.

Overall, for the baseline fleet our analysis shows the consumption of electricity is inversely related to the consumption of gasoline, and other liquid fuels,[9] for the overall predicted future vehicle fleet. Figure 1-1 shows the translation of gasoline to equivalent British Thermal Units (BTUs) of energy and compares the reduction of gasoline energy to the increase in electrical energy, also converted to equivalent BTUs, over time for the CAFE fleet. This comparison shows the increase of electrical energy is significantly less than the reduction in liquid fuel energy burned. Electrical energy use increase in the baseline fleet represents about 21% of the total gasoline energy use reduction in the baseline fleet, across the years shown in Figure 1-1. The difference in energy reduced and energy gained, by the overall fleet, is likely caused by the continued increase in efficiency of combustion-based technologies, including hybridization, as well as the introduction of BEVs into fleet.[10] The efficiency level of vehicles that use electricity as one of their fuel types is typically significantly higher in their conversion of stored energy to locomotion. A similar behavior is observed for the HDPUV fleet, see Figure 1-2. For reference in the figures below, 1 Quad is equivalent to 10^{15} BTUs.

The effect of the preferred CAFE alternative is also shown in Figure 1-3 and demonstrates a further reduction in gasoline energy use in comparison to the no-action alternative. The preferred alternative for the HDPUV fleet also shows a further reduction in gasoline and diesel energy used in that fleet, see Figure 1-4.

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[9] Other liquid fuels include E85, Diesel and CNG, however in this analysis these fuels represented a very small percentage of the overall energy used by the fleets and were not shown in the figures.

[10] The BEVs introduced into the baseline fleet are a result of other standards and regulations that are not part of this rule making, but considered in our baseline fleet, see Draft TSD Chapter 2.

Figure 1-1: Total Energy use by the CAFE Fleet for the No-Action Alternative (Alt 0)

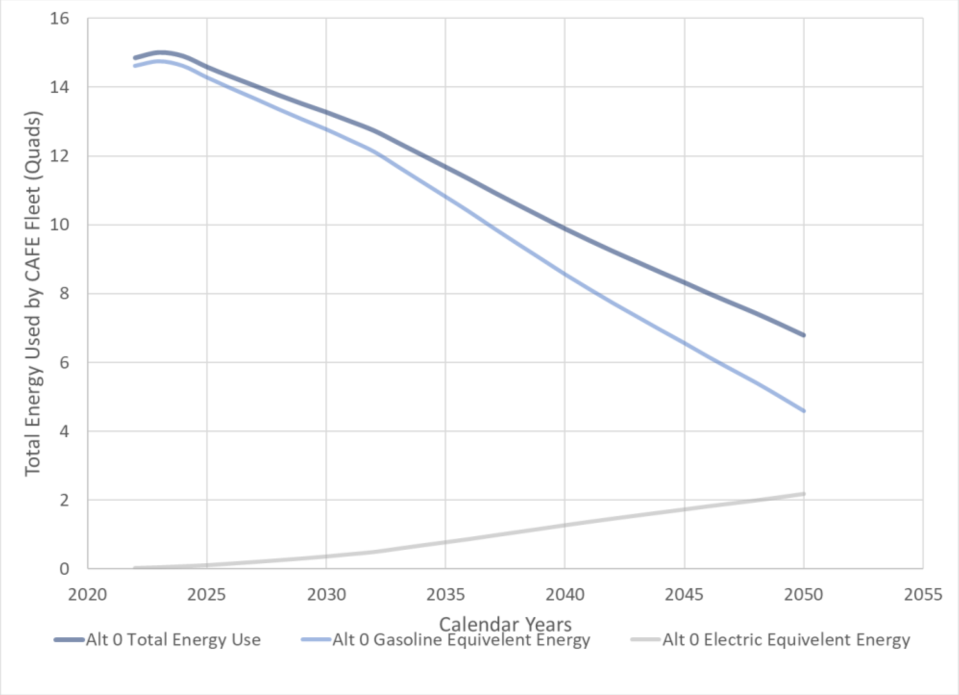


Figure 1-2: Total Energy use by the HDPUV Fleet for the No-Action Alternative (Alt 0)

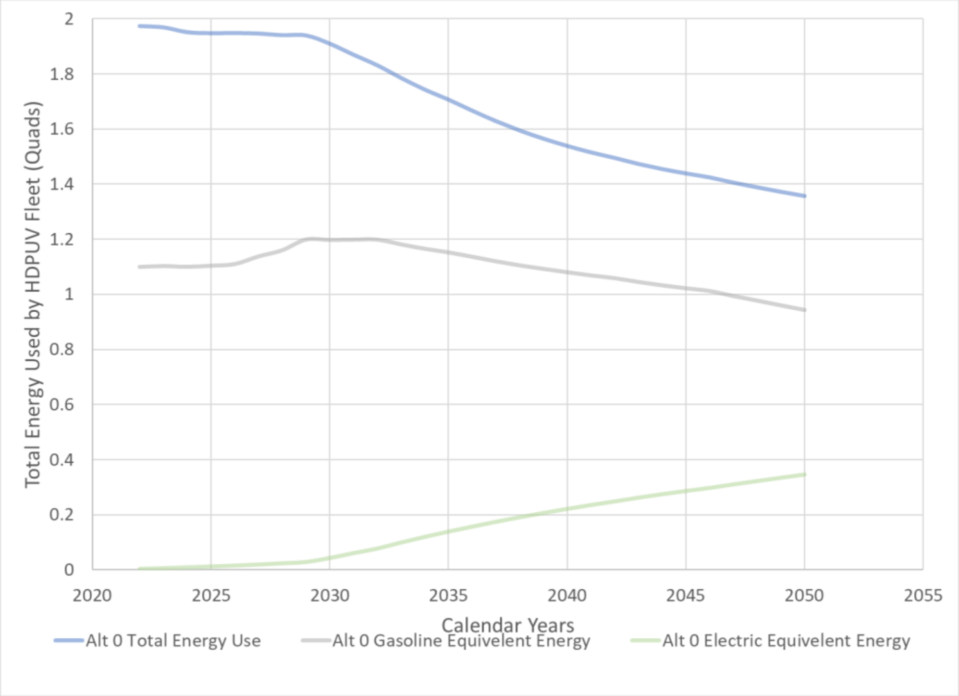


Figure 1-3: Additional Decrease in Gasoline Energy used by the CAFE fleet due to the Preferred Alternative

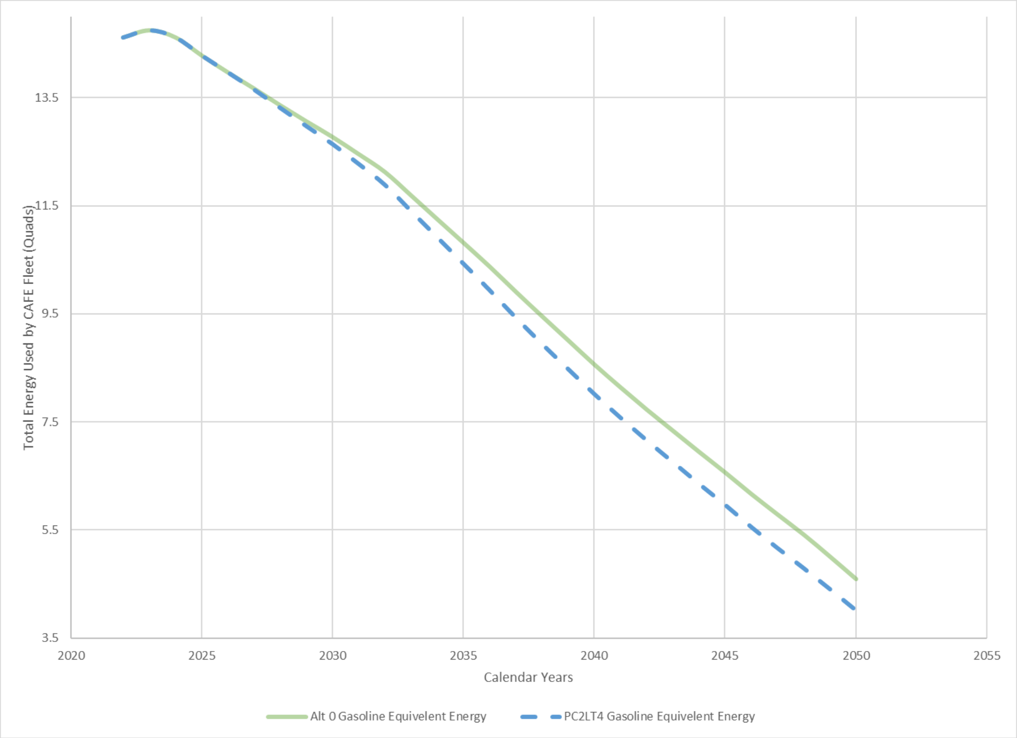
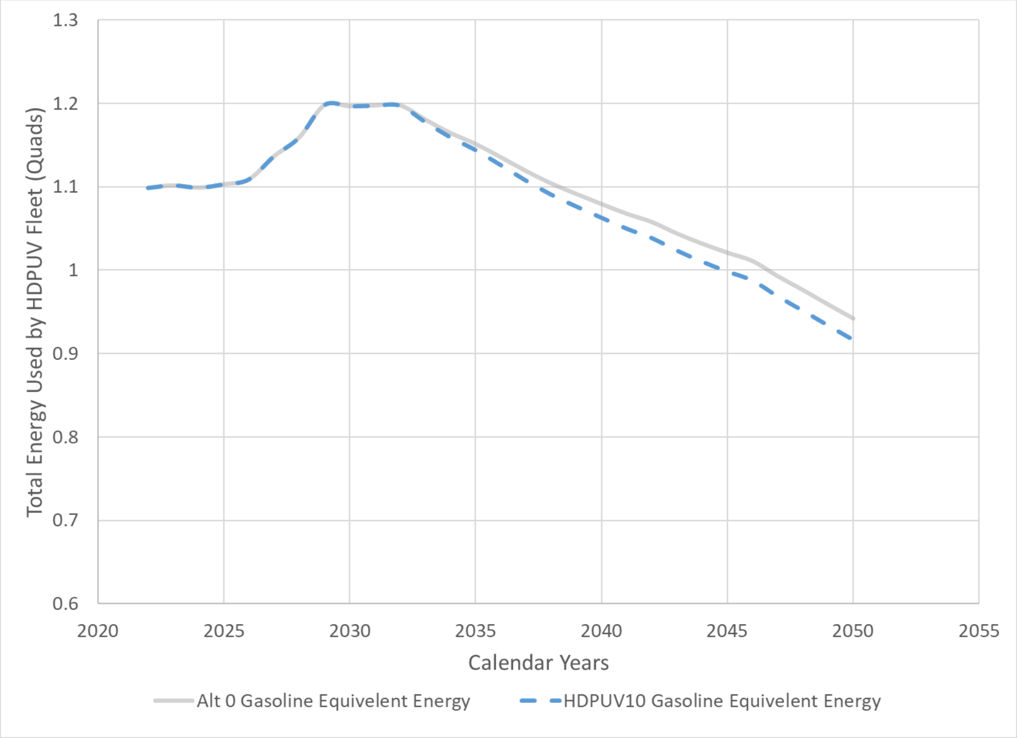


Figure 1-4: Additional Decrease in Gasoline Energy Used by the HDPUV Fleet Due to the Preferred Alternative



The decrease in fuel use also results in a significant decrease in GHG emissions and criteria pollutants that originate directly from vehicle emissions. The increased use of electricity forecast, a result of changes in the baseline fleets, does increase the output of some pollutants from non-vehicle sources.

Accounting for emissions from both vehicles fleets and upstream energy sector processes (e.g., petroleum refining and electricity generation), NHTSA estimates that the proposed standards would reduce GHG emissions as shown in Table 1-1.

Table 1-1: Predicted GHG Change Relative to No-Action Alternative for LD CAFE and HDPUV FE Preferred Alternatives, CY 2022-2050

	Carbon Dioxide (CO_2) (mmt)	Methane (CH_4) (mmt)	Nitrous Oxide (N_2O) (tmt)
Passenger Cars and Light trucks	-885	-1.104	-27.8
HDPUVs	-22	-0.023	-1.1

Relative reductions in CO_2 for each of the proposed alternatives for CAFE and for HDPUV is shown in Figure 1-5 and Figure 1-6:

Figure 1-5: Annual CO_2 emissions projected as a function of proposed CAFE Stringencies

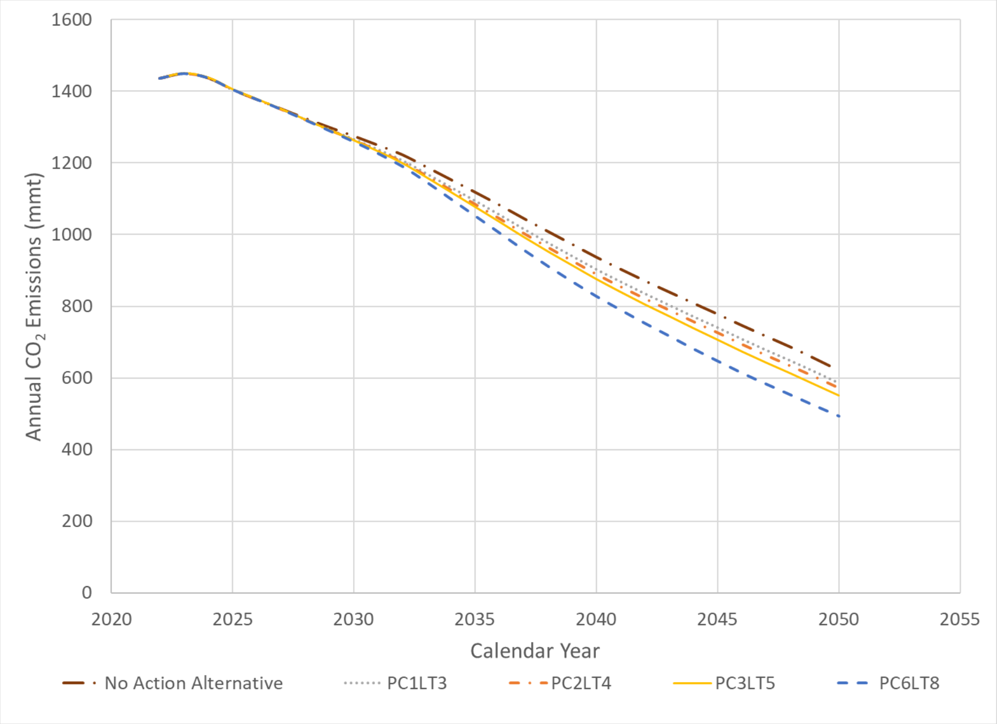
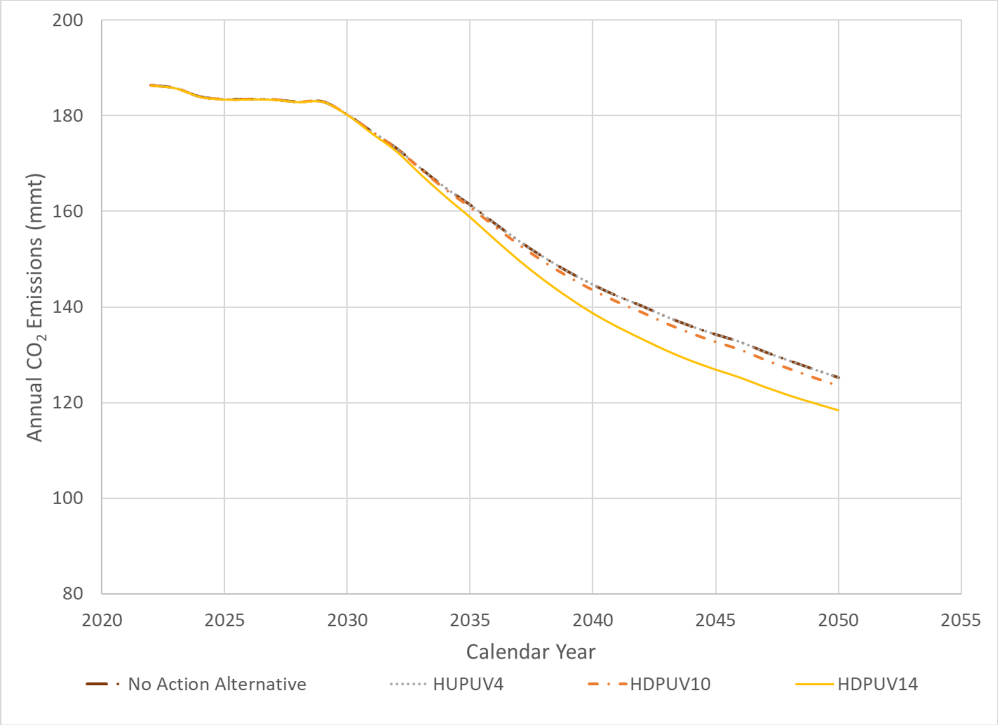


Figure 1-6: Annual CO_2 Emissions Projected as a Function of Proposed HDPUV Stringencies



For passenger cars and LTs, NHTSA projects that under these proposed standards, required technology costs could increase by $10.6 billion over the lifetimes of vehicles through MY 2032, and civil penalty payments could increase by about $3.1 billion, although the standards are performance-based and manufacturers are always free to choose their own compliance path (which can include civil penalty payments, but need not). If those costs are passed on to consumers as average increases in manufacturer suggested retail price (MSRP) (rather than, for example, to shareholders as foregone gains, or to employees as foregone compensation), we estimate that per-vehicle costs paid by U.S. consumers for new passenger cars and LTs would increase by roughly $932 in MY 2032, on average, as compared to if the MY 2026 standards were retained; but concurrently, fuel savings for those vehicles would increase, by roughly $1,043, on average, so that consumers would see an overall net benefit in savings.[11] Overall total discounted benefits (MY accounting) attributable to the proposed passenger car and LT standards range from $75 billion at a 3 percent discount rate (DR) (3% percent DR for the social cost of GHGs (SC-GHG)), to $47 billion at a 7 percent DR (3% percent DR for SC-GHG).[12] It is important to stress that these estimates could change – sometimes dramatically – with different assumptions and are, likely, very conservative. For example, if estimates of future fuel prices (FPs) or the SC-GHG are too low, corresponding input revisions could significantly increase net benefits.

For HDPUVs, NHTSA projects that under these proposed standards, required technology costs could increase by $0.14 billion over the lifetimes of vehicles through MY 2038. If those costs are passed on to consumers as average increases in MSRP, we estimate that per-vehicle costs paid by U.S. consumers for new HDPUVs would increase by roughly $131, on average, as compared to if the Phase 2 standards were

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[11] The value of lifetime fuel savings assumes a discount rate of 3 percent.

[12] Climate benefits are based on changes reductions in carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N2O) emissions and are calculated using four different estimates of the social cost of carbon (SCC), methane (SC-CH_4), and nitrous oxide (SC-N2O) (model at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). We emphasize the importance and value of considering the benefits calculated using all four estimates. We show the SC-GHG discount of 3 percent for climate benefits in this rule for presentational purposes. The full range of climate benefits is shown in Chapter 8 in the PRIA. As discussed in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (IWG 2021), a consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, are also warranted when discounting intergenerational impacts. Additionally, monetized values do not include other important unquantified effects, such as certain climate benefits, certain energy security benefits, distributional effects, and certain air quality benefits from the reduction of toxic air pollutants and other emissions, among other things. As discussed in the Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990 (IWG 2021), a consideration of climate benefits calculated using discount rates below 3 percent, including 2 percent and lower, are also warranted when discounting intergenerational impacts.

retained; but concurrently, fuel savings for those vehicles would increase, by roughly $439, on average.[13] Overall total discounted benefits attributable to the proposed HDPUV standards range from $4.3 billion at a 3 percent DR (3% percent DR for SC-GHG), to $2.4 billion at a 7 percent DR (3% percent DR for SC-GHG). As above, these estimates could change with different assumptions. The columns in the tables below represent the different regulatory alternatives considered for passenger cars and light trucks, in Table 1-2, and HDPUVs, in Table 1-3. The numbers in each column represent the rate of increase, year over year, in stringency that the standards would represent – so, for example, PC1LT3 refers to the regulatory alternative in which passenger car standard stringency would increase at 1 percent year over year, and light truck standard stringency would increase at 3 percent year over year. "DR" is an abbreviation for "discount rate."

Table 1-2: Estimated Monetized Costs and Benefits – Passenger Cars and Light Trucks – Model Year (MY) and Calendar Year (CY) Perspectives, 3% SC-GHG DR[14]

	PC1LT3		**PC2LT4**		**PC3LT5**		**PC6LT8**	
Monetized Benefits ($billion)								
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1983-2032	59	37	75	47	88	55	120	75
CYs 2022-2050	150	88	203	119	261	152	437	252
Monetized Costs ($billion)								
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1983-2032	47	31	59	39	79	52	105	70
CYs 2022-2050	116	65	157	87	240	130	386	206
Monetized Net Benefits ($billion)								
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1983-2032	13	6	17	8	9	3	16	5
CYs 2022-2050	34	23	46	32	21	21	51	46

Table 1-3: Estimated Monetized Costs and Benefits – HDPUVs – CY Perspective, 3% SC-GHG DR[15]

	HDPUV4		**HDPUV10**		**HDPUV14**	
Monetized Benefits ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
CYs 2022-2050	0.11	0.07	4.32	2.43	17.43	10.12

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[13] The value of lifetime fuel savings assumes a discount rate of 3 percent.

[14] Climate benefits are based on reductions in CO_2, CH_4, and N_2O emissions and are calculated using four different estimates of the global cost of each greenhouse gas (SC-GHG model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate), which each increase over time. For the presentational purposes of this table and other similar summary tables, we show the benefits associated with the global SC-GHG at a 3 percent discount rate, but the agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits calculated using all four SC-GHG estimates. *See* Section II.G.2 of this preamble for more information. Where percent discount rate values are reported in this table, the social benefits of avoided climate damages are discounted at 3 percent. The climate benefits are discounted at the same discount rate as used in the underlying SC-GHG values for internal consistency.

[15] Climate benefits are based on reductions in CO_2, CH_4, and N_2O emissions and are calculated using four different estimates of the global cost of each greenhouse gas (SC-GHG model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate), which each increase over time. For the presentational purposes of this table and other similar summary tables, we show the benefits associated with the global SC-GHG at a 3 percent discount rate, but the agency does not have a single central SC-GHG point estimate. We emphasize the importance and value of considering the benefits calculated using all four SC-GHG estimates. *See* Section II.G.2 of this preamble for more information. Where percent discount rate values are reported in this table, the social benefits of avoided climate damages are discounted at 3 percent. The climate benefits are discounted at the same discount rate as used in the underlying SC-GHG values for internal consistency.

Monetized Costs ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
CYs 2022-2050	0.09	0.04	2.07	0.99	9.43	4.67
Monetized Net Benefits ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
CYs 2022-2050	0.03	0.03	2.25	1.44	8.00	5.45

The results of this analysis are set forth in the rest of this document.

2. The Need for CAFE and HDPUV Regulations

NHTSA is required by statute to set CAFE and HDPUV standards and does not have the discretion not to do so. 49 U.S.C. 32902(a) and (b) direct the Secretary of Transportation (by delegation, NHTSA) to prescribe by regulation average fuel economy standards for passenger cars and LTs at least 18 months before the beginning of each model year, and to establish those standards at the maximum feasible average fuel economy level that the Secretary decides the manufacturers can achieve in that model year. If NHTSA does not set passenger car and LT CAFE standards for a given model year, then no CAFE standards are in effect for that model year.

For HDPUV standards, while NHTSA interprets its standards to continue in perpetuity, NHTSA is still obligated by 49 U.S.C. 32902(k) to set standards designed to achieve the maximum feasible improvement in fuel economy, subject to the regulatory lead-time and stability requirements. If NHTSA determines that more stringent standards than those established previously would be the maximum feasible, NHTSA interprets 32902(k) as requiring the agency to set standards at that level.

The overarching purpose of EPCA/EISA, and of CAFE/HDPUV regulations, is energy conservation. Energy conservation is important to our nation because it can save consumers money; it can reduce our dependence on potentially hostile foreign nations and actors, because we need to consume fewer of their resources; and it can help reduce pollution associated with energy consumption, which can mitigate climate change and its negative health and environmental impacts as well as exposure to harmful conventional air pollutants. This PRIA, as well as the accompanying the notice of proposed rulemaking (NPRM) and Draft Technical Support Document (TSD), discuss these effects at length, as well as the possible market failure(s) that inform the need for regulation.

2.1. Market Failure

Executive Order 12866 states that in determining whether regulation is justified, "Each agency shall identify the problem that it intends to address (including, where applicable, the failures of private markets or public institutions that warrant new agency action) as well as assess the significance of that problem." As the preceding chapter explains, NHTSA is required by law to regulate fuel economy, but there are also market failures that can be mitigated or exacerbated by changing fuel economy standards. This chapter summarizes the various energy security, environmental, safety, and consumer-related market failures that may be affected by changes in fuel economy and fuel efficiency standards.

2.1.1. Energy Security Market Failure

U.S. consumption and imports of petroleum products have three potential effects on the domestic economy that are often referred to as “energy security externalities,” and increases in their magnitude are sometimes cited as possible SCs of increased U.S. demand for petroleum.[16] First, any increase in global petroleum prices that results from higher U.S. gasoline demand will cause a transfer of revenue from consumers of petroleum products to oil producers worldwide, because consumers throughout the world are ultimately subject to the higher global prices for petroleum and refined products that result. With competitive markets, this transfer is simply a shift of resources that produces no change in global economic output or welfare. But because individual consumers of petroleum products are unlikely to consider the financial drain higher prices impose on the U.S. economy, the transfer is sometimes described as an external cost of increased U.S.

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[16] See Brown, S. and Huntington, H, 2013. Assessing the U.S. oil security premium. *Energy Economics.* Vol. 38. pp. 118-127. Available at: https://doi.org/10.1016/j.eneco.2013.03.010. (Accessed: May 31, 2023).

petroleum consumption.[17] To the degree that global suppliers like Organization of the Petroleum Exporting Countries (OPEC) and Russia exercise market power, oil prices will be above their level in a competitive market, and will generate a loss in potential Gross Domestic Product (GDP).[18] In the presence of such market power, increases in U.S. gasoline demand can in theory drive prices further above competitive levels and increase the opportunity for suppliers to engage in monopolistic behavior, thus exacerbating this loss.

Increased U.S. consumption of refined products such as gasoline can also expose domestic users of other petroleum products – whose consumption would be unrelated to changes in CAFE or fuel efficiency standards – to added economic risks by increasing the likelihood of sudden changes in their prices or interruptions in their supply. Because users of petroleum products are unlikely to consider any effect their own consumption has on other consumers, the expected economic cost of that increase in risk is often cited as an external cost of increased U.S. petroleum consumption. Finally, some analysts argue that domestic demand for imported petroleum may also influence U.S. military spending; since any increase in the cost of military activities necessary to enable additional petroleum imports would not be reflected in the price paid at the gas pump, this effect is often asserted to be a third category of external costs from increased U.S. petroleum consumption.[19]

Each of these three effects costs is likely to decline incrementally as a consequence of the reduction in U.S. petroleum consumption the agency estimates would result from the alternative increases in CAFE and fuel efficiency standards it is evaluating. This is discussed in detail in Draft TSD Chapter 6.2.4.

2.1.2. Environmental Market Failures

The burning of fossil fuels and associated emission of carbon dioxide, CH_4, and nitrous oxide (GHGs) is a textbook example of an externality, a failure of private markets which occurs when an economic transaction imposes uncompensated costs on or provides benefits (in this case costs) to a third party.[20] Emitting GHGs creates a global externality, in that GHG emitted in one country mix uniformly with other gases in the atmosphere and impose damages on all nations by trapping heat in the earth’s atmosphere and inhibiting it from radiating back into space, thereby causing the earth’s climate to warm. Because GHGs degrade slowly and tend to accumulate in the earth’s atmosphere, they are considered stock pollutants, whose economic damages increase as their atmospheric concentration (or stock) increases. Because some GHGs emitted today can remain in the atmosphere for hundreds of years, burning fossil fuels today not only imposes uncompensated costs on others around the globe today, but also imposes uncompensated damages on future generations. US fuel economy and fuel efficiency standards reduce the current flow of GHGs into the atmosphere and thus reduce the climate-related damages their accumulation causes.

Abating climate-related damages is generally viewed as a global public good, because the benefits it produces can be extended to additional nations at no cost and it is impossible to exclude individuals from experiencing them.[21] In other words, there exists no market that would compensate a driver who chooses a vehicle that emits less GHGs for the benefits that driver creates for present and future generations.

The United States cannot address the domestic consequences of climate change by itself; instead, we need other nations to take action to reduce their own domestic emissions and to consider the benefits that doing so

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[17] The United States became a net exporter of oil on a weekly basis several times in late 2019, and EIA’s subsequent analyses continue to project that it will do so on a sustained, long-term basis after 2020; see EIA, AEO 2022 Reference Case, Table 11, https://www.eia.gov/outlooks/aeo/data/browser/#/?id=11-AEO2022&cases=ref2022&sourcekey=0. As the United States has approached self-sufficiency in petroleum production, this transfer of revenue has increasingly been from U.S. consumers of refined petroleum products to U.S. petroleum producers, so any price increase that results from increased domestic petroleum demand not only leaves welfare unaffected, but even ceases to be a financial burden on the U.S. economy. In fact, as the United States has become a net petroleum exporter (AEO 2022 projects the nation to be a net exporter of petroleum and other liquids through 2050), the transfer from global consumers to petroleum producers created by higher world oil prices provides a net financial benefit to the U.S. economy. Uncertainty about the nation’s long-term import-export balance makes it difficult to project precisely how this situation might change in response to changes in U.S. domestic consumption of petroleum products, but the important point is that changes in revenue flows resulting from variation in global petroleum prices are not a measure of economic costs or benefits that can be attributed to policies that affect petroleum demand.

[18] Greene, D. 2010. Measuring energy security: Can the United States achieve oil independence? *Energy Policy*. Volume 38: pp. 1614-621. Available at: https://www.sciencedirect.com/science/article/pii/S0301421509000755. (Accessed: May 31, 2023).

[19] See Delucchi, M. and Murphy, J. 2008. US military expenditures to protect the use of Persian Gulf oil for motor vehicles. *Energy Policy.* Vol. 36. Pp. 2253-2264. Available at: https://doi.org/10.1016/j.enpol.2008.03.006. (Accessed: May 31, 2023).

[20] Hanley, N., Shogren, J., and White, B. 2007. Environmental Economics in Theory and Practice. 2nd ed. Red Globe Press London: London, UK. Chapter 3, “Market Failure”. Available at: https://www.bloomsbury.com/us/environmental-economics-9780333971376. (Accessed: May 31, 2023).

[21] Nordhaus, W. 2013. Chapter 16 – Integrated Economic and Climate Modeling. *Handbook of Computable General Equilibrium Modeling*. Volume 1: pp. 1069-131. Available at: https://www.sciencedirect.com/science/article/abs/pii/B978044459568300016X. (Accessed: May 31, 2023).

will have for the United States. In order to ensure that other nations take action to reduce their GHG emissions, the United States is actively involved in developing and implementing international commitments to secure those reductions. Concrete actions to reduce domestic emissions such as increasing fuel efficiency and fuel economy standards may help the United States secure reductions from other nations. Also, innovations by manufacturers resulting from increases in fuel economy standards may have spillovers in foreign markets that reduce climate damages at home. Any such positive externalities are unlikely to be considered by vehicle buyers when they choose among models offering different fuel economy levels.

The scientific evidence that burning fossil fuels is causing the earth to warm is abundant. The greenhouse effect is a natural process whereby certain gases in the atmosphere, called GHGs, trap and absorb heat from the sun, which warms the Earth's surface and helps to maintain a habitable temperature for life on Earth. GHGs include water vapor, CO_2, CH_4, and nitrous oxide (N_2O). The increase in atmospheric concentrations of these GHGs due to human activities, primarily the burning of fossil fuels, land-use changes, and agriculture, is causing the planet to warm. The scientific evidence for this is based on a wide range of observations and analyses, including measurements of atmospheric concentrations of GHGs, surface and satellite measurements of temperature, and changes in ocean heat content, sea level, and other indicators of climate change. These observations show that the Earth's temperature has increased by about 1.1°C since the pre-industrial era, and that this warming is unequivocally due to human activities.[22]

Criteria pollutants emitted by light-duty (LD) vehicles also exemplify an externality because their associated costs and consequences are borne by society at large, rather than the vehicle owners and manufacturers themselves. These pollutants, including particulate matter, nitrogen oxides, and sulfur oxides contribute to air pollution, adversely affecting public health. As vehicle owners and manufacturers do not directly incur the costs of the environmental and health damages caused by these emissions, they have less incentive to reduce them. Fuel economy regulation reduces the external damages caused by these pollutants.

2.1.3. External Safety Risks

The “rebound effect” is a measure of the additional driving that vehicle users may choose to do when the cost of driving declines. More stringent standards reduce vehicle operating costs, and in response, some consumers may choose to drive more. This additional driving increases drivers’ and their passengers’ exposure to the safety risks associated with auto travel, and this added exposure ultimately translates into more frequent fatalities and injuries. Because fuel economy standards merely make driving less costly and do not require drivers to drive more miles, NHTSA believes that a large fraction of the safety risks associated with additional driving must be offset by benefits from added driving. Although the actual fraction of crash risks that drivers “internalize” is unknown, we suspect that drivers are more likely to internalize the potential consequences of serious crashes than of minor ones, and that some drivers may not completely internalize the consequences of injuries to other individuals involved in potential crashes, especially occupants of other vehicles and pedestrians. However, legal consequences from crash liability, both criminal and civil, should also act as a caution for drivers considering added crash risk exposure. The rebound effect is discussed in greater detail in Draft TSD Chapter 4.3.3, while the extent of the external safety risk of rebound miles is discussed in Draft TSD Chapter 7.4.

2.1.4. Consumer-Related and Supply-Side Market Failures

How potential buyers value fuel savings from purchasing new cars, LTs, and HDPUVs that offer higher fuel economy is an important issue in assessing the benefits and costs of government regulation. In the absence of other market failures, if buyers fully valued the savings in fuel costs that result from higher fuel economy and fuel efficiency, manufacturers would presumably supply all improvements that buyers valued highly enough to justify the costs to make them. Vehicle prices would then fully reflect both the costs of supplying added fuel saving technology and the future cost savings consumers would realize from owning—and potentially re-selling—more fuel-efficient models. In this situation, imposing more stringent fuel economy and fuel efficiency standards will invariably impose net costs on vehicle buyers, because they would already fully incorporate the resulting savings into their purchase decisions, so raising standards could provide social

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[22] Intergovernmental Panel on Climate Change (IPCC). 2021. Climate Change 2021: The Physical Science Basis. Contribution of Working Group I to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press: New York, NY. Available at: https://www.ipcc.ch/report/sixth-assessment-report-working-group-i/. (Accessed: May 31, 2023).

benefits only by correcting externalities that buyers do not recognize. If consumers instead systematically undervalue future fuel savings when choosing among competing vehicle models, or if manufacturers systematically undersupply fuel-efficient technologies, more stringent CAFE standards or fuel efficiency standards will lead manufacturers to make improvements in fuel economy that buyers might not initially choose but would ultimately improve their welfare.

The potential for car buyers to voluntarily forego improvements in fuel economy that offer savings exceeding their initial costs is one example of what is often termed the “energy efficiency gap.” The appearance of such a gap between the level of energy efficiency that would minimize consumers’ overall expenses and what they actually purchase is frequently based on comparisons of engineering-based estimates of initial costs for providing higher energy efficiency to the present value of the resulting savings in future energy costs.

There has long been an active debate about whether such a gap actually exists, and why it might arise. Manufacturers have consistently told the agency that new vehicle buyers will pay for 2-3 years of anticipated fuel savings before price increases reflecting the cost of improving fuel economy begin to affect sales. Of course, it is possible that manufacturers are incorrect in their assumptions; the same manufacturers, for example, long assumed that consumers would not pay extra for safety features that later became popular options. Manufacturers may also play some role in shaping consumer preferences, or they would presumably not spend large sums on advertising. As NHTSA discusses in this section, published economic literature provides support for assuming both full valuation of energy savings and their substantial undervaluation.

Economic theory predicts, in the absence of market failures, that informed individuals will purchase more energy-efficient products when the discounted savings in future energy costs they offer promise to offset their higher initial purchase prices. However, the additional costs of purchasing and using more energy-efficient products can potentially include more than just the cost of the technology necessary to improve their efficiency. They also could include losses in the utility vehicles provide to their buyers if manufacturers make tradeoffs in vehicles’ other desirable features in their efforts to improve fuel efficiency.

In the context of vehicles, whether the expected fuel savings outweigh any opportunity cost of purchasing a model offering higher fuel economy or fuel efficiency will depend on how much its buyer expects to drive, expectations about future FPs, available financing options, (discount rates buyers apply to future expenses, the expected effect of a vehicle’s higher fuel economy or fuel efficiency on its resale value, and whether more efficient models offer equivalent attributes such as performance, safety, carrying capacity, reliability, quality, or other characteristics. Importantly, the availability of additional consumer information through window stickers, education by dealers, or other sources may cause some consumers to place greater value on the benefit of fuel savings at the time they purchase vehicles. Likewise, advertising, financing options and incentives will also impact buyer’s choices among competing models.

Published literature has not arrived at a consensus about consumers’ willingness-to-pay for greater fuel economy, and whether it implies that they correctly value the appropriately discounted value of expected fuel savings from purchasing a model with higher fuel economy. Most studies have relied on car buyers’ purchasing behavior to estimate their willingness-to-pay for future fuel savings; a common approach has been to use “discrete choice” models that relate individual buyers’ choices among competing vehicles to their purchase prices, fuel economy, and other attributes (such as performance, carrying capacity, and reliability), and to infer buyers’ valuation of higher fuel economy from the relative importance of purchase prices and fuel economy.[23] Because a vehicle’s price is often correlated with its other attributes (both measured and unobserved), analysts have often resorted to instrumental variables or other approaches to address endogeneity and other resulting concerns.[24] Empirical estimates using this approach span a wide range, extending from substantial undervaluation of fuel savings to significant overvaluation, thus making it difficult to draw solid conclusions about the influence of fuel economy on vehicle buyers’ choices.[25]

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[23] In a typical vehicle choice model, the ratio of estimated coefficients on fuel economy — or more commonly, fuel cost per mile driven — and purchase price is used to infer the dollar value buyers attach to slightly higher fuel economy.

[24] Berry, S., Levinsohn, J., & Pakes, A. 1995. Automobile Prices in Market Equilibrium. *Econometrica*, *63*(4), 841–890. Available at: https://www.jstor.org/stable/2171802. (Accessed: May 31, 2023).

[25] See Greene et al. (2018), Helfand and Wolverton (2011) and Greene (2010) for detailed reviews of these cross- sectional studies.

More recent research has criticized these studies, with some questioning the power of the statistical instruments they use,[26] while others have observed that coefficients estimated using non-linear statistical methods can be sensitive to the optimization algorithm and starting values.[27] Collinearity (i.e., high correlations) among vehicle attributes—most notably among fuel economy, performance or power, and vehicle size—and between vehicles' measured and unobserved features also raises questions about the reliability and interpretation of estimated coefficients, since they may conflate the value of fuel economy with other attributes (Sallee et al., 2016; Busse et al., 2013; Allcott & Wozny, 2014; Allcott & Greenstone, 2012; Helfand & Wolverton, 2011).

To overcome shortcomings of past analyses, four more recent studies rely on prices for repeated sales of large numbers of individual vehicle models to improve their reliability in identifying the association between vehicles' prices and their fuel economy (Sallee et al. 2016; Allcott & Wozny, 2014; Busse et al., 2013; Leard et al., 2023). Although they differ in certain details, each of these analyses relates changes over time in individual models' selling prices to fluctuations in FPs, differences in their fuel economy, and increases in their age and accumulated use between subsequent sales (which affect their expected remaining life and thus their market value). Because a vehicle's future fuel costs are a function of both its fuel economy and expected gasoline prices, changes in FPs have different effects on the market values of vehicles with varying fuel economy; comparing individual models' actual selling prices to those that would be expected if their buyers fully valued future fuel costs reveals the fraction of changes in fuel costs that is reflected in changes in their selling prices (Allcott & Wozny, 2014). Using very large samples of sales allows these studies to define vehicle models at an extremely disaggregate level, which enables their authors to isolate differences in their fuel economy from other attributes (including those that are difficult to observe or measure) that affect their sale prices.[28]

These studies point to a somewhat narrower range of estimates than suggested by previous cross-sectional studies; more importantly, they consistently suggest that buyers value a large proportion—and perhaps even all—of the future savings that models with higher fuel economy offer.[29] Because they rely on estimates of fuel costs over vehicles' expected remaining lifetimes, these studies' estimates of how buyers value fuel economy are sensitive to how they measure differences among individual models' fuel economy and how they estimate vehicles' remaining "life expectancy," as well as to their assumptions about buyers' DRs and expectations for future gasoline prices. Anderson et al. (2013) found evidence that consumers expect future gasoline prices to resemble current prices, and the agency uses this assumption to compare the findings of the three studies and examine how they vary with the DRs buyers are assumed to apply to future fuel savings.[30]

Allcott and Wozny (2014) found that consumers incorporate 55 percent of future fuel costs into vehicle purchase decisions if they are assumed to discount future costs at a six percent rate and their expectations for future gasoline prices are assumed to reflect prevailing prices at the time of their purchases. With the same expectation about future FPs, the authors report that consumers would fully value fuel costs only if they apply DRs of 24 percent or higher. However, these authors' estimates are closer to full valuation when using

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[26] Allcott, Hunt, and Michael Greenstone. 2012. Is There an Energy Efficiency Gap? *Journal of Economic Perspectives* 26(1): 3–28.

[27] Metaxoglou, Konstantinos, and Christopher Roland Knittel. 2014. Estimation of Random-Coefficient Demand Models: Two Empiricists' Perspective. MIT Press. Available at: https://dspace.mit.edu/handle/1721.1/87587. (Accessed: May 31, 2023).

[28] These studies rely on individual vehicle transaction data from dealer sales and wholesale auctions, which includes actual sale prices and allows their authors to define vehicle models at a highly disaggregated level. For instance, Allcott and Wozny (2014) differentiate vehicles by manufacturer, model or nameplate, trim level, body type, fuel economy, engine displacement, number of cylinders, and "generation" (a group of successive model years during which a model's design remains largely unchanged). All three studies include transactions only through mid- 2008 to limit the effect of the recession on vehicle prices. To ensure that the vehicle choice set consists of true substitutes, Allcott and Wozny (2014) define the choice set as all gasoline-fueled light-duty cars, trucks, SUVs, and minivans that are less than 25 years old (i.e., they exclude vehicles where the substitution elasticity is expected to be small). Sallee et al. (2016) exclude diesels, hybrids, and used vehicles with less than 10,000 or more than 100,000 miles.

[29] Killian and Sims (2006) and Sawhill (2008) rely on similar longitudinal approaches to examine consumer valuation of fuel economy except that they use average values or list prices instead of actual transaction prices. Since these studies remain unpublished, their empirical results are subject to change, and they are excluded from this discussion.

[30] Each of the studies makes slightly different assumptions about appropriate discount rates. Sallee et al. (2016) use five percent in their base specification, while Allcott and Wozny (2014) rely on six percent. As some authors note, a five to six percent discount rate is consistent with current interest rates on car loans, but they also acknowledge that borrowing rates could be higher in some cases, which could be used to justify higher discount rates. Rather than assuming a specific discount rate, Busse et al. (2013) directly estimate implicit discount rates at which future fuel costs would be fully internalized; they find discount rates of six to 21 percent for used cars and one to 13 percent for new cars at assumed demand elasticities ranging from -2 to -3. Their estimates can be translated into the percent of fuel costs internalized by consumers, assuming a particular discount rate. To make these results more directly comparable to the other two studies, we assume a range of discount rates and uses the authors' spreadsheet tool to translate their results into the percent of fuel costs internalized into the purchase price at each rate. Because Busse et al. (2013) estimate the effects of future fuel costs on vehicle prices separately by fuel economy quartile, these results depend on which quartiles of the fuel economy distribution are compared; our summary shows results using the full range of quartile comparisons.

gasoline price forecasts that mirror oil futures markets, because the petroleum market expected prices to fall during this period (this outlook reduces the discounted value of a vehicle's expected remaining lifetime fuel costs). With this expectation, Allcott and Wozny (2014) find that buyers value 76 percent of future cost savings (discounted at six percent) from choosing a model that offers higher fuel economy, and that a DR of 15 percent would imply that they fully value future cost savings.

Sallee et al. (2016) begin with the perspective that buyers fully internalize future fuel costs into vehicles' purchase prices and cannot reliably reject that hypothesis; their base specification actually suggests that changes in vehicle prices incorporate slightly *more* than 100 percent of changes in future fuel costs. For DRs of five to six percent, the Busse et al. (2013) results imply that vehicle prices reflect 60 to 100 percent of future fuel costs. Leard et al. (2023) uses an instrumental variables approach to account for endogeneity in fuel costs and performance of vehicles and reports a central value of 53.6 percent assuming a discount rate of 1.3 percent.

The studies also explore the sensitivity of the results to other parameters that could influence their results. Busse et al. (2013) and Allcott and Wozny (2014) find that assuming lower annual vehicle use or survival probabilities (which imply that vehicles will not last as long) moves their estimates closer to full valuation, an unsurprising result because both reduce the changes in expected future fuel costs caused by FP fluctuations. Allcott and Wozny's (2014) base results rely on an instrumental variables estimator that groups miles-per-gallon (MPG) into two quantiles to mitigate potential attenuation bias due to measurement error in fuel economy, and they find that greater disaggregation of the MPG groups implies greater undervaluation. Busse et al. (2013) allow gasoline prices to vary across local markets in their main specification; using national average gasoline prices, an approach more directly comparable to the other studies, results in estimates that are closer to or above full valuation. Sallee et al. (2016) find modest undervaluation by vehicle fleet operators or manufacturers making large- scale purchases, compared to buyers purchasing vehicles at retail dealers (i.e., 70 to 86 percent).

Since they rely predominantly on changes in vehicles' prices between repeat sales, of the valuation estimates reported in these studies apply most directly to buyers of used vehicles. Only Busse et al. (2013) and Leard (2023) examine new vehicle sales. Busse (2013) finds that consumers value between 75 to 133 percent of future fuel costs for new vehicles, a higher range than they estimate for used vehicles. Leard (2023) finds results suggesting less consumer valuation of fuel cost savings using a different approach and dataset. When the authors of the later paper apply their methodology to the dataset used in Busse (2013), they obtain similar results to the earlier paper; however, when they apply the methodology of Busse (2013) to their own dataset, they find undervaluation comparable to their own baseline results, suggesting sensitivity of the results to sample period rather than methodology. Allcott and Wozny (2014) examine how their estimates vary by vehicle age and find that fluctuations in purchase prices of younger vehicles imply that buyers whose FP expectations mirror the petroleum futures market value a much higher fraction of future fuel costs: 93 percent for one- to three-year-old vehicles, compared to their estimate of 76 percent for all used vehicles assuming the same price expectation.[31]

Accounting for differences in their data and estimation procedures, the three studies described here suggest that car buyers who use DRs of five to six percent value at least half—and perhaps all—of the savings in future fuel costs they expect from choosing models that offer higher fuel economy. Perhaps more important, one study (Busse et al., 2013) suggests that buyers of new cars and LT value three-quarters or more of the savings in future fuel costs they anticipate from purchasing higher-MPG models, although this result is based on more limited information.

Economists have identified numerous ways the decision making of both consumers and firms can deviate from the standard competitive market models of rational consumer and firm behavior, especially when their choices involve uncertainty.[32] The future value of purchasing a model that offers higher fuel economy is uncertain for several reasons, but particularly because the mileage any particular consumer experiences will

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[31] Allcott and Wozny (2014) and Sallee et al. (2016) also find that future fuel costs for older vehicles are substantially ucondervalued (26-30 percent). The pattern of Allcott and Wozny's results for different vehicle ages is similar when they use retail transaction prices (adjusted for customer cash rebates and trade-in values) instead of wholesale auction prices, although the degree of valuation falls substantially in all age cohorts with the smaller, retail price based sample.

[32] Dellavigna, S. 2009. Psychology and economics: Evidence from the field. *Journal of Economic Literature.* Volume 47(2): pp. 315-72. Available at: https://www.jstor.org/stable/27739926. (Accessed: May 31, 2023).

generally differ from that shown on fuel economy labels, potential buyers may be uncertain how much they will actually drive a new vehicle, and future FPs are highly uncertain.[33] Recent research indicates that typical consumers exhibit several behavioral departures from the rational economic model,[34] some of which could explain undervaluing of fuel economy to an extent roughly consistent with the agency's assumed 30-month payback rule. These include loss aversion (valuing potential losses more than potential gains when faced with an uncertain choice), present bias (the tendency to use DRs that decrease over time, also known as hyperbolic discounting), certainty bias (a preference for certain over uncertain options) and inattention or satisficing.[35] Behavioral economic theory also differs from rational economic theory by recognizing that consumers' preferences may change depending on the context of a choice. In addition, behavioral economics recognizes that by conscious deliberation or learning by experience consumers, can overrule behaviors that differ from the rational economic model.[36] There are also a variety of classic externalities that could prevent consumers in an unregulated market from fully purchasing levels of fuel efficiency that will deliver positive net present value, including informational asymmetries between consumers, dealerships, and manufacturers; market power; first-mover disadvantages for both consumers and manufacturers; principal-agent split incentives between vehicle purchasers and vehicle drivers; and positional externalities.[37]

If the behavioral explanation for how potential new buyers choose fuel economy is more accurate than the rational economic model, there could be important implications for our cost-benefit analysis.[38] Because preferences can be context dependent, some consumers may view the decision whether to buy a model offering increased fuel economy in a market without increasing fuel economy standards as a risky choice, because their return from the purchase will vary with their future travel activity and gasoline prices. In contrast, if the fuel economies of most new vehicles are increasing in response to higher standards, they may view the relative risk/reward of purchasing a vehicle with higher fuel economy more favorably. When fuel economy standards increase incrementally over several years, consumers' experience might lead them to conclude that the value of fuel savings was worth the higher cost to purchase more fuel-efficient models, even if that was not their initial view. Such differences from rational economic theory could affect the agency's estimates of the impacts of raising CAFE standards on new vehicle sales as well as the usage and retirement rates of used vehicles, with important implications for safety, emissions, and employment, as well as for the welfare of producers and consumers.

Based on a meta-analysis of the literature from 1995-2015 that included the papers discussed above, Greene et al. (2018) concluded that economic literature from that period did not support a consensus estimate of consumers' willingness to pay for fuel economy, although it clearly ruled out the possibility of zero valuation. The National Academies of Sciences, Engineering, and Medicine (NASEM, 2021) fuel economy committee agreed, observing that, "Many papers found undervaluation, and many have found full or even overvaluation. Both earlier studies and more recent ones have found undervaluation. Studies using both methodologies (discrete choice or otherwise) have found undervaluation." (NASEM, 2021, p. 11-351). More recently, Gillingham et al. (2021) analyzed the effects of changes in fuel economy *ratings* of 1.6 million vehicles on their purchase prices and concluded that if those correctly predicted their actual on-road fuel economy consumers appeared willing to pay only 16-39 cents per dollar of fuel savings, assuming an annual DR of 4 percent.[39] Analyzing a data set of more than half a million vehicles purchased by households between 2009 and 2014,

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[33] Greene, D.L. 2011. Uncertainty, Loss Aversion and Markets for Energy Efficiency. *Energy Economics*, 33; 608-616.; Hamilton, J. 2009. Understanding Crude Oil Prices. *The Energy Journal*, 30(2): 179-206.; Greene, D., A. Khattak, J. Liu, X. Wang, J. Hopson and R. Goeltz. 2017. What is the evidence concerning the gap between on-road and EPA fuel economy ratings?. *Transport Policy*, 53: 146-160.

[34] Stango, V. and J. Zinman. 2020. We are all behavioral, more or less: A taxonomy of consumer decision making. NBER Working Paper 28138, National Bureau of Economic Research, Cambridge, MA. Based on nationally representative panel data, the study concludes that the typical U.S. consumer exhibits 10 "behavioral biases".

[35] Leard, B. 2018. Consumer inattention and the demand for vehicle fuel cost savings. *Journal of Choice Modeling*, 29, 1-16.; Heutel, G. 2019. Prospect theory and energy efficiency. *Journal of Environmental Economics and Management*, 96: 236-254.; Greene, D.L., D.H. Evans and J. Hiestand. 2013. Survey evidence on the willingness of U.S. consumers to pay for automotive fuel economy. *Energy Policy*, 61, 1539-1550.

[36] Kahneman, D. 2011. Thinking Fast and Slow. Farrar, Straus and Giroux: New York, New York. Available at: https://us.macmillan.com/books/9780374533557/thinkingfastandslow. (Accessed: May 31, 2023).

[37] Academic literature on these market failures is collected and summarized by Rothschild, R. & J. Schwartz. 2021. Tune Up: Fixing Market Failures to Cut Fuel Costs and Pollution from Cars and Trucks. Institute for Policy Integrity Report.

[38] Sunstein, C., 2020. Behavioral Welfare Economics. *Journal of Benefit Cost Analysis*, doi: 10.1017/bca.2020.14, p. 1-25.; Greene, D.L. 2019. Implications of Behavioral Economics for the Costs and Benefit of Fuel Economy Standards. *Current Sustainable/Renewable Energy Reports*, 6(4): 177-192.

[39] Gillingham, K. et al. 2021. Consumer myopia in vehicle purchases: Evidence from a natural experiment. American Economic Journal: Economic Policy. Volume 13(3): pp. 207–38. Available at: https://www.nber.org/papers/w25845. (Accessed: May 31, 2023).

NHTSA also examined whether the heterogeneity in consumer response was different for commercial HDPUVs. Even if commercial operators are rational buyers of fuel economy, that assumption does not necessarily mean that commercial operators are willing to pay $1 for every future $1 of fuel savings. Tight profit margins, uncertainty about the on-road performance benefits of energy saving technologies, a short term focus on maximizing stock price, and the differing incentives faced by fleet owners and truck drivers, all act to limit the value that fleet managers place upon potential fuel savings, according to a recent report from the International Energy Agency.[40] Smaller fleet operators are reportedly less willing to adopt new cost saving technologies due to more limited financial resources, and greater risk aversion.[41] In the heavy-duty commercial vehicle realm the required payback period reported by truck buyers ranged from 6 to 36 months for small fleets (1-20 vehicles), and up to 18-48 months for larger fleets.[42] The average payback period for fleet operators in the HDPUV market could be influenced by the share of the market made up by larger operators, and consumer preferences for fuel efficiency could change over time based on new information, innovation, and changing prices (e.g. fuel prices).

NHTSA examined several sources of information to ascertain the composition of consumers in the HDPUV market. The agency analyzed data from a 2018 draft Advanced Clean Trucks (ACT) Market Segment Analysis, prepared by the Truck and Engine Manufacturers Association (EMA) for the California Air Resources Board (CARB), and found that commercial users represented just under half of new vehicle sales in the HDPUV market.[43] While there is thus some evidence to conclude that buyers in this market are on average more likely to be fleet operators than in the LD market, there is significant uncertainty about the extent of this difference. For this proposal, the model mirrors the LD approach to willingness to pay for HDPUV, but also includes sensitivity cases that vary this assumption.

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[40] International Energy Agency. 2017. The Future of Trucks: Implications for Energy and the Environment. Second Edition. Available at: https://www.iea.org/reports/the-future-of-trucks. (Accessed: May 31, 2023).

[41] Birky, A. et al. U.S. 2017. Electrification Beyond Light Duty: Class 2b-3 Commercial Vehicles. No. ORNL/TM-2017/744. Energy and Transportation Science Division. Oak Ridge National Laboratory. (ORNL). Prepared for: DOE. Washington, D.C. Available at: https://info.ornl.gov/sites/publications/Files/Pub106416.pdf. (Accessed: May 31, 2023).

[42] Schoettle, B et al. 2016. A survey of fuel economy and fuel usage by heavy-duty truck fleets. No. SWT-2016-12. Available at: https://www.semanticscholar.org/paper/A-Survey-of-Fuel-Economy-and-Fuel-Usage-by-Truck-Schoettle-Sivak/28838cfa69923f0f7d63e83e7dd2ff1deef1d445. (Accessed: May 31, 2023).

[43] For this analysis personal use pickup trucks were considered to be the only non-commercial vehicle sale classification. These vehicles represented 50.7 percent of the overall market. This report was presented at the December 4, 2018 Public Workshop on Advanced Clean Trucks. Data can be accessed at: https://ww2.arb.ca.gov/our-work/programs/advanced-clean-trucks/act-meetings-workshops.

3. Baseline and Alternatives Considered

Agencies typically consider regulatory alternatives as a way of evaluating the comparative effects of different potential ways of accomplishing their desired goal, which in this case is the statutory mandate to set maximum feasible standards. Executive Orders 12866 and 13563, the National Environmental Policy Act, as well as Office of Management and Budget (OMB) Circular A-4,[44] encourage agencies to evaluate regulatory alternatives in their rulemaking analyses. This does not amount to a requirement that agencies evaluate the widest conceivable spectrum of alternatives. Rather, the range of alternatives must be reasonable and consistent with the purpose and need of the action.

CAFE Model Files Referenced in this Chapter

Below is a list of CAFE Model Files referenced in this chapter. See TSD Chapter 2.1.9 Where can I find the internal NHTSA files? for a full list of files referenced in this document and their respective file locations.

- Market Data Input File

Alternatives analysis begins with a “No-Action” Alternative, typically described as what would occur in the absence of any regulatory action by the agency. OMB Circular A-4 states that the “baseline should be the best assessment of the way the world would look absent the regulatory action.” The choice of an appropriate baseline may require consideration of a wide range of potential factors, including:

- Evolution of the market,
- Changes in external factors affecting expected benefits and costs,
- Changes in regulations promulgated by the agency or other government entities, and
- The degree of compliance by regulated entities with other regulations.[45]

Besides the No-Action Alternative, this proposal includes four “action alternatives” for PCs and LT, and three action alternatives for HDPUVs. The proposed standards may, in places, be referred to as the “Preferred Alternative(s),” which is National Environmental Policy Act (NEPA) parlance, but NHTSA intends “proposed standards” and “Preferred Alternative(s)” to be used interchangeably for purposes of this document.

The different action alternatives are defined in terms of percent-increases in stringency from year to year, but they differ slightly between PCs and LT on the one hand, and HDPUVs on the other. For PCs and LT, readers should recognize that those year-over-year changes in stringency are *not* measured in terms of mile per gallon differences (as in, 1 percent more stringent than 30 MPG in one year equals 30.3 MPG in the following year), but rather in terms of shifts in the *footprint functions* that form the basis of the *actual* CAFE standards (as in, on a gallon per mile basis, the CAFE standards change by a given percentage from one model year to the next). Under each action alternative for PCs and LT, the stringency changes at a constant rate year over year, respectively, in each model year in the rulemaking time frame, although the rates of change for PCs are different then for LT. One action alternative is less stringent than the Preferred Alternative for PCs and LT, and two action alternatives are more stringent.[46]

In a departure from recent CAFE rulemaking trends, we have applied individual rates of increase to the PC and the LT fleets. Rather than have both fleets increase their respective standards at the same rate, LT standards will increase at a faster rate than PC standards. Each action alternative evaluated for this proposal has a PC fleet rate-of-increase of fuel economy lower than the rate-of-increase of fuel economy for the LT fleet. NHTSA has discretion, by law, to set CAFE standards that increase at different rates for cars and trucks, because NHTSA must set maximum feasible CAFE standards separately for cars and trucks.[47] We have selected this approach for the current proposal for several reasons.

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[44] See https://www.whitehouse.gov/wp-content/uploads/legacy_drupal_files/omb/circulars/A4/a-4.pdf.
[45] OMB Circular A-4. General Issues, 2. Developing a Baseline. Available at: https://www.whitehouse.gov/wp-content/uploads/legacy_drupal_files/omb/circulars/A4/a-4.pdf. (Accessed: May 31, 2023).
[46] See Draft TSD Chapter 1.2.1 for a complete discussion about the footprint curve functions and how they are calculated.
[47] See, e.g., the 2012 final rule establishing CAFE standards for MYs 2017 and beyond, in which rates of stringency increase for passenger cars and LTs were different. 77 FR 62623, 62638-39 (Oct. 15, 2012).

First, NHTSA believes that manufacturers will deploy considerable amounts of technology to reach the existing increased PC fuel economy standards implemented for MYs 2024-26. This is not to say that NHTSA now concludes those standards set in 2022 are beyond maximum feasible, but simply to note that as manufacturers continue to improve in fuel economy in response to those standards, less technology will remain on the table to be used for additional stringent increases in subsequent years, particularly for PCs. Because the CAFE statute prohibits us from considering BEVs and full PHEVs combined fuel economy, we believe manufacturers would find it difficult to improve fuel economy with internal combustion engine (ICE) engine technologies more than what we are proposing for PCs and maintain a reasonable cost. This is supported by feedback we have received from industry stakeholders, that consumers are less willing to absorb significant additional regulatory costs for PCs than they are for LT. This phenomenon is more pronounced for smaller cars where cost increase represents a much larger percentage of the overall vehicle cost. Our (statutorily-constrained) analysis also suggests that costs for improvements in fuel economy for PCs are, increasingly, no longer offset by the value of the fuel saved (or other benefits to the purchaser), which makes ongoing rapid increases less feasible. We do not believe this is a trend that is in the best interests of American consumers, particularly those who are seeking affordable new cars.

Second, as discussed in Draft TSD Chapter 1.2.4 where we stated, “NHTSA carefully considered the existing curve shapes in light of ongoing trends in the fleet,[48] and determined, as in the 2022 TSD, that changing our approach to standard *stringency* made more sense for CAFE standards than changing the *curve shapes* at this point.” We believe the ongoing trend to also be driven by vehicles classified as LT simply on the basis of having all-wheel drive that would otherwise be subject to the generally-more-stringent PC curve; consumers appear receptive to these offerings, but they may end up with less fuel savings than if the vehicles had been classified, instead, as PCs. Attribute-based standards and separate standards for cars and trucks are statutorily required and are designed to accommodate these market trends but has resulted in less fuel savings which would otherwise accrue to American consumers. Additionally, we believe LT have significantly more opportunity for fuel economy improvements due to lower baseline technology levels,[49] and greater average vehicle miles traveled (VMT) values. Our analysis shows that for LT stringency increases, the value of fuel savings outweighs the increased regulatory cost. In short, there appears to be more room to improve the LT fleet, and thus NHTSA has considered relatively larger ongoing increases in stringency for this fleet.

For HDPUVs, the different action alternatives are also defined in terms of percent-increases in stringency from year to year, but in terms of fuel consumption reductions rather than fuel economy increases, so that increasing stringency appears to result in standards going *down* (representing a direct reduction in fuel consumed) over time rather than *up*. Also, unlike for the PC and LT standards, because HDPUV standards are in the fuel consumption space, year-over-year percent changes do actually represent gallon/mile differences across the work-factor range. Under each action alternative for HDPUVs, the stringency changes at the same percentage rate in each model year in the rulemaking time frame. One action alternative is less stringent than the Preferred Alternative for HDPUVs, and one action alternative is more stringent.[50]

Table 3-1: Regulatory Alternatives Under Consideration for MYs 2027-2032 Passenger Cars and Light Trucks

Name of Alternative	Passenger Car Stringency Increases, Year-Over-Year	Light Truck Stringency Increases, Year-Over-Year
No Action Alternative	n/a	n/a
Alternative PC1LT3	1%	3%
Alternative PC2LT4 (Preferred Alternative)	2%	4%
Alternative PC3LT5	3%	5%
Alternative PC6LT8	6%	8%

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[48] See trends discussion in Draft TSD Chapter 1.2.3.1.
[49] See Market Data Input File.
[50] See Draft TSD Chapter 1.2.1 for a complete discussion about the WF curve functions and how they are calculated.

Table 3-2: Regulatory Alternatives Under Consideration for MYs 2030-2035 HDPUVs

Name of Alternative	HDPUV Stringency Increases, Year-Over-Year
No Action Alternative	n/a
Alternative HDPUV4	4%
Alternative HDPUV10 (Preferred Alternative)	10%
Alternative HDPUV14	14%

A variety of factors will be at play simultaneously as manufacturers seek to comply with the eventual standards that NHTSA promulgates. Foreseeably, NHTSA, EPA, and CARB will all be regulating simultaneously; manufacturers will be responding to those regulations as well as to foreseeable shifts in market demand during the rulemaking time frame (both due to cost/price changes for different types of vehicles over time, FP changes, and the recently-passed tax credits for BEVs and PHEVs). Many costs and benefits that will accrue as a result of manufacturer actions during the rulemaking time frame will be occurring for reasons other than CAFE standards, and NHTSA believes it is important to try to reflect many of those factors in order to present an accurate picture of the effects of different potential CAFE and HDPUV standards to decision-makers and to the public.

The following chapters define each regulatory alternative, including the No-Action Alternative, for each program, and explain their derivation.

3.1. Baseline/No-Action Alternative

As with the 2022 final rule analysis, our No-Action Alternative is fairly nuanced. In this analysis, the No-Action Alternative assumes:

- The existing national CAFE and GHG standards are met, and that the CAFE and GHG standards for MY 2026 finalized in 2022 continue in perpetuity.
- Manufacturers who committed to the California Framework Agreements met their contractual obligations for MY 2022.
- The HDPUV MY 2027 standards finalized in the Phase 2 program continue in perpetuity.
- Manufacturers will comply with the ZEV/ACC2/ACT standards that California and other states have adopted through 2035.
- Manufacturers will make production decisions in response to estimated market demand for fuel economy or fuel efficiency, considering estimated FPs, estimated product development cadence, the estimated availability, applicability, cost, and effectiveness of fuel-saving technologies, and available tax credits.

NHTSA continues to believe that to properly estimate fuel economies/efficiencies (and achieved CO_2 emissions) in the No-Action Alternative, it is necessary to simulate all of these legal requirements (extant and foreseeable) affecting automakers and vehicle design simultaneously. Consequently, the CAFE Model evaluates each requirement in each model year, for each manufacturer/fleet. Differences among fleets and compliance provisions often creates over-compliance in one program, even if a manufacturer is able to exactly comply (or under-comply) in the other program. This is similar to how manufacturers approach the question of concurrent compliance in the real world – when faced with multiple regulatory programs, the most cost-effective path may be to focus efforts on meeting one or two sets of requirements, even if that results in “more effort” than would be necessary for another set of requirements, in order to ensure that all regulatory obligations are met. We elaborate on those model capabilities below. Generally speaking, the model treats each manufacturer as applying the following logic when making technology decisions, both for simulating PC and LT compliance, and HDPUV compliance, with a given regulatory alternative:

1. What do I need to carry over from last year?
2. What should I apply more widely in order to continue sharing (of, e.g., engines) across different vehicle models?

3. What new BEVs do I need to build in order to satisfy anticipated manufacturer compliance with state ZEV mandates?
4. What further technology, if any, could I apply that would enable buyers to recoup additional costs within 30 months after buying new vehicles?
5. What additional technology, if any, should I apply to respond to potential new CAFE and CO_2 standards for PCs and LT, or HDPUV standards?

Additionally, within the context of 4 and 5, the CAFE Model may consider, as appropriate, the applicability of recently-passed tax credits for battery-based vehicle technologies, which improve the attractiveness of those technologies to consumers and thus the model's likelihood of choosing them as part of a compliance solution. The model can also apply over-compliance credits if applicable and not legally prohibited. The CAFE Model simulates all of these simultaneously. As mentioned above, this means that when manufacturers make production decisions in response to actions other than CAFE or HDPUV standards, those costs and benefits are not attributable to possible future CAFE or HDPUV standards. One of the effects of that, in turn, is that the effects of the proposal appear less cost-beneficial than they would otherwise, but NHTSA believes that this is appropriate in order to give the decision-maker the clearest possible understanding of the effects of the decision being made, as opposed to the effects of many things that will be occurring simultaneously.

Existing NHTSA standards during the rulemaking time frame are modeled as follows:

To account for the existing CAFE standards finalized in MY 2026 for PCs and LT, the No-Action Alternative includes the following coefficients defining those standards, which (for purposes of this analysis) are assumed to persist without change in subsequent model years:

Table 3-3: Passenger Car CAFE Target Function Coefficients for No-Action Alternative[51]

	2027	2028	2029	2030	2031	2032
a (mpg)	66.95	66.95	66.95	66.95	66.95	66.95
b (mpg)	50.09	50.09	50.09	50.09	50.09	50.09
c (gpm per s.f.)	0.00034	0.00034	0.00034	0.00034	0.00034	0.00034
d (gpm)	0.00120	0.00120	0.00120	0.00120	0.00120	0.00120

Table 3-4: Light Truck CAFE Target Function Coefficients for No-Action Alternative[52]

	2027	2028	2029	2030	2031	2032
a (mpg)	53.73	53.73	53.73	53.73	53.73	53.73
b (mpg)	32.30	32.30	32.30	32.30	32.30	32.30
c (gpm per s.f.)	0.00037	0.00037	0.00037	0.00037	0.00037	0.00037
d (gpm)	0.00327	0.00327	0.00327	0.00327	0.00327	0.00327

These coefficients are used to create the graphic below, where the x-axis represents vehicle footprint and the y-axis represents fuel economy, showing that in "CAFE space," targets are higher in fuel economy for smaller footprint vehicles and lower for larger footprint vehicles:

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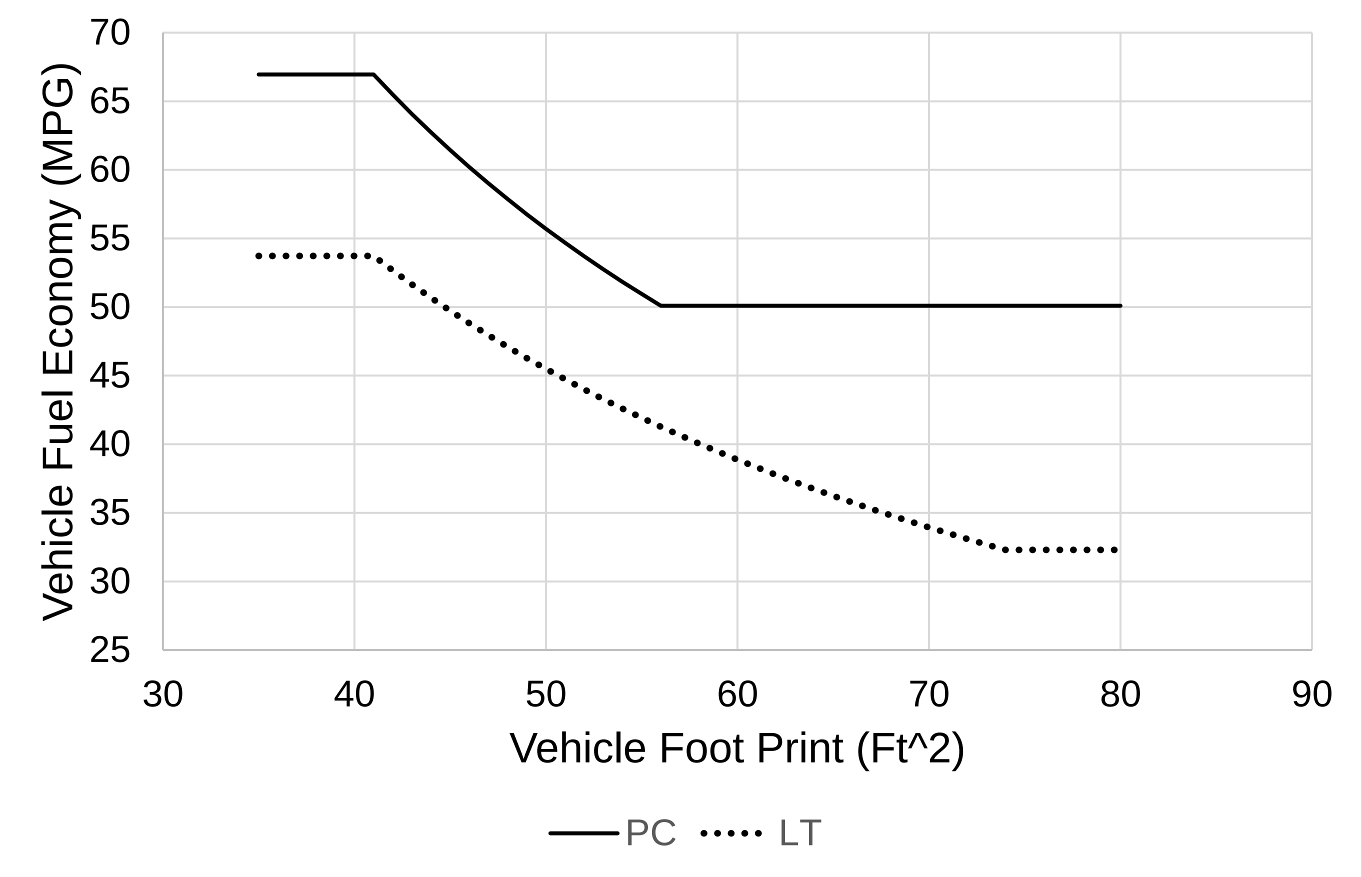
[51] The Passenger Car Function Coeffiecnts 'a','b','c', and 'd' are defined in Draft TSD Chapter 1.2.1, Equation 1-1.
[52] The Light Truck Function Coeffiecnts 'a','b','c', and 'd' are defined in Draft TSD Chapter 1.2.1, Equation 1-1.

Figure 3-1: No-Action Alternative, Passenger Car and Light Truck Fuel Economy, Target Curves



Note: There is no model year associated with the No-Action Alternative in this figure because the same curve would apply in all relevant model years.

Additionally, EPCA, as amended by EISA, requires that any manufacturer's domestically-manufactured PC fleet must meet the greater of either 27.5 mpg on average, or 92 percent of the average fuel economy projected by the Secretary for the combined domestic and non-domestic passenger automobile fleets manufactured for sale in the United States by all manufacturers in the model year. NHTSA retains the 1.9 percent offset to the Minimum Domestic Passenger Car Standard (MDPCS), first used in the 2020 final rule, to account for recent projection errors as part of estimating the total PC fleet fuel economy, and used in rulemakings since.[53,54] The projection shall be published in the Federal Register when the standard for that model year is promulgated in accordance with 49 U.S.C. 32902(b).[55,56] For purposes of the No-Action Alternative, the MDPCS is as it was established in the 2022 final rule for MY 2026, as shown in Table 3-5 below:

Table 3-5: No-Action Alternative – Minimum Domestic Passenger Car Standard (MPG)

2027	2028	2029	2030	2031	2032
53.5	53.5	53.5	53.5	53.5	53.5

To account for the existing HDPUV standards finalized in the Phase 2 rule, the No-Action Alternative for HDPUVs includes the following coefficients defining those standards, which (for purposes of this analysis) are assumed to persist without change in subsequent model years. The four-wheel drive coefficient is maintained

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[53] Preamble Section V.A.2 (titled "Separate Standards for Passenger Cars, Light Trucks, and Heavy-Duty Pickups and Vans, and Minimum Standards for Domestic Passenger Cars") discusses the basis for the offset.

[54] 87 FR 25710 (May 2, 2022).

[55] 49 U.S.C. 32902(b)(4).

[56] The offset will be applied to the final regulation numbers, but was not used in this analysis. The values for the MDPCS for the proposed action alternatives are nonadjusted values.

at 500 (coefficient ‘a’) and the weighting multiplier coefficient is maintained at 0.75 (coefficient ‘b’). The compression ignition (CI) and spark ignition (SI) coefficients are in the tables below:

Table 3-6: HDPUV CI Vehicle Target Function Coefficients for No-Action Alternative[57]

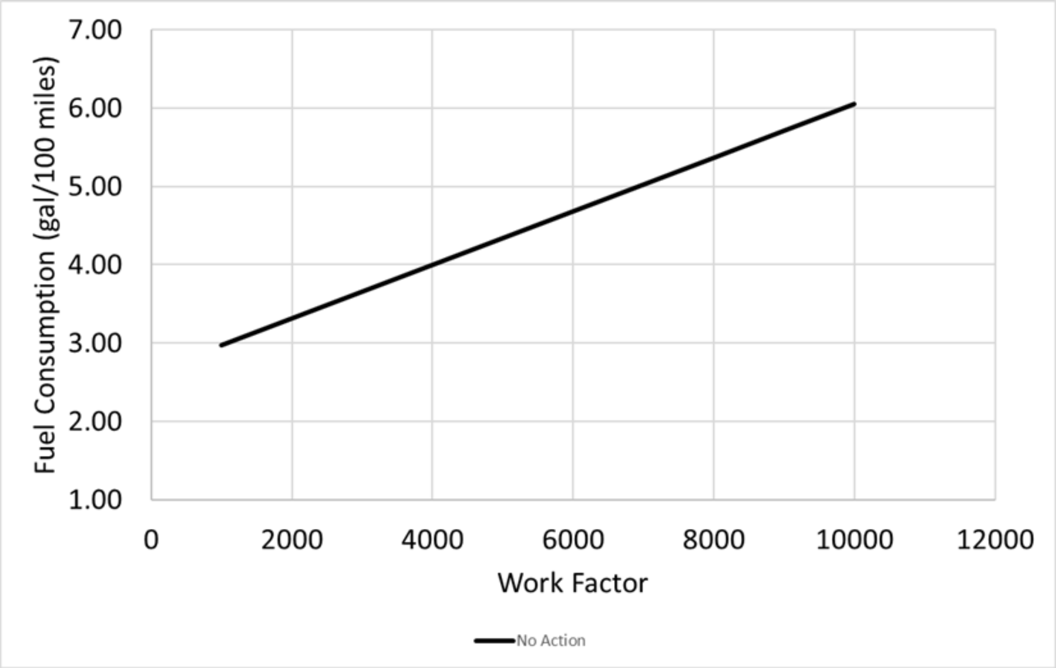
	2030	2031	2032	2033	2034	2035
e (gal/100 miles per WF)	0.0003418	0.0003418	0.0004152	0.0003418	0.0003418	0.0003418
f (gal/100 miles per WF)	2.633	2.633	2.633	2.633	2.633	2.633

Table 3-7: HDPUV SI Vehicle Target Function Coefficients for All Alternatives[58]

	2030	2031	2032	2033	2034	2035
c (gal/100 miles per WF)	0.0004152	0.0004152	0.0004152	0.0004152	0.0004152	0.0004152
d (gal/100 miles per WF)	3.196	3.196	3.196	3.196	3.196	3.196

These equations are represented graphically below:

Figure 3-2: No-Action Alternative, HDPUV – CI Vehicles, Target Curves



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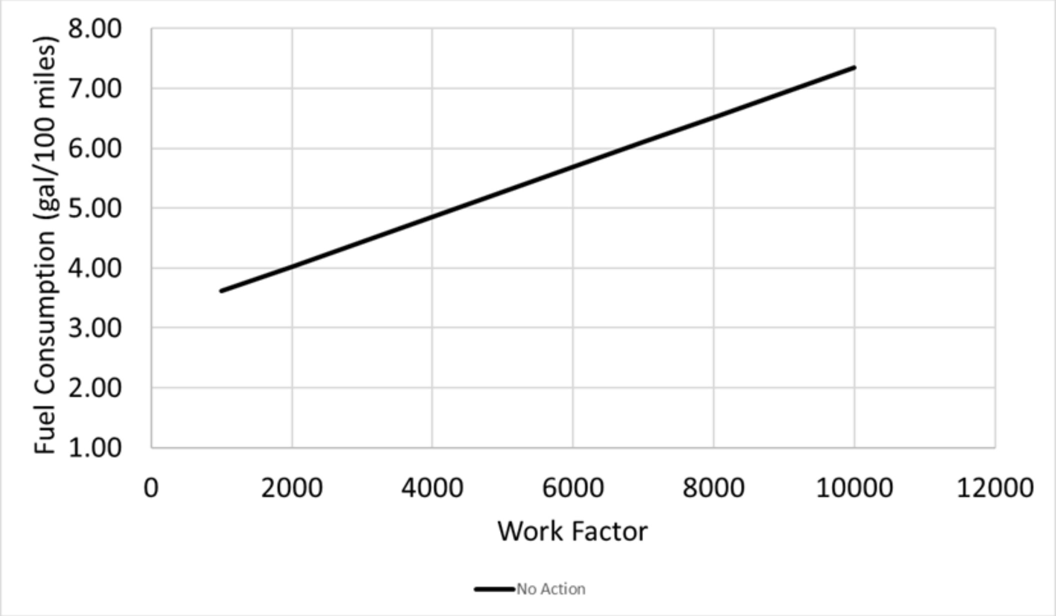
[57] In the CAFE Model, these are Linear work-factor-based function where coefficients e and f are for diesels, BEVs and FCEVs, see Draft TSD Chapter 1.2.1.

[58] In the CAFE Model, these are Linear work-factor-based function where coefficients c and d are for gasoline, CNG, strong hybrid vehicles and PHEVs, see Draft TSD Chapter 1.2.1.

Figure 3-3: No-Action Alternative, HDPUV – SI Vehicles, Target Curves



As the baseline scenario, the No-Action Alternative also includes the following other actions that NHTSA believes will occur in the absence of further regulatory action by NHTSA:

To account for the existing national GHG emissions standards, the No-Action Alternative for PCs and LT includes the following coefficients defining the GHG standards set by EPA in 2022 for MY 2026, which (for purposes of this analysis) are assumed to persist without change in subsequent model years:

Table 3-8: Passenger Car CO_2 Target Function Coefficients for No-Action Alternative

	2027	2028	2029	2030	2031	2032
a (g/mi)	114.3	114.3	114.3	114.3	114.3	114.3
b (g/mi)	160.9	160.9	160.9	160.9	160.9	160.9
c (g/mi per s.f.)	3.11	3.11	3.11	3.11	3.11	3.11
d (g/mi)	-13.10	-13.10	-13.10	-13.10	-13.10	-13.10
e (s.f.)	41.0	41.0	41.0	41.0	41.0	41.0
f (s.f.)	56.0	56.0	56.0	56.0	56.0	56.0

Table 3-9: Light Truck CO_2 Target Function Coefficients for All Alternatives

	2027	2028	2029	2030	2031	2032
a (g/mi)	141.8	141.8	141.8	141.8	141.8	141.8
b (g/mi)	254.4	254.4	254.4	254.4	254.4	254.4
c (g/mi per s.f.)	3.41	3.41	3.41	3.41	3.41	3.41
d (g/mi)	1.90	1.90	1.90	1.90	1.90	1.90
e (s.f.)	41.0	41.0	41.0	41.0	41.0	41.0
f (s.f.)	74.0	74.0	74.0	74.0	74.0	74.0

Coefficients *a*, *b*, *c*, *d*, *e*, and *f* define the existing MY 2026 federal CO_2 standards for PCs and LT, respectively, in Table 3-8 and Table 3-9 above. Analogous to coefficients defining CAFE standards, coefficients *a* and *b* specify minimum and maximum CO_2 targets in each model year. Coefficients *c* and *d* specify the slope and intercept of the linear portion of the CO_2 target function, and coefficients *e* and *f* bound the region within which CO_2 targets are defined by this linear form.

To account for the existing national GHG emission standards, the No-Action Alternative for HDPUVs include the following coefficients defining the WF based standards set by EPA for the MY2027 and beyond. The four-wheel drive coefficient is maintained at 500 (coefficient 'a') and the weighting multiplier coefficient is maintained at 0.75 (coefficient 'b'). The CI and SI coefficients are in the tables below:

Table 3-10: HDPUV CI Vehicle Target Function Coefficients for No-Action Alternative

	2027 and Later
e	0.0348
f	268

Table 3-11: HDPUV SI Vehicle Target Function Coefficients for All Alternatives

	2027 and Later
c	0.0369
d	284

Coefficients *c, d, e*, and *f* define the existing MY2027 and beyond CO_2 standards from Phase 2 rule for HDPUVs, in Table 3-10 and Table 3-11 above. The coefficients are linear work-factor based function with c and d representing gasoline, Compressed Natural Gas Engine (CNG) vehicles, strong hybrid electric vehicle (SHEVs) and PHEVs and *e* and *f* representing diesels, BEVS and Fuel Cell Electric Vehicles (FCEV). For this rule, this is identical to the NHTSA's fuel efficiency standards no action alternative.

The No-Action Alternative also includes NHTSA's estimates of ways that each manufacturer could introduce new PHEVs and BEVs in response to state ZEV mandates. To account for the ZEV programs, NHTSA has included the main provisions of the ACC II and ACT programs in the CAFE Model's analysis of compliance pathways. Incorporating these programs into the model includes converting vehicles that have been identified as potential ZEV candidates into BEVs so that a manufacturer's fleet meets the calculated ZEV credit requirements.[59] The two programs have different requirements per model year, so they are modeled separately in the CAFE analysis. Chapter 2.5.1 in the Draft TSD discusses, in detail, how NHTSA developed these estimates.

The No-Action Alternative also includes NHTSA's estimates of ways that manufacturers could take advantage of recently-passed tax credits for battery-based vehicle technologies. NHTSA explicitly models portions of two provisions of the Inflation Reduction Act (IRA) when simulating the behavior of manufacturers and consumers. The first is the Advanced Manufacturing Production Tax Credit (AMPC). This provision of the IRA provides a $35 per kWh tax credit for manufacturers of battery cells and an additional $10 per kWh for manufacturers of battery modules (all applicable to manufacture in the United States).[60] These credits, with the exception of the critical minerals credit, phase out from 2030 to 2032. The second provision explicitly modeled is the Clean Vehicle Tax Credit (CVC),[61] which provides up to $7,500 toward the purchase of clean

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[59] NHTSA made the decision to focus on BEVs for ZEV compliance based on several factors; first, because CARB only allows partial compliance with PHEVs, second, because NHTSA had conversations with manufacturers that indicated an interest in focusing on BEV development over developments of PHEV systems in the rulemaking time frame, and third, because including PHEVs in the ZEV modeling would have introduced unnecessary complication. See Docket Submission of Ex Parte Meetings Prior to Publication of the Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks for Model Years 2027-2032 and Fuel Efficiency Standards for Heavy-Duty Pickup Trucks and Vans for Model Years 2030-2035 Notice of Proposed Rulemaking memorandum, which can be found under References and Supporting Material in the rulemaking Docket No. NHTSA-2023-0022.

[60] 26 U.S.C. 45X. If a manufacturer produces a battery module without battery cells, they are eligible to claim up to $45 per kWh for the battery module. The provision includes other provisions related to vehicles such as a credit equal to 10 percent of the manufacturing cost of electrode active materials, and another 10 percent for the manufacturing cost of critical minerals. We are not modeling these credits directly because of how we estimate battery costs and to avoid the potential to double count the tax credits if they are included into other analyses that feed into our inputs.

[61] 26 U.S.C. 30D.

vehicles with critical minerals and battery components manufactured in North America.[62] The AMPC and CVC provide tax credits for PHEVs, BEVS, and FCVs. Chapter 2.5.2 in the Draft TSD discusses, in detail, how NHTSA has modeled these tax credits.

The No-Action Alternative for the PC, LT and HDPUV fleets also includes NHTSA's assumption, for purposes of compliance simulations, that manufacturers will add fuel economy- or fuel efficiency-improving technology voluntarily, if the value of future undiscounted fuel savings fully offsets the cost of the technology within 30 months. This assumption is often called the "30-month payback" assumption, and NHTSA has used it for many years and in many CAFE rulemakings.[63] It is used to represent consumer demand for fuel economy. It can be a source of apparent "over-compliance" in the No-Action Alternative, especially when technology is estimated to be extremely cost-effective, as occurs later in the analysis time frame when learning has significant effects on some technology costs.

NHTSA staff believe that manufacturers do at times improve fuel economy even in the absence of new standards, for several reasons. First, overcompliance is not uncommon in the historical data, both in the absence of new standards, and with new standards – NHTSA's analysis in the 2022 TSD included CAFE compliance data showing that from 2004-2017, while not *all* manufacturers consistently over-complied, a number did. Of the manufacturers who did over-comply, some did so by 20 percent or more, in some fleets, over multiple model years.[64] Others have similarly observed the auto industry's secular march toward higher fuel economy over time, even in the absence of standards.[65]

Second, manufacturers have consistently told NHTSA that they do make fuel economy improvements where the cost can be fully recovered in the first 2-3 years of ownership. The 2015 National Academy of Sciences (NAS) report discussed this assumption explicitly, stating: "There is also empirical evidence supporting loss aversion as a possible cause of the energy paradox. Greene (2011) showed that if consumers accurately perceived the upfront cost of fuel economy improvements and the uncertainty of fuel economy estimates, the future price of fuel, and other factors affecting the present value of fuel savings, the loss-averse consumers among them would appear to act as if they had very high DRs or required payback periods of about 3 years."[66] Furthermore, the 2020 NAS HD report states: "The committee has heard from manufacturers and purchasers that they look for 1.5- to 2-year paybacks or, in other cases, for a payback period that is half the expected ownership period of the first owner of the vehicle."[67] Naturally, there are heterogenous preferences for vehicle attributes in the marketplace, – at the same time that we are observing record sales of electrified vehicles, we are also seeing sustained demand for pickup trucks with higher payloads and towing capacity. This analysis, like all the CAFE analyses preceding it, uses an average value to represent these preferences for the CAFE fleet and the HDPUV fleet. The analysis balances the risks of estimating too low of a payback period, which would preclude most technologies from consideration regardless of potential cost reductions due to learning, against the risk of allowing too high of a payback period, which would allow an unrealistic cost increase from technology addition in the baseline fleet.

Third, as in previous CAFE analyses, our FP projections assume sustained increases in real FPs over the course of the rule (and beyond). As readers are certainly aware, FPs have changed over time – sometimes quickly, sometimes slowly, generally upward:

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[62] There are vehicle price and consumer income limitations on the CVC as well. Congressional Research Service. 2022. Tax Provisions in the Inflation Reduction Act of 2022 (H.R. 5376). Available at: https://crsreports.congress.gov/product/pdf/R/R47202/6. (Accessed: May 31, 2023).

[63] Even though NHTSA uses the 30-month payback assumption to assess how much technology manufacturers would add voluntarily in the absence of new standards, the benefit-cost analysis accounts for the full lifetime fuel savings that would accrue to vehicles affected by the proposed standards.

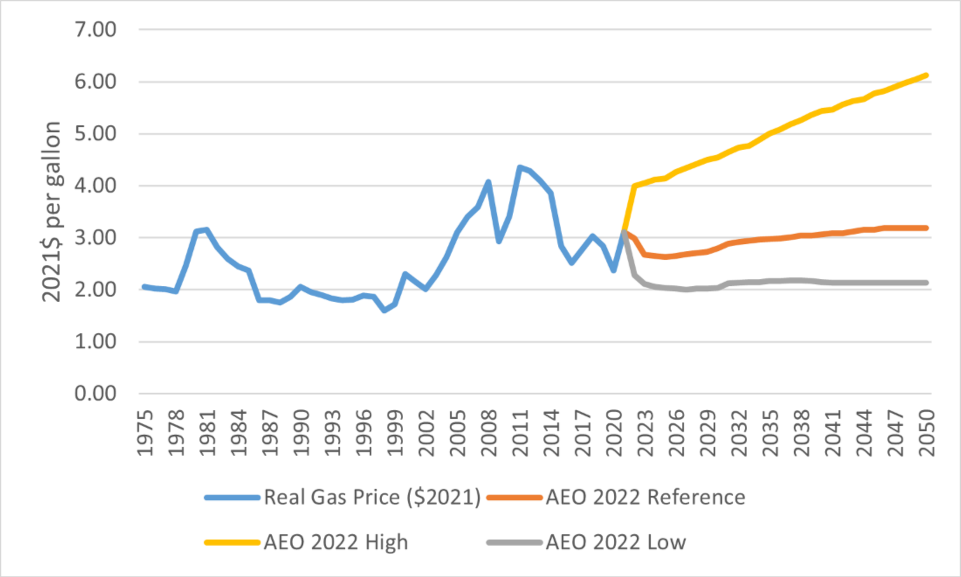
[64] See 2022 TSD, at 68.

[65] Meyer, R. 2020. Trump's New Auto Rollback Is an Economic Disaster. Last revised: Apr. 13, 2020. Available at: https://www.theatlantic.com/science/archive/2020/04/trumps-auto-rollback-will-eliminate-13500-jobs-cafe/609748. (Accessed: May 31, 2023).

[66] National Research Council. 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, DC: The National Academies Press. Page 31. Available at: https://nap.nationalacademies.org/21744/. (Accessed: May 31, 2023). (hereinafter "2015 NAS report").

[67] National Academies of Sciences, Engineering, and Medicine. 2020. Reducing Fuel Consumption and Greenhouse Gas Emissions of Medium- and Heavy-Duty Vehicles, Phase Two: Final Report. Washington, DC: The National Academies Press. p. 296. Available at: https://nap.nationalacademies.org/25542/. (Accessed: May 31, 2023).

Figure 3-4: Real Fuel Prices Over Time



In the 1990s, when FPs were historically low (as shown above), manufacturers did not tend to improve their fuel economy, in part because there simply was very little consumer demand for improved fuel economy and CAFE standards remained flat. In subsequent decades, when FPs were higher, many manufacturers have exceeded their standards in multiple fleets, and for multiple years. Our current FP projections look more like the last two decades, where prices have been more volatile, but also closer to $3/gallon on average. In recent years, when FPs have generally declined on average and CAFE standards have continued to increase, fewer manufacturers have exceeded their standards. However, our compliance data shows that at least some manufacturers do improve their fuel economy if FPs are high enough, even if they are not able to respond perfectly to fluctuations precisely when they happen. This highlights the importance of FP assumptions both in the analysis and in the real world on the future of fuel economy improvements.

3.2. Action Alternatives for Passenger Cars, Light Trucks, and HDPUVs

In addition to the No-Action Alternative, NHTSA has considered four "action" alternatives for PCs and LT and three action alternatives for HDPUVs, each of which is more stringent than the No-Action Alternative during the rulemaking time frame. These action alternatives are specified below and demonstrate different possible approaches to balancing the statutory factors applicable for PCs, LT, and HDPUVs. Section V of the preamble discusses in more detail how the different alternatives reflect different possible balancing approaches.

3.2.1. Alternative PC1LT3

Alternative PC1LT3 would increase CAFE stringency by 1 percent per year, year over year, for MYs 2027-2032 PCs, and by 3 percent per year, year over year, for MYs 2027-2032 LT.

Table 3-12: Passenger Car CAFE Target Function Coefficients for Alternative PC1LT3[68]

	2027	2028	2029	2030	2031	2032
a (mpg)	67.63	68.31	69.00	69.70	70.40	71.11
b (mpg)	50.60	51.11	51.63	52.15	52.68	53.21
c (gpm per s.f.)	0.00033	0.00033	0.00033	0.00032	0.00032	0.00032
d (gpm)	0.00118	0.00117	0.00116	0.00115	0.00114	0.00113

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[68] The Passenger Car Function Coeffiecnts 'a','b','c', and 'd' are defined in Draft TSD Chapter 1.2.1.

Table 3-13: Light Truck CAFE Target Function Coefficients for Alternative PC1LT3[69]

	2027	2028	2029	2030	2031	2032
a (mpg)	55.39	57.10	58.87	60.69	62.56	64.50
b (mpg)	33.30	34.33	35.39	36.48	37.61	38.78
c (gpm per s.f.)	0.00036	0.00035	0.00034	0.00033	0.00032	0.00031
d (gpm)	0.00317	0.00308	0.00299	0.00290	0.00281	0.00273

These coefficients create equations that are represented graphically in Chapter 1.4 of the Draft TSD.

Under this alternative, the MDPCS would be as follows:

Table 3-14: Alternative PC1LT3 – Minimum Domestic Passenger Car Standard (MPG)

2027	2028	2029	2030	2031	2032
54.6	55.2	55.7	56.3	56.9	57.4

3.2.2. Alternative PC2LT4 – Preferred Alternative

Alternative PC2LT4 would increase CAFE stringency by 2 percent per year, year over year, for MYs 2027-2032 PCs, and by 4 percent per year, year over year, for MYs 2027-2032 LT.

Table 3-15: Passenger Car CAFE Target Function Coefficients for Alternative PC2LT4[70]

	2027	2028	2029	2030	2031	2032
a (mpg)	68.32	69.71	71.14	72.59	74.07	75.58
b (mpg)	51.12	52.16	53.22	54.31	55.42	56.55
c (gpm per s.f.)	0.00033	0.00032	0.00032	0.00031	0.00030	0.00030
d (gpm)	0.00117	0.00115	0.00113	0.00110	0.00108	0.00106

Table 3-16: Light Truck CAFE Target Function Coefficients for Alternative PC2LT4[71]

	2027	2028	2029	2030	2031	2032
a (mpg)	55.96	58.30	60.73	63.26	65.89	68.64
b (mpg)	33.64	35.05	36.51	38.03	39.61	41.26
c (gpm per s.f.)	0.00036	0.00034	0.00033	0.00032	0.00031	0.00029
d (gpm)	0.00314	0.00302	0.00289	0.00287	0.00267	0.00256

These coefficients create equations that are represented graphically in Chapter 1.4 of the Draft TSD. Under this alternative, the MDPCS would be as follows:

Table 3-17: Alternative PC2LT4 – Minimum Domestic Passenger Car Standard (MPG)

2027	2028	2029	2030	2031	2032
55.2	56.3	57.5	58.6	59.8	61.1

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[69] The Light Truck Function Coeffiecnts ‘a’,’b’,’c’, and ‘d’ are defined in Draft TSD Chapter 1.2.1.

[70] The Passenger Car Function Coeffiecnts ‘a’,’b’,’c’, and ‘d’ are defined in Draft TSD Chapter 1.2.1.

[71] The Light Truck Function Coeffiecnts ‘a’,’b’,’c’, and ‘d’ are defined in Draft TSD Chapter 1.2.1.

3.2.3. Alternative PC3LT5

Alternative PC3LT5 would increase CAFE stringency by 3 percent per year, year over year, for MYs 2027-2032 PCs, and by 5 percent per year, year over year, for MYs 2027-2032 LT.

Table 3-18: Passenger Car CAFE Target Function Coefficients for Alternative PC3LT5[72]

	2027	2028	2029	2030	2031	2032
a (mpg)	69.02	71.16	73.36	75.63	77.97	80.38
b (mpg)	51.64	53.24	54.89	56.58	58.33	60.14
c (gpm per s.f.)	0.00033	0.00032	0.00031	0.00030	0.00029	0.00028
d (gpm)	0.00116	0.00113	0.00109	0.00106	0.00103	0.00100

Table 3-19: Light Truck CAFE Target Function Coefficients for Alternative PC3LT5[73]

	2027	2028	2029	2030	2031	2032
a (mpg)	56.55	59.53	62.66	65.96	69.43	73.09
b (mpg)	34.00	35.79	37.67	39.65	41.74	43.94
c (gpm per s.f.)	0.00036	0.00034	0.00032	0.00030	0.00029	0.00028
d (gpm)	0.00311	0.00295	0.00280	0.00266	0.00253	0.00240

These coefficients create equations that are represented graphically in Chapter 1.4 of the Draft TSD.

Under this alternative, the MDPCS would be as follows:

Table 3-20: Alternative PC3LT5 – Minimum Domestic Passenger Car Standard (MPG)

2027	2028	2029	2030	2031	2032
55.8	57.5	59.3	61.1	63.0	64.9

3.2.4. Alternative PC6LT8

Alternative PC6LT8 would increase CAFE stringency by 6 percent per year, year over year, for MYs 2027-2032 PCs, and by 8 percent per year, year over year, for MYs 2027-2032 LT.

Table 3-21: Passenger Car CAFE Target Function Coefficients for Alternative PC6LT8[74]

	2027	2028	2029	2030	2031	2032
a (mpg)	71.23	75.77	80.61	85.75	91.23	97.05
b (mpg)	53.29	56.69	60.31	64.16	68.26	72.61
c (gpm per s.f.)	0.00032	0.00030	0.00028	0.00026	0.00025	0.00023
d (gpm)	0.00112	0.00106	0.00099	0.00093	0.00088	0.00083

Table 3-22: Light Truck CAFE Target Function Coefficients for Alternative PC6LT8[75]

	2027	2028	2029	2030	2031	2032
a (mpg)	58.40	63.48	69.00	74.99	81.52	88.60
b (mpg)	35.11	38.16	41.48	45.09	49.01	53.27

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[72] The Passenger Car Function Coefficients ‘a’,’b’,’c’, and ‘d’ are defined in Draft TSD Chapter 1.2.1.
[73] The Light Truck Function Coefficients ‘a’,’b’,’c’, and ‘d’ are defined in Draft TSD Chapter 1.2.1.
[74] The Passenger Car Function Coefficients ‘a’,’b’,’c’, and ‘d’ are defined in Draft TSD Chapter 1.2.1.
[75] The Light Truck Function Coefficients ‘a’,’b’,’c’, and ‘d’ are defined in Draft TSD Chapter 1.2.1.

c (gpm per s.f.)	0.00034	0.00032	0.00029	0.00027	0.00025	0.00023
d (gpm)	0.00301	0.00277	0.00255	0.00234	0.00216	0.00198

These coefficients create equations that are represented graphically in Chapter 1.4 of the Draft TSD.

Under this alternative, the MDPCS would be as follows:

Table 3-23: Alternative PC6LT8 – Minimum Domestic Passenger Car Standard (MPG)

2027	2028	2029	2030	2031	2032
57.5	61.2	65.1	69.3	73.7	78.4

3.2.5. Alternative HDPUV4

Alternative HDPUV4 would increase HDPUV standard stringency by 4 percent per year for MYs 2030-2035 HDPUVs. The four-wheel drive coefficient is maintained at 500 (coefficient ‘a’) and the weighting multiplier coefficient is maintained at 0.75 (coefficient ‘b’).

Table 3-24: Characteristics of Alternative HDPUV4 – CI Vehicle Coefficients[76]

	2030	2031	2032	2033	2034	2035
e	0.0003281	0.0003150	0.0003024	0.0002903	0.0002787	0.0002675
f	2.528	2.427	2.330	2.236	2.147	2.061

Table 3-25: Characteristics of Alternative HDPUV4 – SI Vehicle Coefficients[77]

	2030	2031	2032	2033	2034	2035
c	0.0003986	0.0003826	0.0003673	0.0003526	0.0003385	0.0003250
d	3.068	2.945	2.828	2.715	2.606	2.502

These coefficients create equations that are represented graphically in Chapter 1.4 of the Draft TSD.

3.2.6. Alternative HDPUV10 – Preferred Alternative

Alternative HDPUV10 would increase HDPUV standard stringency by 10 percent per year for MYs 2030-2035 HDPUVs. The four-wheel drive coefficient is maintained at 500 (coefficient ‘a’) and the weighting multiplier coefficient is maintained at 0.75 (coefficient ‘b’).

Table 3-26: Characteristics of Alternative HDPUV10 – CI Vehicle Coefficients[78]

	2030	2031	2032	2033	2034	2035
e	0.0003076	0.0002769	0.0002492	0.0002243	0.0002018	0.0001816
f	2.370	2.133	1.919	1.728	1.555	1.399

Table 3-27: Characteristics of Alternative HDPUV10 – SI Vehicle Coefficients[79]

	2030	2031	2032	2033	2034	2035

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[76] In the CAFE Model, these are Linear work-factor-based function where coefficients e and f are for diesels, BEVs and FCEVs. See Draft TSD Chapter 1.2.1.

[77] In the CAFE Model, these are Linear work-factor-based function where coefficients c and d are for gasoline, CNG, strong hybrid vehicles and PHEVs. See Draft TSD Chapter 1.2.1.

[78] In the CAFE Model, these are Linear work-factor-based function where coefficients e and f are for diesels, BEVs and FCEVs. See Draft TSD Chapter 1.2.1.

[79] In the CAFE Model, these are Linear work-factor-based function where coefficients c and d are for gasoline, CNG, strong hybrid vehicles and PHEVs. See Draft TSD Chapter 1.2.1.

c	0.0003737	0.0003363	0.0003027	0.0002724	0.0002452	0.0002207
d	2.876	2.589	2.330	2.097	1.887	1.698

These coefficients create equations that are represented graphically in Chapter 1.4 of the Draft TSD.

3.2.7. Alternative HDPUV14

Alternative HDPUV14 would increase HDPUV standard stringency by 14 percent per year for MYs 2030-2035 HDPUVs. The four-wheel drive coefficient is maintained at 500 (coefficient ‘a’) and the weighting multiplier coefficient is maintained at 0.75 (coefficient ‘b’).

Table 3-28: Characteristics of Alternative HDPUV14 – CI Vehicle Coefficients[80]

	2030	2031	2032	2033	2034	2035
e	0.0002939	0.0002528	0.0002174	0.0001870	0.0001608	0.0001383
f	2.264	1.947	1.675	1.440	1.239	1.065

Table 3-29: Characteristics of Alternative HDPUV14 – SI Vehicle Coefficients[81]

	2030	2031	2032	2033	2034	2035
c	0.0003571	0.0003071	0.0002641	0.0002271	0.0001953	0.0001680
d	2.749	2.364	2.033	1.748	1.503	1.293

These coefficients create equations that are represented graphically in Chapter 1.4 of the Draft TSD.

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[80] In the CAFE Model, these are Linear work-factor-based function where coefficients e and f are for diesels, BEVs and FCEVs. See Draft TSD Chapter 1.2.1.

[81] In the CAFE Model, these are Linear work-factor-based function where coefficients c and d are for gasoline, CNG, strong hybrid vehicles and PHEVs. See Draft TSD Chapter 1.2.1.

4. Approach to Modeling CAFE Standards

This chapter describes NHTSA's approach to analyzing the wide range of effects of fuel economy and fuel efficiency standards. To allow the agency to do this analysis NHTSA developed the CAFE model. The CAFE model is the result of numerous prior rulemaking efforts and NHTSA continues to refine the CAFE Model's methodology to allow NHTSA to consider an increasingly wide range of impacts.

CAFE Model Files Referenced in this Chapter

Below is a list of CAFE Model Files referenced in this chapter. See TSD Chapter 2.1.9 Where can I find the internal NHTSA files? for a full list of files referenced in this document and their respective file locations.

- Market Data Input File

Today's analysis involves, among other things, estimating how the application of various combinations of technologies could impact vehicles' costs, fuel economy and efficiency levels, and CO_2 emission rates; estimating how vehicle manufacturers might respond to standards by adding fuel-saving technologies to new vehicles; estimating how changes in new vehicles might affect vehicle sales and operation; and estimating how the combination of these changes might influence national-scale energy consumption, emissions, highway safety, and public health. In addition, the Draft Environmental Impact Statement (Draft EIS) accompanying today's notice addresses the proposal's effect on air quality and climate, and the role that those changes have on the environment and human health. The analysis of these components informs and supports NHTSA's application of the statutory factors involved in determining "maximum feasible" fuel-economy under EPCA, including, among others, economic practicability, and the need of the United States to conserve energy, and for fuel efficiency whether a given fuel efficiency standard would be appropriate, cost-effective, and technologically feasible. The CAFE Model plays a central role in NHTSA's analysis supporting today's proposal.

In general, changes to the standards create streams of benefits and costs that accrue to vehicle producers when they build and sell vehicles, owners when they purchase and use vehicles, and the rest of society as they interact with a population of vehicles that has been influenced in some way by the standards. This chapter provides an overview of these pillars of the CAFE Model's structure. The purpose of this overview is not to provide a comprehensive technical description of the model, but rather to give an overview of the model's functions, and to describe how it simulates the effects of changes to fuel efficiency standards. The model documentation accompanying today's proposal provides a comprehensive and detailed description of the model's functions, design, inputs, and outputs.[82]

The basic design of the CAFE Model is as follows: the system first estimates how vehicle manufacturers might respond to a given regulatory scenario, using inputs that define, among other things, the range of their specific products; the projected efficacy and cost of technologies projected to be commercially available; projected FPs and consumer willingness to pay for fuel economy or efficiency improvements; and the standards defining the regulatory scenario. The system then quantifies the effect this response will have on vehicle sales and retirements, fuel consumption, emissions, and economic externalities. A regulatory scenario involves specification of the form, or shape, of the standards (e.g., flat standards, or linear or logistic attribute-based standards), scope of regulatory classes,[83] and stringency of the CAFE, fuel efficiency, and CO_2 standards for each model year to be analyzed.

Manufacturer compliance simulation begins with a detailed, user-provided initial representation of the vehicle models offered for sale in a recent model year (MY 2022 for the LD fleet and the most recent representation available for the HDPUV fleet).[84] The compliance simulation then attempts to bring each manufacturer into compliance with the standards defined by the regulatory scenario. For example, a regulatory scenario may

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[82] The CAFE Model is available at https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-compliance-and-effects-modeling-system, with documentation and all inputs and outputs supporting today's proposal.

[83] While the set of regulatory classes is typically consistent across the set of CAFE alternatives, it may occasionally be necessary, as it is in the No-Action Alternative in this proposal, to capture the regulatory classification of the GHG program which uses a similar, but not identical, scheme of classification.

[84] For more detail on the compliance data used to construct the light-duty and HDPUV fleets, see Draft TSD Chapter 2.2.1.1.

define CAFE and fuel efficiency standards that increase in stringency by a given percent per year for a given number of consecutive years.

The model applies various technologies to different vehicle models in each manufacturer's product line to simulate how each manufacturer might make progress toward compliance with the specified standard. Subject to a variety of user-controlled constraints, the model applies technologies based on their relative cost-effectiveness, as determined by several input assumptions regarding the cost and effectiveness of each technology, the cost of compliance (determined by the change in CAFE or CO_2 credits, CAFE-related civil penalties, or value of CO_2 credits, depending on the compliance program being evaluated), and the consumer's willingness to pay for avoided fuel expenses. For a given manufacturer, the compliance simulation algorithm applies technologies either until the manufacturer runs out of cost-effective technologies,[85] until the manufacturer exhausts all available technologies, or, if the manufacturer is assumed to be willing to pay civil penalties, until paying civil penalties becomes more cost-effective than increasing vehicle fuel economy. At this stage, the system assigns an incurred technology cost and updated fuel economy to each vehicle model, as well as any civil penalties incurred. This compliance simulation process is repeated for each model year included in the study period (through MY 2050 in this analysis).[86]

This point marks the system's transition between compliance simulation and effects calculations. At the conclusion of the compliance simulation for a given regulatory scenario, the system produces a full representation of the registered LD or HDPUV vehicle population in the United States. The CAFE Model then uses this fleet to generate estimates of the following (for each model year and CY included in the analysis): lifetime travel, fuel consumption, CO_2 and criteria pollutant emissions, the magnitude of various economic externalities related to vehicular travel (e.g., congestion and noise), and energy consumption (e.g., the economic costs of short-term increases in petroleum prices, or social damages associated with GHG emissions). The system then uses these estimates to measure the benefits and costs associated with each regulatory alternative (relative to the No-Action Alternative).

4.1. Representing Manufacturers' Potential Responses to Standards

To simulate how manufacturers may respond to the proposed standards, the CAFE Model requires information outlining the engineering characteristics and technology content attributable to each vehicle, platform, engine, and transmission produced by that manufacturer. This information provides the model with an overall view of the initial state of the fleet, for each manufacturer regulated by the standards. The MY 2022 analysis fleet is contained in the Market Data Input File and includes information about each regulated manufacturer's:

- Vehicle models offered for sale – their current (again, for this notice, MY 2022) production volumes and MSRPs; fuel economy (as measured on the compliance test procedure); fuel saving technology content (relative to the set of technologies summarized in Table 2-4 and Table 2-5 of the Draft TSD Chapter 2.2.1.3); footprint (necessary to compute the vehicle's fuel economy target under each regulatory alternative for the LD fleet); curb weight, GVWR, and Gross Combined Weight Rating (GCWR) (for computing the vehicle's work-factor and target for the HDPUV fleet); as well as other attributes (drive type, assignment to technology class and regulatory class);
- Production constraints – product cadence of vehicle models (i.e., schedule of model redesigns and less significant "freshenings"); vehicle platform membership; degree of engine and/or transmission sharing (for each model variant) with other vehicles in the fleet; and
- Compliance constraints and flexibilities – including historical preference for full compliance or civil penalty payment/credit application; manufacturers' perception of consumer's willingness to pay for fuel economy (we assume manufacturers add technologies that payback within 30 months); deployment of air

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[85] Generally, the model considers a technology "cost-effective" if it pays for itself in fuel savings within 30 months, a duration that reflects buyers' significant undervaluation of fuel savings relative to a simple actuarial projection of lifetime fuel savings. Depending on the settings applied, the model can continue to apply technologies that are *not* cost-effective rather than choosing other compliance options; if it does so, it will apply those additional technologies in order of cost-effectiveness.

[86] The extension through calendar year 2050 reflects a balance between completeness and uncertainty, as well as the need to capture the interactions of the new and used vehicle markets as the vehicles produced in the regulated model years are used, age, and retire. The Energy Information Administration's 2022 Annual Energy Outlook also uses a modeling horizon that extend through 2050.

conditioning (AC) improvements and off-cycle (OC) technologies for compliance purposes; and current CAFE (and/or GHG) credit balance (by model year and regulatory class) at the start of the simulation.

All of that information together provides the foundation on which the CAFE Model builds an assessment of how each manufacturer could comply with a given regulatory alternative. The regulatory alternatives, while applicable to all manufacturers in the analysis, affect individual manufacturers differently. Whether considering the LD or HDPUV fleet, each manufacturer's actual CAFE or fuel efficiency compliance obligation represents the production-weighted harmonic mean of their vehicles' targets in each regulated fleet. In the case of the LD fleet, the fuel economy target is a function of the vehicles' footprints, whereas for the HDPUV vehicles, the target is defined as a function of the vehicles' WFs. This means that no individual vehicle has a "standard," merely a target, and each manufacturer is free to identify a compliance strategy that makes the most sense given its unique combination of vehicle models, consumers, and competitive position in the various market segments. As the CAFE Model provides flexibility when defining a set of CAFE or fuel efficiency standards, each manufacturer's requirement is dynamically defined based on the specification of the standards for any simulation and the distribution of footprints or WFs within each fleet. The specific details of the MY 2022 analysis fleet are discussed in the Draft TSD Chapter 2.2 and Preamble Section II.C.

4.2. Representing Consumer Responses to Standards

As manufacturers apply technology to their vehicle offerings to comply with more stringent standards, the cost to supply vehicles will increase. We assume that all costs related to compliance (the cost of technology or civil penalties) are passed through to buyers of new vehicles. The CAFE Model explicitly simulates these price effects on the new vehicle market. The model uses a price elasticity to adjust aggregate new vehicle sales, relative to the No-Action Alternative. The price elasticity acts on an adjusted average price increase—the average price increase net of some portion of realized fuel savings (the first 30 months in this analysis) and any incentives passed through to consumers. While the value of the elasticity is a user-defined input, this analysis assumes an elasticity equal to -0.4. The assumption is discussed in greater detail in the context of estimating the response of sales to higher prices and increased fuel economy, in Draft TSD Chapter 4.2.1 and Preamble Section III.E.1. NHTSA also explored the sensitivity of its results to this assumption in PRIA Chapter 9.2.3.6.

This portion of the sales response only creates deviations from the No-Action Alternative vehicle sales forecast. The baseline sales forecast is a function of macroeconomic inputs and trends in historical sales. The PC/LT composition of new vehicle sales in the light duty fleet is determined by the CAFE Model's fleet share module. Fleet share forecasts are determined by two possible mechanisms, selectable by the user. The first incorporates exogenous projections of vehicle fleet share. The second reacts to changes to attributes of vehicles (fuel economy, curb weight, and horsepower, the last of which does not change in the analysis) and FPs. These fleet share projections can be propagated across regulatory alternatives or can be adjusted based on estimated costs and fuel savings of cars relative to LT.

The sales and fleet share modules work together to modify the total number of new vehicles, the share of PCs and LT, and, as a consequence, the number of each given model sold by a given manufacturer. Changes to aggregated sales (either total sales or PC/LT body styles) are distributed to individual manufacturers and vehicle models based on their observed shares in the MY 2022 fleet. For more detail on the CAFE Model's approach to sales and fleet share, please see Draft TSD Chapter 4.2.1.

In addition to capturing the influence of changes to average new vehicle prices on total new vehicle sales, the model also accounts for expected changes to the used vehicle population as a consequence of those price increases (and fuel savings). In particular, the CAFE Model dynamically estimates the probability that used vehicles of a given age and body style remain in service each year. It uses this function to dynamically retire portions of older vehicle cohorts in a manner that is responsive to both macroeconomic conditions and simulated price changes in the new vehicle market that influence used vehicle transaction prices and residual value. As new vehicles enter the registered population, their retirement rates are governed by this equation, but so are the vehicles already registered. To the extent that a given set of standards accelerates or decelerates the retirement (or scrappage) of those vehicles, additional fuel consumption and SCs may accrue to those vehicles under that standard. The CAFE Model accounts for those costs and benefits, as well as tracking all the standard benefits and costs associated with the lifetimes of new vehicles produced under the rule. For more detail about the CAFE Model's approach to vehicle scrappage, see Draft TSD Chapter 4.2.2.

Another critical element of the consumer response to changes in standards is the effect on demand for travel. As new vehicles become more efficient, the cost-per-mile of driving them decreases, which is assumed to spur additional demand for travel. This assumed behavior is often called the "rebound effect." The CAFE Model implements a travel demand function that governs total LD travel demand, absent rebound-induced demand, given a set of economic conditions related to travel. The function itself is the LD VMT forecasting model that the Federal Highway Administration (FHWA) uses to generate forecasts, though the inputs to that model are consistent with the assumed macroeconomic conditions of this analysis rather than any specific inputs used to generate official FHWA forecasts. The rebound effect is incorporated into the VMT analysis via a rebound elasticity (i.e., the percentage change in VMT demanded for a given percentage change in fuel economy).

When modeling regulatory alternatives for the light duty fleet, the CAFE Model uses this function to define a constraint on "non-rebound" VMT that is held constant across regulatory alternatives, and implicitly includes any changes to both FPs over time and the average efficiency of the on-road fleet (as newer more efficient vehicles replace older ones over time). It is our perspective that the total demand for VMT should not vary excessively across alternatives; the basic travel needs for an average household are unlikely to be influenced heavily by the stringency of the CAFE standards (i.e., by the impact of CAFE standards on new vehicle prices and fuel economy levels), as the daily need for a vehicle will remain the same. That said, it is reasonable to assume that fleets with differing age distributions and inherent cost of operation will have slightly different annual VMT (even without considering VMT associated with rebound miles); however, the difference could conceivably be small. Based on the structure of the CAFE Model, the combined effect of the sales and scrappage responses can create small percentage differences in total VMT across the range of regulatory alternatives if steps are not taken to constrain VMT.

This methodology constrains the model so that the only estimated differences in VMT among the alternatives is a direct consequence of the degree of fuel economy improvement relative to MY 2022 and the magnitude of the rebound effect assumption. However, this also implies that, as fleet composition varies by alternative (the most aggressive alternatives may also produce on-road fleets with higher average ages), some of the total VMT demanded is redistributed from the new vehicle fleet to the newer vehicles in the used fleet. And this redistribution creates additional costs and benefits that are associated with the regulatory alternative.

Analogous VMT projections for the HDPUV fleet are not currently available and VMT for this analysis is therefore not constrained in the same manner as LD VMT is constrained. Estimates of aggregate vehicle use in the HDPUV fleet are instead the product of a bottom-up accounting of vehicle use based on estimated mileage accumulation schedules. For more detail about the treatment of VMT for both vehicle fleets in the CAFE Model, see Draft TSD Chapter 4.3.

4.3. Representing the Physical and Environmental Effects of Standards

The CAFE Model carries a complete representation of the registered vehicle population in each CY, starting with an aggregated version of the most recent available data about the registered population for the first year of the simulation. This national registered fleet is used to calculate both annual and lifetime: fuel consumption (by fuel type), VMT, pollutant emissions, and health impacts under each regulatory alternative. For the current analysis, MY 2022 is the first model year of the included vehicle fleet; the registered vehicle population enters the model as it appeared at the end of CY 2021.

For the LD fleet, the initial vehicle population is stratified by age (or model year cohort) and body style (cars, vans and sport utility vehicles ((SUVs)), and pickup trucks), while for the HDPUV fleet, the entirety of the population is grouped by model year cohort only (there is less variation in body style in the HDPUV fleet as most vehicles share similar chassis designs). Once the simulation begins, new vehicles are added to the population from the new vehicle market and age throughout their lives during the simulation, with some fraction of them being retired (or scrapped) in each year along the way. For example, in CY 2023, the new vehicles (age 0) are MY 2023 vehicles (added by the CAFE Model simulation and represented at the same level of detail used to simulate compliance). The age 1 vehicles are MY 2022 vehicles (added by the CAFE

Model simulation), and the age 2 vehicles are MY 2021 vehicles (inherited from the registered vehicle population and carried through the analysis with less granularity).

The product of on-road fuel economy (or fuel efficiency) and VMT determines fuel consumption, by fuel type, of each vehicle and cohort in the analysis (vehicles produced after MY 2021 are simulated at the model level and all older vehicles as body-style/age cohorts). All the physical and environmental impacts in the analysis are the consequence of either fuel consumption or VMT. The CAFE Model accumulates these totals on an annual (CY) basis but can also compute the lifetime totals of any physical quantity by model year cohort. Importantly, the CY totals for quantities like fuel consumed or miles traveled include both the new vehicle fleet (produced after MY 2021) and the legacy fleet (produced before MY 2022). While some concessions were necessary to represent these MY in the CAFE Model (for example, the CAFE Model only accounts for vehicles until age 40, while the actual on-road fleet has a nontrivial number of vehicles older than that), even with these concessions, it is reasonable to compare CY totals of physical quantities to observed values in earlier years and some projections from other sources.

Rather than rely on the compliance values of fuel economy for either legacy vehicles or vehicles that go through the full compliance simulation, the model applies an “on-road gap” to represent the expected difference between fuel economy on the laboratory test cycle and fuel economy under real-world operation. While the model currently allows the user to specify an on-road gap that varies by fuel type (gasoline, E85, diesel, electricity, hydrogen, and compressed natural gas CNG), it does not vary over time, by vehicle age, or by technology combination. As discussed in the accompanying Draft TSD, today’s analysis uses input values that range from 24 to 29 percent, depending on the fuel type as shown in Table 4-1. It is possible that the “gap” between laboratory fuel economy and real-world fuel economy has changed over time, that fuel economy degrades over time as a vehicle ages, or that specific combinations of fuel-saving technologies have a larger (or smaller) discrepancy between laboratory and real-world fuel economy than others.

Table 4-1: "Gap" Between Test and On-Road MPG (by Fuel Type)

Fuel type	On-road Fuel Economy Gap
Gasoline	24%
Ethanol-85	24%
Diesel	24%
Electricity	29%
Hydrogen	29%
Compressed Natural Gas	24%

In addition to the above effects, the model also calculates emissions effects and projected revenue consequences of reduced fuel consumption. Regarding emissions, the CAFE Model uses the entire on-road fleet, calculated VMT (discussed above), and emissions factors (which are an input to the CAFE Model, specified by model year and age) to calculate downstream emissions associated with a given alternative. In addition to the vehicle-based “downstream” emissions of CO_2 and other pollutants, each gallon of gasoline produced for consumption by the on-road fleet has associated “upstream” emissions that occur in the extraction, transportation, refining, and distribution of the fuel. The model accounts for these emissions as well (on a per-gallon basis) and reports them accordingly. Similar calculations occur for the upstream component of electricity consumption (by BEVs), though these calculations do not reach as far up the fuel cycle. Just as it does for additional GHG emissions associated with upstream emissions from fuel production, the model captures criteria pollutants that occur during other parts of the fuel life cycle. While this is typically a function of the number of gallons of gasoline consumed (and miles driven, for vehicle-based criteria pollutant emissions), the CAFE Model also estimates electricity consumption and the associated upstream emissions (resource extraction and generation, based on U.S. grid mix). For more detail about emissions inputs for the analysis, see Draft TSD Chapter 5.

Because the model produces an estimate of the aggregate number of gallons sold in each CY, it is possible to calculate both the total expenditures on motor fuel and the total contribution to the Highway Trust Fund (HTF) that result from that fuel consumption. The Federal fuel excise tax is levied on every gallon of gasoline and diesel sold in the United States, with diesel facing a higher per-gallon tax rate. The model uses a national perspective, where the state taxes in the input files represent an estimated average fuel tax across all U.S. states. While the model produces an estimate of HTF revenue changes, it is not possible to use the CAFE Model to reasonably estimate potential losses to state fuel tax revenue from increasing the fuel economy of new vehicles. Additionally, states and the federal government have occasionally raised motor fuel tax rates to partially compensate for revenue losses due to inflation and increased fuel economy.[87] However, such actions have been sporadic and not predictable, and so we assume continuation of the present fuel tax rates.

4.4. Costs and Benefits to Producers, Consumers, and Society

As the CAFE Model simulates manufacturer compliance with regulatory alternatives, it estimates and tracks several consequences that generate SCs and benefits. The most obvious cost associated with the CAFE and HDPUV FE programs is the cost of additional fuel saving technology that is added to new vehicles as a result of the alternatives considered in this analysis. For each technology that the model adds to a given vehicle, it accumulates cost. As the model carries forward technologies that it has already applied to future model years, it similarly adjusts the costs of those technologies based on their individual learning rates.

The other costs that manufacturers incur as a result of CAFE and FE standards are civil penalties resulting from non-compliance with the standards. When modeling the LD fleet, the CAFE Model applies the real dollar fine rate based on statute, accumulating costs of $16 per 1/10-MPG under the standard starting in MY 2023, multiplied by the number of vehicles produced in that fleet, in that model year.[88] The model reports as the full "regulatory cost" the sum of total technology cost and total fines by the manufacturer, fleet, and model year.

The costs and benefits of each alternative are defined relative to the No-Action Alternative. For example, the CAFE Model reports absolute values for the amount of money spent on fuel in the No-Action Alternative, then reports the amount spent on fuel in the alternatives relative to this baseline. So, if standards in the No-Action Alternative were fixed at current levels, and an alternative requires fuel economy improvements, the total expenditures on fuel in the alternative would be lower, creating a fuel savings "benefit."

The CAFE Model also enforces a constraint on benefit-cost accounting that spans the alternatives. When applying technology to reach compliance, multi-year planning considers as many years as possible to smooth out the costs of the optimal compliance pathway. However, for years close to the present, this has the potential to create different simulations for the same historical year. For example, the LD market data are based on MY 2022 and this proposal is published after MY 2023 planning and production is effectively complete and after manufacturers have made tentative plans to comply with standards established during prior rulemakings (currently, LD standards are defined through MY 2026). If the CAFE Model did not impose the constraint that MYs 2023 to 2026 be identical across alternatives (and, in fact, identical to the No-Action Alternative for that year), the multi-year planning algorithm would reach back to as early as MY 2023 to apply additional technology under more stringent alternatives. In this analysis, we assume that manufacturers are unable to modify product offerings during MY 2022 under <u>any</u> alternative (No-Action or otherwise), or during MYs 2023 to 2026 (which have been fully or partially planned) under the Action Alternatives (beyond the level by which the manufacturers' fleet was improved to comply with the standards posed by No-Action Alternative). The technology outcomes of the compliance simulation in MYs 2022 to 2026 under the No-Action Alternative are, therefore, forced in those years for the other alternatives as well. As a result, the CAFE Model simulates no incremental costs or benefits for those years across alternatives.[89]

Other SCs and benefits emerge as the result of physical phenomena, like emissions or highway fatalities, which are the result of changes in the composition and use of the on-road fleet. The SCs (in dollars) associated with those quantities represent an economic estimate of the social damages associated with the changes in each quantity. The model tracks and reports each of these quantities by model year and vehicle

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[87] Greene, D.L. 2011. What is greener than a VMT tax? The case for an indexed energy user fee to finance US surface transportation. Transportation Research D, 16: 451-458.

[88] The rate at which fines are assessed increases over time with inflation. For model years before model year 2019, the civil penalty is $5.50; for model years 2019 through 2021, the civil penalty is $14; for model year 2022, the civil penalty is $15. In the case of the HDPUV fleet, fines are not levied on a per-fuel-economy-unit basis. Currently, the specified fine rate acts as a proxy for per-vehicle fines. For additional detail, see Preamble Section VI.

[89] In the case of the HDPUV fleet, we apply a similar constraint, but up to and including MY 2029. That is, the technology outcomes from the No Action Alterantive for MYs 2022 to 2029 are forced for all other alternatives during the same years.

age (the combination of which can be used to produce CY totals), regulatory class, fuel type, and social DR. The list of SCs and benefits is presented in Table 4-2, as well as the population of vehicles that determines the size of the factor (i.e., new vehicles, or all registered vehicles) and the mechanism that determines the size of the effect (i.e., vehicle use in terms of miles driven, the amount of fuel consumed, or the number of vehicles produced).

Table 4-2: Social Costs and Benefits in the CAFE Model

Cost/Benefit	Population	Mechanism
Technology cost	New vehicles	Production volume
Consumer surplus	New vehicles	Production volume
Benefit of additional mobility	New vehicles	Vehicle use
Benefit of less frequent refueling	New vehicles	Fuel consumption
Retail fuel savings	All vehicles	Fuel consumption
Fuel tax revenue	All vehicles	Fuel consumption
Energy security cost	All vehicles	Fuel consumption
Congestion and noise costs	All vehicles	Vehicle use
Non-fatal injuries	All vehicles	Vehicle use
Fatalities	All vehicles	Vehicle use
Criteria pollutant damages (NO_X, SO_X, PM)	All vehicles	Vehicle use, Fuel consumption
GHG emissions damages (CO_2, CH_4, N_2O)	All vehicles	CO_2: Fuel consumption CH_4, N_2O: Vehicle use

4.5. Representing the Safety Effects of Standards

In the context of the CAFE Modeling framework, there are three avenues by which adjusting standards affects fleet-wide safety: fleet size and composition, rebound-effect driving, and changes in vehicle mass. The first effect arises from changes in the price of new vehicles as manufacturers attempt to recover their incremental costs for complying more demanding standards, which can alter total sales of new vehicles, the shares of cars and light-duty trucks (LDT) in total light-duty vehicles (LDV) sales, and retirement rates for used vehicles. Increased prices for new vehicles reduce their sales and slow the retirement of used models, and these two effects combine to slow the rate of fleet turnover. In turn, this causes a redistribution of some VMT from newer to older vehicles. In the light duty market, it may also shift sales and VMT between the PC fleet and the LT fleet.

Because the safety of new vehicles has gradually improved over time, redistributing VMT from newer to older vehicles reduces the overall safety of the entire vehicle fleet, increasing fatalities and injuries very slightly. We measure this effect by projecting differential fatality and injury rates for vehicles of different vintages (i.e., model years) and ages during future CYs, and applying these rates to estimates of the redistribution of total VMT by model year and age that results from reduced sales of new models and slower retirement of older vehicles.

Second, by when drivers choose to drive more and increase the VMT of new vehicles via the rebound effect, increasing the stringency of standards exposes their drivers and passengers to increased risks of being involved in crashes. Although vehicles produced during each successive model year are anticipated to be safer than their predecessors, their increased use results in slightly more crashes, and slightly larger numbers of fatalities and injuries. We measure this effect as the product of the increase in driving in each future vintage of vehicles over their lifetimes, and the per-mile risks that occupants will suffer fatal and non-fatal injuries in crashes, which decline gradually over future model years. Because this additional driving is a choice made by individuals who are generally cognizant of the injury and fatality risks it involves, we assume that drivers internalize 90 percent of the increased safety risk and thus must experience an offsetting benefit of this magnitude.

Finally, manufacturers are expected to reduce the mass of some of their vehicle models as a strategy to comply with more stringent standards, since doing so can sometimes offer a low-cost strategy to improve their fuel economy or, for HDPUVs, fuel efficiency. Depending on how the initial weight of those models compares to other vehicles in the fleet and how much manufacturers elect to reduce it, this can modify the risks that occupants of these vehicles – and occupants of vehicles and non-motorists that would be struck by these vehicles – will be killed or injured if these vehicles become involved in crashes. We estimate this effect as the change in the risks that occupants of vehicles whose mass is reduced and occupants of vehicles and non-motorists that would be struck by these vehicles will be injured or killed in crashes, multiplied by the number of miles they are driven each year over their expected lifetimes.

These three effects occur simultaneously and interactively within the simulation. Each vehicle model produced in a future model year has a base fatality rate that changes as it ages and accumulates mileage, but that rate can be modified by changes in its mass. At the same time, it will be driven more if its manufacturer elects to improve its fuel economy/fuel efficiency, and it can then be driven more (or fewer) miles over its lifetime as its retirement probability at each age changes. The rebound and sales/scrappage effects are identified outside of statistical models, and hence do not have estimated confidence bounds (in turn, neither do the aggregated safety effects). The estimated effects associated with changes in mass are identified based on a statistical model, but the component estimates are not statistically significant at the 95-percent confidence level. For a detailed discussion of how the model measures safety outcomes, see Draft TSD Chapter 7.

5. Economic Impact of Fuel Economy Standards

This chapter describes NHTSA's approach for measuring the economic costs and benefits that are likely to result from establishing alternative standards for future model years. It distinguishes the impacts of raising standards on private actors such as vehicle manufacturers and buyers from their broader impacts on the U.S. economy and general public, describes the agency's perspective for measuring benefits and costs, discusses procedures for comparing impacts that occur when new vehicles are produced and sold to those resulting from their subsequent use, and illustrates how the agency summarizes and reports benefits and costs. The agency's empirical estimates of costs and benefits likely to result from the alternative increases in standards it considered are then presented in Chapter 8 of this PRIA.

As OMB Circular A-4 states, benefits and costs reported in regulatory analyses should be defined and measured consistently with economic theory, and should also reflect how alternative regulations are anticipated to change the behavior of producers and consumers from a baseline scenario.[90] The following chapters illustrate how our measures of benefits and costs from adopting higher standards are derived from economic analysis of markets for new and used vehicles, vehicle owners' decisions about how much to drive, and how supplies of petroleum and gasoline are likely to respond to higher fuel economy and efficiency. As this discussion shows, raising standards is likely to change the behavior of a wide range of economic actors including vehicle manufacturers, buyers of new vehicles, owners of used vehicles, and suppliers of petroleum and refined fuel compared to a baseline in which standards remain at their currently prevailing levels.

5.1. Overview of Effects from Increasing Fuel Economy Standards

Figure 5-1 provides an overview of the inputs used in NHTSA's analysis of the standards, traces the influence of fuel economy and efficiency standards on the behavior of producers and consumers of vehicles and fuel, and highlights the resulting economic benefits and costs of higher standards. As it shows, vehicle manufacturers respond to increases in required fuel economy and efficiency by accelerating their use of existing and new technology to improve their individual models' efficiency. Doing so raises manufacturers' costs to produce the models whose fuel economy or efficiency are improved, and they will attempt to recover their additional costs and maintain profitability by raising prices for those—and perhaps other—models.

Increasing vehicles' fuel economy or efficiency may also entail potential tradeoffs with other attributes that buyers also value, such as their seating and cargo-carrying capacity, ride comfort, safety, or performance, but manufacturers are aware that sacrifices in these attributes make vehicles less attractive to buyers and are likely to approach them warily. NHTSA recognizes the reluctance of both vehicle manufacturers and buyers to make such tradeoffs in exchange for higher fuel economy, as well as the conceptual and empirical challenges to measuring the resulting "opportunity costs." The agency's analysis assumes that manufacturers will comply with stricter standards exclusively by using more advanced technology and vehicle designs to increase vehicle efficiency while holding some key vehicle attributes unchanged, such as acceleration, towing, and hauling.[91] Thus, its estimates of the direct costs to improve fuel economy include only those for added technology while maintaining performance neutrality for the attributes that the model holds constant, while excluding any potential opportunity costs for sacrifices in other attributes that NHTSA does not constrain (but also excluding any other countervailing effects on out-of-pocket costs to the consumer associated with such tradeoffs).

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[90] White House Office of Management and Budget. *Circular A-4: Regulatory Analysis*. September 17, 2003. Section E. Available at: https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/. (Accessed: May 31, 2023).

[91] Some technologies that manufacturers employ to improve fuel economy may produce incidental enhancements or sacrifices in other vehicle attributes, but the agency does not attempt to estimate these or any resutling changes in vehicles' value.

Figure 5-1: Overview of NHTSA's Analysis of Changes in Fuel Economy Standards

Inputs	Analysis	Outputs
• Sales, fuel economy/efficiency, and use of future MY under current standards • Technology and costs to improve efficiency • Economic assumptions (e.g., future FPs, income levels) • Number, retirement rates, fuel economy, and use of cars and LT currently in use	• Changes in prices, fuel economy/efficiency, and other attributes of new vehicles • Changes in sales and use of new vehicles • Changes in retirement rates and use of vehicles by model year and age	• Vehicle fuel consumption and fuel costs by model year and age • Safety of vehicle travel • Environmental externalities from refining and using fuel • Energy security costs from consuming and importing petroleum • Fuel tax revenue

Manufacturers design their vehicle models to provide at least the levels of fuel economy or efficiency that prevailing standards require, while also offering them with combinations of other features and selling prices they believe will be most attractive to buyers and thus maximize their profits.[92] Increasing the stringency of standards requires manufacturers to raise some models' fuel economy or efficiency from this baseline, and to attempt to minimize any impact on revenue and profits by raising prices. NHTSA's analysis assumes that manufacturers will raise prices only for models whose fuel economy or efficiency they improved and will do so only as necessary to recover their increased costs for producing those models. Where tax credits or other subsidies are offered to manufacturers or buyers, the agency uses specific assumptions about how those will ultimately affect specific models' production costs and prices in its analysis of costs and benefits from raising standards, and clearly identifies those assumptions.

The agency believes that setting appropriate standards will provide economic benefits to vehicle buyers and users – as well as to the general public – that exceed the costs of the additional technology necessary to achieve higher fuel economy. Of course, manufacturers may change other vehicle attributes as part of their efforts to comply with fuel economy standards, both to facilitate making the required improvements in fuel economy and to enhance the attractiveness of their vehicles to consumers. Manufacturers may design vehicles with "less" of other attributes to facilitate greater fuel economy if doing so would reduce compliance costs and maximize profits. While doing so could make them less attractive to potential buyers, it might also reduce manufacturers' technology costs for meeting new standards and thus lead to smaller increases in vehicle prices relative to the baseline. Conversely, using some fuel economy technologies may enhance vehicles' other attributes, thus making them more attractive.

The combination of improvements in some models' fuel economy/efficiency and accompanying increases in prices is likely to affect their sales, but the size of the market response (and even possibly its direction) depends on how potential buyers' value of the future savings in fuel costs from buying a model with improved fuel economy compares to the increase in its price. For the variety of reasons discussed previously in Chapter 2 of this PRIA, NHTSA assumes that typical buyers value future savings in fuel costs from purchasing models that offer improved fuel economy over only the first 30 months of vehicles' lifetimes. The agency's analysis assumes that manufacturers will add technologies that offer fuel savings sufficient to repay their initial costs within this period under the baseline alternative, but the proposed standards would require manufacturers to employ additional technologies requiring longer than 30 months to repay their costs in the form of fuel savings. Of course, adding these technologies will produce some additional savings in buyers' fuel costs, but manufacturers will attempt to preserve their profitability by raising vehicles' selling prices to recover their higher costs for using additional technology.

Because the resulting price increases will thus exceed buyers' willingness to pay for the incremental fuel savings, the agency projects that total sales of new models will decline when it raises standards, and that the size of this decline will grow as it adopts more stringent standards. The clearest evidence that a decline in

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[92] Manufacturers will presumably increase fuel economy beyond what current standards require when they believe doing so will increase their profits, but raising CAFE standards is intended to require most or all producers to increase fuel economy beyond this market-determined level.

sales represents the most likely response is that if manufacturers could increase sales and profits by improving some models' efficiency and raising prices to recover their added costs, they would presumably do so even in the absence of higher standards, but such behavior is seen only occasionally.

The response of new vehicle sales will also be influenced by how the combination of price changes and higher fuel economy affects potential buyers' choices between new and used models, since acquiring or keeping a used vehicle can often substitute for buying a new one. If vehicle prices increase when NHTSA adopts higher standards and consumers do not recognize the full value of fuel savings, some would-be new vehicle buyers are likely to purchase used models instead while others may simply decide to retain their used vehicles for longer, and these responses will increase demand for used vehicles.

Higher demand will in turn increase the market value of used cars and LT because their supply is limited (although it is not fixed, as will be discussed in detail later), so some vehicles that would otherwise have been retired will instead be maintained in working condition and driven longer. The combination of reduced sales of new vehicles and slower retirement of used ones will in effect transfer some travel from new to older vehicles, so a larger share of total driving will be in used cars and LT after standards are raised than if prevailing standards remained in effect. At the same time, the resulting increases in prices for *both* new and used vehicles will raise their owners' depreciation-related costs for driving, which would be expected to reduce total travel demand and offset some fraction of increased driving due to the fuel economy rebound effect.

As Figure 5-1 also shows, these responses will generate other economic consequences. Improving new vehicles' fuel economy/efficiency reduces their operating costs and enables owners to choose to increase the number of miles they are driven via the fuel economy "rebound effect," offsetting a modest fraction of the fuel savings that raising standards produce. New cars and LT featuring higher fuel economy and HDPUVs with higher fuel efficiency will have extended driving ranges and require less frequent refueling, thus reducing the inconvenience from locating stations and economizing on their drivers' and passengers' time while refueling. Despite their increased use, the total amount of fuel new vehicles consume over their lifetimes will decline and their owners will economize on fuel costs, and while increased fuel used by older vehicles will offset an additional portion of the anticipated savings, total fuel use will nevertheless decline. Finally, although new vehicles have become progressively safer over time and have reduced fatalities and injuries, there continues to be a strong association between vehicles' age and their involvement in crashes, so shifting travel from newer to older vehicles will affect the safety of drivers and their passengers.

Reducing the volume of fuel distributed and consumed will lower domestic emissions of GHGs and criteria air pollutants, thus reducing the costs that potential climate-related impacts and adverse health effects from air pollution impose on the public. Reducing the volume of fuel refined or imported may also reduce some consequences of U.S. petroleum consumption and imports, including large revenue transfers from consumers to suppliers of petroleum products and costs to businesses and households for adjusting to rapid changes in FPs. These costs are distributed broadly across the U.S. economy, so reducing them by curtailing fuel consumption represents an economy-wide benefit of raising standards that extends well beyond the immediate savings in fuel costs and other benefits to buyers of more fuel-efficient new vehicles.

5.2. Measuring Benefits and Costs from Raising CAFE Standards

In theory, the economic benefits and costs resulting from higher standards are measured by the combined changes in consumers' and producers' welfare in all of the markets they ultimately affect, plus any accompanying changes in externalities generated by producing and consuming fuel. The agency's assessment of alternative increases in standards focuses on benefits and costs arising in those markets that are most likely to be affected, either directly or indirectly. These include the markets for new cars, LT, and HDPUVs; used vehicles; transportation fuels (including those refined from petroleum and, increasingly, electricity); and crude petroleum. The agency examines benefits and costs in these markets in the order they arise: raising standards affect the market for new vehicles directly, and its consequences for the fuel economy and efficiency, prices, and sales of new vehicles in turn generate indirect impacts on new vehicles' use, the number of used cars and LT in service and how much they are driven, production and consumption of gasoline and other transportation fuels, and U.S. production, imports, and refining of crude petroleum and petroleum-based fuels.[93]

Insofar as possible, the agency's analysis estimates theoretically correct measures of changes in economic welfare in the affected markets, which consist of changes in consumer and producer surplus plus any changes in the value of externalities arising from fuel production and consumption. Throughout its analysis, however, NHTSA makes various assumptions to simplify measuring these benefits and costs. One of these assumptions is that the supply of transportation fuels is "perfectly elastic," so that changes in demand do not lead to changes in their prices. While acknowledging that this is a simplification of real-world production conditions, the agency believes that this assumption is likely to have little effect on its estimates of benefits and costs from the final action.[94] The agency's analysis generally assumes that the magnitude of externalities varies proportionally with changes in production or consumption activity that generates them; in other words, the value of externalities per unit of activity (such as per mile driven or gallon of fuel consumed) is assumed to be unaffected by changes in production or consumption levels. Again, the agency acknowledges that in some cases this assumption simplifies real-world conditions but believes any effect on its estimates of benefits or costs from changes in the relevant externalities is likely to be modest.

5.2.1. Private versus "External" Benefits and Costs

Throughout this analysis, the agency is careful to distinguish between costs and benefits from raising standards that are experienced by private actors and those likely to fall more broadly on the public or throughout the U.S. economy. The former includes private businesses that produce vehicles, households that purchase and use them, and suppliers of transportation fuels and crude petroleum. NHTSA also reports estimated costs and benefits of alternative increases in standards using a format that clearly distinguishes between private benefits and costs they would create for vehicle manufacturers, households, and businesses that purchase vehicles, and those that would be distributed more widely throughout the U.S. population and economy. This distinction highlights the fact that by far the largest share of benefits and costs that result from raising standards would be experienced by private households and businesses – who could realize those same benefits without regulation absent a market failure – while the external benefits and costs from raising standards are likely to be smaller, even if more widely distributed.

5.3. NHTSA's Perspective for Measuring Benefits and Costs

This analysis relies on many economic assumptions and forecasts, and while these generally do not differ between the baseline scenario and the various regulatory alternatives it evaluates, these inputs nevertheless contribute to the estimated benefits and costs of each regulatory alternative when those are measured by comparison to the regulatory baseline. Forecasts of overall U.S. economic activity, personal income, and other macroeconomic variables, which affect the projections of new vehicle sales and retirement rates of used vehicles, are taken from the U.S. Energy Information Administration (EIA)'s Annual Energy Outlook 2022 (AEO 2022).[95] This is also the source used for forecasts of U.S. FPs, global petroleum supply and prices, and U.S. imports of crude petroleum and refined fuel that are used throughout this analysis.[96] Finally, the agency relies on U.S. Department of Transportation guidance for valuing travel time when assessing benefits from less frequent refueling and costs of increased congestion delays.[97]

NHTSA's PRIA measures and reports benefits and costs using two different perspectives on the vehicle fleet. The agency's "model year" perspective focuses on benefits and costs of establishing alternative CAFE standards for individual MYs (in the current analysis, from 2027 through 2032), and measures these over

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[93] Some gasoline consumed in the United States is imported in already-refined form, rather than refined domestically.

[94] More specifically, the agency's analysis implicitly assumes that the *sum* of changes in consumer and producer surplus in each affected market is likely to vary relatively little under alternative assumptions about the extent to which supply is inelastic and prices change because of changes in demand of the magnitude likely to result from imposing higher CAFE standards.

[95] EIA. Annual Energy Outlook 2022. Reference Case Table 20. Available at: https://www.eia.gov/outlooks/aeo/tables_ref.php. (Accessed: May 31, 2023).

[96] EIA. Annual Energy Outlook 2021. Reference Case Tables 11 and 12. Available at: https://www.eia.gov/outlooks/aeo/tables_ref.php. (Accessed: May 31, 2023).

[97] U.S. Department of Transportation. Office of the Assistant Secretary for Transportation Policy. Revised Departmental Guidance on Valuation of Travel Time in Economic Analysis. Available at: https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-valuation-travel-time-economic. (Accessed: May 31, 2023).

each model year's entire lifetime.[98] This perspective usually omits the majority of the effects that establishing standards for a specific model year can have on the number, use, and fuel consumption of vehicles produced during earlier or later model years. NHTSA often reports benefits and costs for groups of consecutive MY to recognize that establishing new standards for one model year can change the number of vehicles from other MY remaining in use and how much they are driven, both of which can affect benefits and costs.

In contrast, the "CY" perspective estimates the impacts of changing fuel economy standards on the entire vehicle fleet during a future CY, and typically aggregates these over a series of CYs (in this analysis, 2022 to 2050). This perspective combines the effects of past and currently proposed changes in standards on the number, use, and fuel consumption of vehicles from each model year in use during any future CY. Using this perspective, NHTSA assumes that standards are maintained at the levels established for model year 2032 level in MY 2033 and beyond (the same assumption is made for the model year approach, but the impact is less pronounced on the cost-benefit analysis). The impacts of maintaining standards at that level for MY beyond those for which this proposed rule would establish standards (2027-32) are attributed to this proposed rule, despite the fact that NHTSA is not setting standards for those more distant MY as part of this proposed rule.

Both MY and CY accounting have strengths and limitations. The strength of MY accounting is it allows NHTSA to focus on the costs and benefits (and generally the effects) accruing only from those vehicles for which it is currently setting CAFE standards, as well as best conforming to the OMB A-4 guidance that the time horizon "should be far enough in the future to encompass all the significant benefits and costs likely to result from the rule."[99] However, NHTSA's assumption that CAFE standards for MY 2033 and beyond would be maintained at the levels required for model year 2032 can create some inconsistency in assigning the impacts of raising standards to specific model years, because the agency's analysis of higher standards incorporates their effects on the composition and use of the entire LDV fleet (as described in Draft TSD Chapter 4.2). For example, higher prices for new vehicles produced and sold during MY 2035 due to higher fuel economy standards would reduce their sales and increase the use of vehicles produced during earlier model years, including those for which the current rule would establish higher CAFE standards (MYs 2027 through 2032), thus increasing the safety risks drivers of those earlier models face. Although the agency's model year accounting would capture this indirect safety consequence of increasing MY 2035 fuel economy standards, it would not capture other benefits or other costs of the assumed increase in MY 2035 standards (such as technology costs, fuel savings, and environmental benefits).

The strength of the CY approach avoids the potentially inconsistent accounting of benefits and costs described above, but it has other limitations. For one, CY accounting inevitably misses a significant portion of the lifetime fuel savings and environmental benefits of higher fuel economy standards for vehicles produced later in the analysis period—only the first year of fuel savings will be observed for MY 2049 vehicles. Secondly, the CY approach inevitably captures significantly more MYs beyond our standard setting years, and because of this, those MYs for which we are not setting standards tend to dominate the estimated impacts of the standards. This increases the significance of our assumption that the 2032 standard will be maintained throughout the analysis and that we can claim the benefits and costs of the assumed standards for this proposed rule. Finally, since the CY approach tends to be dominated by impacts to more distant future model years, the CY accounting is also more sensitive to uncertainties in key input values such as FPs and other more difficult modeling uncertainties such as technology cost learning.

Unlike CAFE standards for light duty vehicles, NHTSA's fuel efficiency standards for HDPUV would remain in place in perpetuity for MY produced after the last year for which we are increasing standards in this proposal. In other words, the standards we propose today for MY 2035 will remain in place in perpetuity or until they are amended again. Because the HDPUV analysis does not require NHTSA to make assumptions about what future standards will be, NHTSA believes that the CY analysis is more appropriate for accounting the benefits and costs of HDPUV fuel efficiency standards and will only present that approach.

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[98] The lifetime of each model year is assumed to begin in the calendar year when it is initially produced and sold (assumed to be contemporaneous with its model year designation) and to extend for 40 years. By the time a model year cohort reaches the 40-year mark, fewer than 2% of the vehicles originally produced and sold typically remain in use.

[99] Office of Management and Budget, Circular No. A-4. 2003. Available at: https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/. (Accessed: May 31, 2023).

When assessing potential buyers' likely response to requiring manufacturers to meet higher fuel economy targets, we assume that buyers of new vehicles value fuel costs over the first 30 months they own and use their newly purchased vehicles. If buyers discount future fuel costs at a rate of 3%, this is equivalent to assuming that they consider approximately one-third of a vehicle's total fuel costs over its expected lifetime, and that same fraction of future savings in fuel costs from choosing a model that offers higher fuel economy. This assumption implies that competitive automobile manufacturers will voluntarily make any improvements in fuel economy that repay their initial costs within that 30-month period, since they would be able to recover those costs from buyers by raising the prices they charge. Thus, manufacturers of new cars, LT, and HDPUVs would make these lower-cost improvements in fuel economy even without increases in the standards, and buyers would purchase the models that offer them. Potential further improvements in fuel economy that would require more than 30 months to repay their initial costs in the form of savings in fuel expenses may remain, although manufacturers are unlikely to make them because they are assumed to believe that buyers are unwilling to pay higher prices to purchase models that feature them.

When estimating social – that is, private plus external – benefits from raising the standards, the agency assumes that buyers and subsequent owners of new cars, LT, and HDPUVs will benefit from the resulting savings in fuel costs over those vehicles' entire lifetimes, rather than just the first 30 months they own and drive them. Requiring manufacturers to improve fuel economy beyond the levels they would voluntarily offer by raising the standards may thus produce fuel savings that ultimately repay their initial costs, although those improvements require longer than 30 months to do so. Thus, as long as some improvements in fuel economy with "payback periods" longer than 30 months (2½ years) but shorter than vehicles' expected lifetimes (which average 15-16 years for cars and LT, and 17-18 years for HDPUVs) remain available, the agency's analysis will inevitably conclude that imposing stricter standards can provide fuel savings and other benefits that exceed the costs of achieving them, thus making society better off as a result. This result relies on two critical assumptions: first, that new vehicle shoppers act "myopically" and are unwilling to consider the value of fuel savings from purchasing a higher-mpg model over its entire lifetime; and second, that used car buyers act similarly and are thus unwilling to pay as much extra to buy a higher-mpg model as doing so would save in fuel costs over its remaining lifetime. Chapter 2 of this PRIA summarizes recent empirical research on these assumptions and concludes that it suggests both new and used vehicle buyers value much larger fractions of lifetime fuel costs than NHTSA assumes, although as the discussion in Chapter 2 acknowledges, other recent evidence points toward lower valuation of fuel savings than the agency assumes.[100]

5.4. Discounting Future Costs and Benefits

OMB Circular A-4 establishes three rationales for discounting future benefits and costs. The first rationale is that resources that are invested in capital will normally earn a positive return in the future. The second is that people generally prefer present consumption to future consumption. The third is that consumption tends to increase over time due to economic growth, so consumption in the future is incrementally less valuable than consumption today due to diminishing marginal returns.[101]

OMB Circular A-4 recommends that Federal agencies discount future benefits and costs of regulatory actions that affect opportunities for investment using a 7 percent rate and the economic effects of regulations that will primarily affect households' future consumption opportunities at a 3 percent rate. Increases in costs to produce new vehicles that meet higher targets will initially be borne by vehicle manufacturers, but we assume that market conditions will enable them to protect their profitability by passing these cost increases on to buyers in the form of higher selling prices for some models. Fuel savings and most other benefits from tightening standards will be experienced directly by owners of vehicles that offer higher fuel economy and thus affect their future consumption opportunities, while benefits or costs that are experienced more widely throughout the economy will also primarily affect future consumption. Circular A-4 indicates that discounting at the consumption rate of interest is the "analytically preferred method" when effects are presented in consumption-equivalent units. Thus, applying OMB's guidance to NHTSA's proposed rule suggests the 3

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[100] In additon, much of the recent evidence infers buyers' valuation of fuel savings from the response of changes in used cars' selling prices to fluctuations in fuel prices. While this provides important information about how buyers are likely to value the savings that models featuring higher fuel economy can offer, it does not directly measure their response to differences in new cars' fuel economy levels.

[101] Office of Management and Budget, Circular No. A-4. 2003. Available at: https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/. (Accessed: May 31, 2023).

percent rate is the appropriate rate. However, NHTSA reports both the 3 and 7 percent rates for transparency and completeness

One important exception is reductions in climate damages resulting from lower GHG emissions. In this PRIA, NHTSA has not selected a primary DR for the SC-GHG, the unit values used to convert reduced GHG emissions to economic benefits. Instead, the agency discounts all other costs and benefits of the final rule at 3 and 7 percent, and reports these together with estimates of benefits from reducing GHG emissions discounted at each of three DRs used by the Interagency Working Group (IWG) to develop its estimates of the SC-GHG. NHTSA chose this approach because as the agency pointed out in its previous CAFE rulemaking, the IWG does not specify which DR should be considered as its primary estimate, and NHTSA agrees that discounting climate-related benefits using all three DRs provides important information to decision-makers.[102] The agency's analysis showing non-climate impacts at 3 and 7 percent together with climate-related benefits discounted at each rate recommended by the IWG can be found in Chapter 8.2.4.6, Table 8-13, and Table 8-14 of this PRIA.

Because there is some uncertainty about whether and how completely manufacturers' increased costs for providing higher fuel economy and efficiency can be recovered from buyers, and any costs that cannot are likely to displace other investment rather than consumption opportunities, however, the 7 percent rate may still be relevant for discounting some future economic consequences of this action. To acknowledge this uncertainty, we also report the anticipated future costs and benefits of this action other than benefits from reducing GHG emissions discounted using a 7 percent rate. Benefits and costs are discounted using both rates to their present values as of 2022 and are expressed in constant dollars reflecting economy-wide price levels prevailing during 2021.

5.5. Reporting Benefits and Costs

NHTSA believes it is important to report the benefits and costs of the alternative increases in standards we evaluate in a format that illustrates *how* the action will generate the economic impacts that ultimately produce benefits and costs; while also highlighting their incidence on households, private businesses, and the remainder of the U.S. population. As an illustration, Table 5-1 presents the categories of economic benefits and costs from raising standards that NHTSA estimates and indicates where within this PRIA each category is discussed in more detail. For both costs and benefits, the table distinguishes between those experienced by private businesses and households (labeled private costs and benefits), and those experienced throughout the U.S. and global population (labeled "Other" costs and benefits).

The agency believes it is important to distinguish these categories because private households and businesses can readily obtain most or all of the benefits from higher fuel economy levels in an unregulated private market equilibrium absent a market failure, so its main motivation for requiring higher fuel economy other than addressing such market failures must be to provide benefits of enhanced energy conservation to the broader population and U.S. economy. Alternative versions of Table 5-1 that include dollar estimates of costs and benefits for each of the regulatory alternatives we considered before selecting the Preferred Alternative for this Proposed Rule also appear in Chapter 8.2.4.6, Table 8-13, and Table 8-14 of this PRIA. These reflect differing perspectives for measuring benefits and costs, time horizons, and DRs.

Table 5-1: Benefits and Costs Resulting from the Agency's Regulatory Action

Entry	Location of Explanation in RIA
Private Costs	
Technology Costs to Increase Fuel Economy	Chapter 8.2.2.2
Increased Maintenance and Repair Costs	Chapter 8.2.4.6
Sacrifice in Other Vehicle Attributes	Chapter 8.2.4.6

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[102] Interagency Working Group on Social Cost of Greenhouse Gases. U.S. Government. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide, Interim Estimates under Executive Order 13990. February 2021.

Consumer Surplus Loss from Reduced New Vehicle Sales	Chapter 8.2.3.1, 8.2.3.2
Safety Costs Internalized by Drivers	Chapters 8.2.4.5, 8.2.4.6
Subtotal - Private Costs	Sum of above entries
Other Costs	
Congestion and Noise Costs from Rebound-Effect Driving	Chapter 8.2.4.3
Safety Costs Not Internalized by Drivers	Chapters 8.2.4.5
Loss in Fuel Tax Revenue	Chapter 8.2.4.6
Subtotal – Other Costs	Sum of above entries
Social Costs	Sum of private and external costs
Private Benefits	
Savings in Retail Fuel Costs[103]	Chapter 8.2.3.2
Benefits from Additional Driving	Chapter 8.2.3.2
Less Frequent Refueling	Chapter 8.2.3.2
Subtotal – Private Benefits	Sum of above entries
Other Benefits	
Reduction in Petroleum Market Externality	Chapter 8.2.4.4
Reduced Climate Damages	Chapters 8.2.4.1
Reduced Health Damages	Chapters 8.2.4.2
Subtotal - External Benefits	Sum of above entries
Social Benefits	Sum of private and external benefits
Net Private Benefits	Private Benefits – Private Costs
Net External Benefits	External Costs – External Benefits
Net Social Benefits	Social Benefits – Social Costs

As the table shows, many impacts of the regulatory action will fall directly on private businesses and households or individuals, including manufacturers of cars and LT, buyers and subsequent owners of the new models they produce, and owners of used vehicles – that is, vehicles produced during MY prior to those considered in this analysis. The largest category of costs is vehicle producers' expenses for added technology to enable their models to meet higher fuel economy and fuel efficiency targets, although as indicated previously, the agency assumes these increased costs will be reflected in higher purchase prices and thus ultimately borne by new vehicle buyers.

Table 5-1 also includes entries for increased maintenance and repair costs necessary to ensure that their higher fuel economy is sustained throughout these vehicles' lifetimes (since estimated fuel savings assume this will be the case), and for buyers' value of changes in vehicles' other attributes that manufacturers introduce as part of their efforts to improve fuel economy. Including these entries in the table is intended to emphasize that these could represent real economic costs of requiring manufacturers to comply with higher

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[103] Since taxes are transfers from consumers to governments, a portion of the Savings in Retail Fuel Costs includes taxes avoided. The Loss in Fuel Tax Revenue is completely offset within the Savings in Retail Fuel Costs.

standards but that the agency lacks sufficient information to confidently estimate them, rather than to suggest that their true value is likely to be zero. Other privately borne costs include losses in consumer surplus to would-be new car and LT buyers who are deterred by their higher prices, and the economic cost of safety risks that drivers consider (or "internalize") when deciding whether to travel additional miles.

Other costs include the contributions of additional rebound-effect driving to traffic congestion, delays, and roadway noise. Although these costs are largely or completely borne by drivers (and their passengers) *as a whole*, it is unlikely that the individual buyers of new vehicles whose decisions about how much to drive impose these costs consider them when deciding whether to make additional trips. Those drivers may not account for all of the safety risks they create for themselves and other road users (including users who are not vehicle occupants) by making additional trips, and the economic value of risks they do not consider represent external costs they impose on other vehicles' passengers, pedestrians, cyclists, and other road users.

Losses in fuel tax revenue reduce the ability of government agencies who collect them to fund road maintenance and other programs with broad-based benefits, so these are another cost of ensuring higher fuel economy for buyers of new cars and LT. (The agency assumes that states or localities do not respond to declining fuel purchases by raising tax rates to maintain total tax revenues, but other costs would result if they did so.) Of course, lower fuel tax payments by drivers were already reflected in the savings in fuel costs reported previously, because those are valued at retail prices (which include taxes), so the net effect of changing the dollar value of this transfer is zero, as expected.

By far the largest category of benefits from raising standards is the cost of fuel that would be saved by buyers of cars, LT, and HDPUVs that achieve higher fuel economy or fuel efficiency, which as Table 5-1 shows is a private benefit. Those same buyers experience additional benefits from the increased mobility that added rebound-effect driving provides, as well as from the convenience of having to refuel less frequently because they can travel farther before needing to do so. Reducing fuel use also provides significant "external" benefits to the broader population, including less frequent or severe disruptions to economic activity from sudden runups in FPs, greater energy security from lower reliance on fossil fuels, which are subject to global markets, some reduction in future economic damages caused by expected changes in the global climate, and improved health from less frequent exposure to harmful levels of air pollution.

Finally, the table reports SCs, the sum of private and other costs, and social benefits, the sum of private and other benefits, from requiring higher fuel economy. Net social benefits are simply the difference between social benefits and costs, with positive values indicating that raising CAFE and fuel efficiency standards generates benefits exceeding its SCs, while negative values suggest the opposite. The table also reports net private benefits, equal to the difference between private benefits and private costs, as well as net external benefits, or the difference between economy-wide or external benefits and costs. Reporting the private and external components of net benefits separately enables readers of this PRIA to clearly distinguish the value of NHTSA's action to buyers of new cars and LT themselves from the broader benefits it provides throughout the U.S. economy.

6. Simulating Manufacturers' Potential Responses to the Alternatives

The CAFE Model compliance analysis begins with information to represent each manufacturer regulated by the standards. The Market Data Input File includes information about each regulated manufacturer's vehicles models offered for sale in a given model year (or years), production constraints, compliance constraints and flexibilities. The sum of that information provides the foundation on which the CAFE Model builds an assessment of how each manufacturer could comply with a given regulatory alternative. The regulatory alternatives, while applicable to all manufacturers in the analysis, affect individual manufacturers differently. Each manufacturer's actual fuel economy compliance obligation represents the production-weighted harmonic mean of their vehicles' targets in each regulated fleet, where the fuel economy target is a function of the vehicles' footprints for LD and WFs for HDPUV. This means that no individual vehicle has a "standard," merely a target, and each manufacturer is free to identify a compliance strategy that makes the most sense given its unique combination of vehicle models, consumers, and competitive position in the various market segments. As the CAFE Model provides flexibility when defining a set of fuel economy standards, each manufacturer's requirement is dynamically defined based on the specification of the standards for any simulation and the distribution of footprints or WFs within each fleet.

CAFE Model Files Referenced in this Chapter

Below is a list of CAFE Model Files referenced in this chapter. See TSD Chapter 2.1.9 Where can I find the internal NHTSA files? for a full list of files referenced in this document and their respective file locations.

- Market Data Input File
- Technologies Input File
- Scenarios Input File
- CAFE Model Documentation
- CAFE Model Input File
- CAFE Analysis Autonomie Documentation
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6.1. Representing Manufacturer's Decisions

The first step to represent manufacturer's decisions about which fuel economy improving technologies could be applied to their vehicles in future MY is to define the relevant list of technologies available for application. The CAFE Model has extensive technology options and pathways available for application to vehicles. These technologies and pathways are detailed in Draft TSD Chapters 2 and 3 and they include restrictions around which more advanced technologies can be applied based on already applied technologies. The model selects the most cost-effective technologies, subject to additional real-world constraints that are discussed below, that allow manufacturers to meet fuel economy standards.

The Market Data Input File forms the starting point for the CAFE Model analysis. It includes vehicles available for the sale in a model year or years, and their respective technologies; when the model will have opportunities to apply technology; what engines, transmissions, and platforms are shared between vehicles; vehicle sales, fuel economy, footprints, and safety classes; and various other critical pieces of information.[104,105]

The effectiveness of each technology is based on simulations run from the Department of Energy's (DOE) Argonne National Laboratory (Argonne) Autonomie model.[106,107] Argonne runs ten sets of simulations for LDVs and four sets of simulations for HDPUVs that differ by vehicle "technology class." Technology classes are used to accurately represent how vehicles with different characteristics may benefit from fuel economy

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[104] See Draft TSD Chapter 2 for additional details about the Market Data Input File.

[105] See the Market Data Input File, which can be found on the NHTSA CAFE Model website.

[106] Technology effectiveness values are included in the CAFE Model release and are not selectable by the user.

[107] For more information about how the Autonomie model was used, see the Argonne Natinoal Laboratory's report which is titled "Vehicle Simulation Process to Support the Analysis for MY 2027 and Beyond CAFE and MY 2030 and Beyond HDPUV FE Standards**".** For ease of use and consistency with TSD document, it is referred as "CAFE Analysis Autonomie Documentation".

improving technologies. All vehicles in the Market Data Input File are assigned technology classes that allow the model to use the effectiveness values that most closely match a vehicle's characteristics.[108]

The costs of each technology considered in this analysis are stored in the Technologies Input File.[109] The costs are either assigned by vehicle technology class or engine class, depending on whether a technology is deemed a platform technology or an engine technology. All technology costs represent an average direct manufacturing cost with a retail price equivalency factor of 1.5 and decrease in successive MY based on a learning rate that represents manufacturers getting better at producing a technology over time. Battery costs are included in the CAFE Model and the Technologies Input File includes a battery learning rate which allows those costs to decrease in future years when more technology adoption is expected.[110]

Some technologies have federal incentives tied to their application, which are included in the modeling. The Scenarios Input File includes tax credits that will be applicable to vehicles and/or batteries during the years modeled.[111] These incentives are defined by regulatory class and technology. For the battery tax credits, average pack size for a certain technology was used to determine the magnitude for SHEVs, PHEVs, BEVs, and FCVs. The vehicle tax credits are broken up in the same way as battery tax credits but there are none for SHEVs. These incentives reduce the cost of applying a technology which likely results in higher application, when and if the technology is allowed by modeled statutory constraints.[112,113]

Technology application is determined by the "effective cost" of a technology. The effective cost of a technology represents the tradeoffs that manufacturers must make between compliance costs, civil penalties, and consumer demand for fuel economy improvements, among other factors. The CAFE Model attempts to apply technology to each manufacturer's fleet in a manner that minimizes these effective costs. As noted before, the effective cost captures more than the incremental cost of a given technology – it represents the difference between their incremental cost and the value of fuel savings to a potential buyer over the first 30 months of ownership.[114] In addition to the technology cost and fuel savings, the effective cost also includes avoidance of civil penalties from applying a given technology. The effective cost for this analysis also includes the cumulative value of additional vehicle and battery tax credits (or, Federal Incentives) resulting from application of a candidate technology evaluated on a group of selected vehicles. CAFE Model Documentation S5.3.2 has an in-depth discussion of the relevant effective cost equations.

This construction allows the model to choose technologies that both improve a manufacturer's compliance position and are most likely to be attractive to its consumers. This also means that different assumptions about future FPs will produce different rankings of technologies when the model evaluates available technologies for application. For example, if gasoline prices are forecasted to be high, an expensive but very efficient technology may look attractive to manufacturers because the value of the fuel savings is sufficiently high to both counteract the higher cost of the technology and, implicitly, satisfy consumer demand to balance price increases with reductions in operating cost. The model continues to add technology until a manufacturer either:

- Reaches compliance with fuel economy standards or GHG standards, depending on the operating mode and the regulatory alternative, possibly through the accumulation and application of compliance credits.
- Reaches a point at which it is more cost effective to pay civil penalties than to add more technology.[115] This option only exists for some LD manufacturers and the HDPUV fleet.[116]
- Reaches a point (beyond compliance) where the cost of additional fuel-saving technology begins to exceed the fuel savings projected to occur during the first 30 months of vehicle ownership.

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[108] See Draft TSD Chapter 3 for additional details about technology effectiveness values.
[109] See the Technlogies Input File, which can be found on the NHTSA CAFE Model website.
[110] See Draft TSD Chapter 2 and Draft TSD Chapter 3 for more discussion on specifc technology costs and technology types.
[111] See the Scenarios Input File, which can be found on the NHTSA CAFE Model website.
[112] See Draft TSD Chapter 2 for more discussion on technology incentives and tax credits.
[113] See Draft TSD Chapter 2 for a discussion on model standard setting constraints.
[114] The length of time over which to value fuel savings in the effective cost calculation is a model input that can be modified by the user. This analysis uses 30 months' worth of fuel savings in the effective cost calculation, assuming that the price of fuel at the time of purchase persists for at least the next 30 months. This implies that new car buyers will behave as if the fuel price at the time of purchase reflects the fuel price he or she will face over the life of the vehicle. The accompanying Draft TSD Chapters 1.4.1 and 4.2.1 discuss the basis for this model input.
[115] This is only true for light-duty analysis as HDPUV does not consider paying fines over the application of technology.
[116] See the Market Data Input File for information about which manufactures are allowed to pay fines.

The algorithm stops applying additional technology to this manufacturer's products once the above criteria are met. This process is repeated for each manufacturer present in the input fleet. It is then repeated for each model year. Once all MYs have been processed, the compliance simulation algorithm concludes.

The effective cost equations work with a set of rules that determine which technologies are available to be applied and in what quantity. These rules reflect real-world production constraints that influence manufacturers' compliance options and are relevant to evaluating the economic practicability of different regulatory alternatives. While the earliest CAFE analyses did not account for all of these, both public comments on earlier rules and CAFE Model peer reviewers have consistently found them to be relevant and meaningful inclusions.[117] Phase-in caps work like a go/no-go gate in allowing the application of certain technologies. For LD analysis only, manufacturers have a fine paying preference that allows the model to determine if it is more cost effective to pay fines or apply technology. Sharing of engines, transmissions, and platforms restricts technology application so that sharing cannot be broken except with certain electrification technologies. Some technologies might be skipped for specific vehicle types or manufacturers. These rules work together to allow the CAFE Model compliance simulation to better reflect manufacturer's technology application decisions. Standard Setting years have additional rules relating to the application of certain electrification technologies including not allowing BEVs and only accounting for the gasoline fuel economy of PHEVs. The basis for these rules and more explanation is discussed in Chapter 2 of the Draft TSD and Section II.C of the preamble.

6.2. Compliance Example

To better demonstrate how the CAFE Model simulates manufacturer compliance with CAFE standards, we walk through a solution for a single manufacturer, recognizing that no simulation can precisely predict what a manufacturer will do to meet its compliance obligations and that the CAFE Model's modeled technology pathway is just one potential cost-effective way that a manufacturer could meet CAFE standards. The example below examines Honda's modeled fleet and the simulated compliance actions in the preferred alternative (Alternative PC2LT4). This example illustrates different CAFE Model features intended to reasonably simulate manufacturer-decision making, given a full set of assumptions about technology costs and effectiveness (among others), as well as the statutory constraints on technology options.

In MYs 2023-2026, Honda faces requirements under 3 programs: NHTSA's CAFE program (with standards finalized in 2022 for MYs 2024-2026), EPA's GHG program through MY 2026, and CARB's ZEV program, which requires a particular number of ZEVs produced and sold in both California and the other states who have adopted the ZEV program.[118] These simultaneous frameworks interact to influence Honda's decisions about how to increase the fuel efficiency of its various fleets, and the pace at which it must do so. For MYs 2027 and beyond, the CAFE Model considers requirements under NHTSA's Alternative PC2LT4 fuel economy standards, EPA's MY 2026 standards,[119] and CARB's ZEV program.

At the start of the simulation, in MY 2022, Honda produces 10 unique engines shared across 14 unique nameplates, 49 model variants (that differ by nameplate, technology content, curb weight, footprint, or fuel economy), and 3 regulatory classes (domestic passenger cars (DPCs), imported passenger cars (IPC), and LT). The CAFE Model attempts to preserve the observed level of component sharing throughout the simulation to avoid introducing additional production complexity for which we do not estimate additional cost. Sixteen transmissions and nine platforms are shared across the nameplates, model variants, and regulatory classes.

While the CAFE Model's decisions are focused on bringing each manufacturer's fleets into compliance with the relevant standards, the actions taken to do so occur at the level of individual model types offered for sale. Before considering the broader context of compliance, by program and over time, it may be helpful to follow the evolution of a specific model in Honda's portfolio as the simulated company attempts to comply with regulations, within the bounds of our model. Unlike earlier analyses that have shown aggressive improvements taking place to ICEs, early and often, under increasing CAFE stringencies, this analysis is different. Many of those ICE improvements have occurred over the last decade, for manufacturers like

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[117] For a detailed description of the CAFE Model Input File please see the CAFE Model Documentation.
[118] The CAFE Model's handling of CARB's ZEV program components is discussed in Draft TSD Chapter 2.
[119] EPA's proposed GHG standards for MYs 2027 and beyond were not available at the time of writing.

Honda, and starting from MY 2022, there are fewer such opportunities remaining in the model's technology tree, given statutory constraints on technology that must be considered.

The following example follows the progression of the Acura MDX AWD Type S (Vehicle Code: 2151003), a Medium Performance SUV in Honda's Light Truck regulatory class, during Honda's path towards achieving compliance with various regulatory requirements from MY 2022 through MY 2032. As shown in Table 6-1, the MDX AWD Type S shares an engine (Engine Code: 213011) and transmission (Transmission Code: 212212) with two model variants of the Acura TLX (Vehicle Codes: 2155005 and 2155006). While all these vehicles share a single engine (i.e., a 3.0L V6 with TURBOD) and a single transmission (i.e., AT10L2), the MDX AWD Type S has the greatest sales volume within the group, and therefore serves as a candidate component leader for its engine and transmission — meaning that the engine and transmission adopt the redesign cadence of that specific MDX variant in the CAFE Model. In addition to two other MDX model variants (Vehicle Codes: 2151001 and 2151002), the MDX AWD Type S shares its platform (Platform Code: 211105) with some model variants of the Honda Odyssey (Vehicle Codes: 2108001 and 2108002), Honda Passport (Vehicle Codes: 2109001 and 2109002), Honda Pilot (Vehicle Codes: 2110001, 2110002, and 2110003), and the Honda Ridgeline (Vehicle Code: 2111001). The Honda Pilot AWD (Vehicle Code: 2110002) has the greatest sales volume within the group and is, therefore, the candidate component leader for its platform. As a result, upgrades to this platform will occur during the design cadence of the Honda Pilot AWD, with the MDX AWD Type S inheriting those upgrades from the platform during future redesign years. As Table 6-1 shows, the MDX, Odyssey, Passport, Pilot, Ridgeline, and TLX variants all have different redesign cadences (MY 2028 for the MDX variants, 2025 and 2032 for the Odyssey, 2026 for the Passport, 2023 and 2030 for the Pilot, 2023 and 2029 for the Ridgeline, and 2027 for the TLX model variants).

Table 6-1: Honda's Compliance Example for the Various Ford Acura and Honda Variants with Component Sharing

Brand	Model[120]	Regulatory Class	Vehicle Code	Platform Code	Engine Code	Transmission Code	MY 2022 Sales Volume	Candidate Component Leader	Redesign MYs	Refresh MYs
Acura	MDX AWD Type S	Light Truck	2151003	211105	213011	212212	5,545	Engine and Transmission	2028	2025 and 2031
Acura	MDX FWD	Light Truck	2151001	211105	213501	211211	12,098	N/A	2028	2025 and 2031
Acura	MDX AWD	Light Truck	2151002	211105	213501	212211	52,107	Transmission	2028	2025 and 2031
Acura	TLX Type S	Domestic Car	2155005	211107	213011	212212	1,590	N/A	2027	2024 and 2030
Acura	TLX Type S - Performance Tire	Domestic Car	2155006	211107	213011	212212	2,184	N/A	2027	2024 and 2030
Honda	Odyssey - IWC 4500	Light Truck	2108001	211105	213501	211211	59,661	Transmission	2025 and 2032	2028
Honda	Odyssey - IWC 5000	Light Truck	2108002	211105	213501	211211	12,406	N/A	2025 and 2032	2028
Honda	Passport FWD	Domestic Car	2109001	211105	213501	211291	11,843	N/A	2026	2029
Honda	Passport AWD	Light Truck	2109002	211105	213501	212291	36,402	N/A	2026	2029
Honda	Pilot FWD	Light Truck	2110001	211105	213501	211291	46,715	Transmission	2023 and 2030	2026
Honda	Pilot AWD	Light Truck	2110002	211105	213501	212291	96,550	Platform, Engine, and Transmission	2023 and 2030	2026
Honda	Pilot AWD - TrailSport	Light Truck	2110003	211105	213501	212291	12,799	N/A	2023 and 2030	2026
Honda	Ridgeline AWD	Light Truck	2111001	211105	213501	212291	49,405	N/A	2023 and 2029	2026 and 2032

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[120] "AWD" and "FWD" refer, respectivly, to all wheel drive and front-wheel drive.

Table 6-2 through Table 6-6 present technology walks for the MDX and TLX variants in our example. The technology walks[121] contain the technology key ("tech key"), fuel economy target, and compliance fuel economy (via simulation) for each MY in our analysis. A tech key is a series of abbreviations that succinctly describe a vehicle's technology content for a particular MY. Differences in tech keys in successive MYs represent the CAFE Model applying higher levels of technology to comply with standards. Higher levels of technology can only be added to a vehicle in a redesign or refresh MY. For MYs in which a vehicle is not redesigned or refreshed, the CAFE Model simply carries forward its technology content from the previous MY. The light grey rows in the tables reflect MYs when the vehicle is eligible for a refresh and the dark grey rows are MYs when the vehicle is eligible for a redesign. In each technology walk, the fuel economy target increases as the stringency of the CAFE standard increases from MY 2022 through MY 2032. The compliance fuel economy of the MDX and TLX variants only change in MYs where a technology application occurs.

While the MDX AWD Type S's engine and transmission are eligible for upgrades in MY 2028 (see Table 6-1), its first and only redesign year during the analysis period, the TLX model variants could not inherit these upgrades until MY 2030 — their first opportunity to do so after MY 2028, which in this case is a "refresh" rather than a full redesign. However, in the first year the TLX model variants are eligible for a vehicle redesign (i.e., MY 2027), the CAFE Model upgrades them from a MHEV (i.e., 12V strong hybrid/electric vehicle (SS12V)) powertrain with (tire rolling resistance (ROLL20) and AERO5[122] to a SHEV (i.e., P2TRBE) powertrain with ROLL20 and AERO20[123]. During an upgrade from a MHEV to a SHEV, the CAFE Model removes the vehicle's engine and transmission and replaces them with alternate hybrid-specific versions. In this example, the TLX variant engine and transmission (i.e., TURBOD and AT10L2, respectively) are removed and replaced with TURBOE and AT8L2, married to a P2 hybrid system during its vehicle redesign in MY 2027. As a result, the TLX variants will no longer be eligible to inherit an engine or transmission upgrade from their former assigned engine code or former assigned transmission code during future redesign and refresh years.[124] Although the TLX variants are eligible for additional redesign actions after MY 2027, they do not receive any other upgrades for the remainder of the analysis period.

Similar to the TLX model variants, the MDX AWD Type S gets upgraded from a MHEV (i.e., SS12V with TURBOD) to a SHEV (i.e., P2TRBE) powertrain in the first MY it is eligible for a vehicle redesign (i.e., MY 2028), and will no longer be able to inherit an upgrade from its former engine or transmission. Conversely, the remaining MDX model variants begin as MHEVs in the base year (i.e., MY 2022) and remain as MHEVs throughout the analysis years. As a result, they remain eligible to inherit engine and transmission upgrades from their respective assigned engine codes or assigned transmission codes during future redesign and refresh years.

Table 6-2: Technology Walk for the MDX AWD Type S

Model Year	Tech Key	Fuel Economy - Target [mpg]	Fuel Economy - Compliance [mpg]
2022	TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR3	32.2	26.1
2023	TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR3	32.7	26.1
2024	TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR3	35.6	26.1
2025	TURBOD; AT10L3; SS12V; ROLL30; AERO5; MR3	38.6	28.6
2026	TURBOD; AT10L3; SS12V; ROLL30; AERO5; MR3	42.9	28.6
2027	TURBOD; AT10L3; SS12V; ROLL30; AERO5; MR3	44.7	28.6
2028	P2TRBE; ROLL30; AERO20; MR3	46.6	36.3

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[121] A technology walk is a tabular represntation of how a vehicle's technology (and other charateristics) progress over time.
[122] Aero Drag Reduction, Level 1 (5% reduction).
[123] Aero Drag Reduction, Level 4 (20% reduction).
[124] This is a change in the CAFE Model's logic. See Draft CAFE Model Documentation Section 4.4 for more information.

2029	P2TRBE; ROLL30; AERO20; MR3	48.5	36.3
2030	P2TRBE; ROLL30; AERO20; MR3	50.6	36.3
2031	P2TRBE; ROLL30; AERO20; MR3	52.7	36.3
2032	P2TRBE; ROLL30; AERO20; MR3	54.8	36.3

Table 6-3: Technology Walk for the MDX FWD

Model Year	Tech Key	Fuel Economy - Target [mpg]	Fuel Economy - Compliance [mpg]
2022	SOHC; VVL; SGDI; DEAC; AT10L2; SS12V; ROLL0; AERO5; MR3	32.2	29.3
2023	SOHC; VVL; SGDI; DEAC; AT10L2; SS12V; ROLL0; AERO5; MR3	32.7	29.3
2024	SOHC; VVL; SGDI; DEAC; AT10L2; SS12V; ROLL0; AERO5; MR3	35.6	29.3
2025	TURBOD; AT10L2; SS12V; ROLL30; AERO5; MR3	38.6	31.5
2026	TURBOD; AT10L2; SS12V; ROLL30; AERO5; MR3	42.9	31.5
2027	TURBOD; AT10L2; SS12V; ROLL30; AERO5; MR3	44.7	31.5
2028	TURBOD; AT10L2; BISG; ROLL30; AERO20; MR3	46.6	34.9
2029	TURBOD; AT10L2; BISG; ROLL30; AERO20; MR3	48.5	34.9
2030	TURBOD; AT10L2; BISG; ROLL30; AERO20; MR3	50.6	34.9
2031	TURBOD; AT10L2; BISG; ROLL30; AERO20; MR3	52.7	34.9
2032	TURBOD; AT10L2; BISG; ROLL30; AERO20; MR3	54.8	34.9

Table 6-4: Technology Walk for the MDX AWD

Model Year	Tech Key	Fuel Economy - Target [mpg]	Fuel Economy - Compliance [mpg]
2022	SOHC; VVL; SGDI; DEAC; AT10L2; SS12V; ROLL0; AERO5; MR3	32.2	27.8
2023	SOHC; VVL; SGDI; DEAC; AT10L2; SS12V; ROLL0; AERO5; MR3	32.7	27.8
2024	SOHC; VVL; SGDI; DEAC; AT10L2; SS12V; ROLL0; AERO5; MR3	35.6	27.8
2025	TURBOD; AT10L2; SS12V; ROLL30; AERO5; MR3	38.6	29.9
2026	TURBOD; AT10L2; SS12V; ROLL30; AERO5; MR3	42.9	29.9
2027	TURBOD; AT10L2; SS12V; ROLL30; AERO5; MR3	44.7	29.9
2028	TURBOD; AT10L2; SS12V; ROLL30; AERO20; MR3	46.6	31.3
2029	TURBOD; AT10L2; SS12V; ROLL30; AERO20; MR3	48.5	31.3
2030	TURBOD; AT10L2; SS12V; ROLL30; AERO20; MR3	50.6	31.3
2031	TURBOD; AT10L3; SS12V; ROLL30; AERO20; MR3	52.7	31.8
2032	TURBOD; AT10L3; SS12V; ROLL30; AERO20; MR3	54.8	31.8

Table 6-5: Technology Walk for the TLX Type S

Model Year	Tech Key	Fuel Economy - Target [mpg]	Fuel Economy - Compliance [mpg]
2022	TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR0	41.4	29.1
2023	TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR0	42.0	29.1
2024	TURBOD; AT10L2; SS12V; ROLL20; AERO5; MR0	45.7	30.6
2025	TURBOD; AT10L2; SS12V; ROLL20; AERO5; MR0	49.7	30.6
2026	TURBOD; AT10L2; SS12V; ROLL20; AERO5; MR0	55.2	30.6
2027	P2TRBE; ROLL20; AERO20; MR4	56.3	42.7
2028	P2TRBE; ROLL20; AERO20; MR4	57.5	42.7
2029	P2TRBE; ROLL20; AERO20; MR4	58.6	42.7
2030	P2TRBE; ROLL20; AERO20; MR4	59.8	42.7
2031	P2TRBE; ROLL20; AERO20; MR4	61.1	42.7
2032	P2TRBE; ROLL20; AERO20; MR4	62.3	42.7

Table 6-6: Technology Walk for the TLX S - Performance Tire

Model Year	Tech Key	Fuel Economy - Target [mpg]	Fuel Economy - Compliance [mpg]
2022	TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR0	41.4	28.0
2023	TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR0	42.0	28.0
2024	TURBOD; AT10L2; SS12V; ROLL20; AERO5; MR0	45.7	29.4
2025	TURBOD; AT10L2; SS12V; ROLL20; AERO5; MR0	49.7	29.4
2026	TURBOD; AT10L2; SS12V; ROLL20; AERO5; MR0	55.2	29.4
2027	P2TRBE; ROLL20; AERO20; MR4	56.3	41.0
2028	P2TRBE; ROLL20; AERO20; MR4	57.5	41.0
2029	P2TRBE; ROLL20; AERO20; MR4	58.6	41.0
2030	P2TRBE; ROLL20; AERO20; MR4	59.8	41.0
2031	P2TRBE; ROLL20; AERO20; MR4	61.1	41.0
2032	P2TRBE; ROLL20; AERO20; MR4	62.3	41.0

While no individual vehicle is required to exceed its fuel economy target for a manufacturer to achieve compliance, compliance fuel economy values not evolving as fast as fuel economy targets is just one factor manufacturers must consider during their multi-year planning. Because compliance with CAFE standards is determined at the fleet level for each regulatory category, the fuel economy performance of a single model type does not determine final compliance. All vehicles within a regulatory category contribute to its fuel economy performance. The poor performance of a single model type can be offset by the above average performance of one or more other vehicles in that regulatory category. For instance, in MY 2026, the MDX AWD Type S's achieved fuel economy falls short of its target fuel economy. However, the MDX AWD Type S's regulatory category (i.e., the LT regulatory category), exceeds its fuel economy standard and generates an ample number of credits (see Table 6-8). This is due to other vehicles within the LT fleet, like the Honda CRV AWD 2.0L, that exceed their targets. Table 6-7 presents the tech key, fuel economy target, and fuel economy compliance for the CRV AWD 2.0L Hybrid.

Table 6-7: Technology Walk for the CRV AWD 2.0L Hybrid

Model Year	Tech Key	Fuel Economy - Target [mpg]	Fuel Economy - Compliance [mpg]
2022	SHEVPS; ROLL20; AERO10; MR3	36.6	54.3
2023	SHEVPS; ROLL20; AERO10; MR3	37.2	54.3
2024	SHEVPS; ROLL20; AERO10; MR3	40.4	54.3
2025	SHEVPS; ROLL30; AERO10; MR3	43.9	56.5
2026	SHEVPS; ROLL30; AERO10; MR3	48.8	56.5
2027	SHEVPS; ROLL30; AERO20; MR3	50.9	58.8
2028	SHEVPS; ROLL30; AERO20; MR3	53.0	58.8
2029	SHEVPS; ROLL30; AERO20; MR3	55.2	58.8
2030	SHEVPS; ROLL30; AERO20; MR3	57.5	58.8
2031	SHEVPS; ROLL30; AERO20; MR3	59.9	58.8
2032	SHEVPS; ROLL30; AERO20; MR3	62.4	58.8

All vehicle-level technology application decisions occur in the larger context of fleet-level compliance — where the CAFE Model identifies least-cost solutions across the entire fleet to bring it into compliance. The example of Honda's compliance in Alternative PC2LT4 (presented in greater detail in Table 6-8 for CAFE and Table 6-9 for GHG) illustrates the tradeoffs that the CAFE Model makes between applying technology to vehicles in a fleet in a specific MY (including the resulting effects across the product portfolio in future MYs), applying banked credits, transferring credits between fleets, and generating credits in a higher-performing fleet to assist another fleet that struggles to meet its standard. The meaning of "compliance" is also complicated by the fact that three frameworks – CAFE (MY 2022 final standards), GHG, and ZEV – all operate simultaneously in MYs 2023-2032. As the example demonstrates, no one framework represents the binding constraint in all MYs.

The compliance simulation begins with Honda's compliance status in MY 2022, in each fleet, for all frameworks, relative to the MY 2022 standards that were finalized in 2020. In this case, Honda faces several binding constraints; however, the CAFE Model does not apply technology to the MY 2022 fleet, which is the starting point of the simulation and is based on compliance data submitted by the manufacturer. The initial credit banks reflect prior transactions between manufacturers and earned credits by the same manufacturer in prior model years. In Honda's case, there are existing CAFE credits that can be applied to deficits in the IPC fleet and expiring GHG credits that are transferred into the fleet. However, the application of these credits varies by framework.

In MY 2022, Honda's DPC achieved fuel economy exceeds its standard and will therefore generate credits. However, its IPC fleet's achieved fuel economy is below its standard, and the model estimates the civil penalties associated with the deficit. Despite the nearly 15 mpg gap between the standard and compliance value, the sales volumes in the IPC fleet are modest, and the size of the penalty payment is relatively modest as well. In practice, it is more likely that Honda acquires IPC credits from another manufacturer or shuffles credits between fleets in a way that differs from the simulation. Honda's LT fleet exceeds its standard in MY 2022 and generates credits, which the CAFE Model accrues for use in future years.

Under the GHG standards, Honda's PC fleet (i.e., the union of its DPC and IPC fleets) and LT fleet are out of compliance with its standard in MY 2022. However, Honda has a sufficient number of compliance credits available and applies a quantity that exactly offsets the PC and LT deficits in MY 2022 (3,050,252 total credits in the “Credits In” column in Table 6-9).[125] Because credit transfers between fleets are uncapped, earned GHG credits essentially live in a common bank that is not specific to either fleet, only the model year in which they were earned. As such, Honda can take expiring credits and push them into the PC and LT fleets in MY 2022. In this way, a manufacturer can renew expiring credits if a single fleet performs sufficiently better than its standard. In CAFE compliance, this is not the case. Because earned credits are tied to both a specific fleet and a specific MY, the credits must be used to offset deficits in the fleet in which they were earned (or be transferred to another fleet and be subject to required adjustments that could significantly erode their value, even before the transfer cap applies). The CAFE Model accounts for both credit accounting regimes, while simulating compliance with the two programs simultaneously.

In MY 2023, the same scenario occurs in the CAFE Program: Honda’s DPC and LT fleet exceed their standards while its IPC fleet generates a moderate shortfall. However, in MY 2023, Honda uses credits to resolve its shortfall rather than paying a civil penalty. In the GHG Program, Honda’s PC and LT fleets generate credits in MY 2023.

Table 6-8: Simulated CAFE Compliance (Alternative PC2LT4), Honda

Model Year	Regulatory Class	MDPCS [mpg]	Standard [mpg]	CAFE [mpg]	Civil Penalty	Credits Earned	Credits Out	Credits In
2022	Domestic Car	40.6	44.7	45.6	0	7,072,605	0	0
2022	Imported Car		44.9	30.4	637,710	-43,500	0	0
2022	Light Truck		34.0	35.0	0	6,678,770	523,143	0
2023	Domestic Car	41.2	45.4	50.4	0	39,280,100	0	0
2023	Imported Car		45.6	31.3	0	-42,900	0	42,900
2023	Light Truck		34.5	38.1	0	26,263,080	0	0
2024	Domestic Car	44.8	49.4	50.9	0	11,082,420	910	910
2024	Imported Car		49.5	31.5	0	-50,760	0	50,760
2024	Light Truck		37.5	38.4	0	6,613,056	0	0
2025	Domestic Car	48.7	53.7	53.8	0	705,734	1,415,999	1,415,999
2025	Imported Car		53.8	32.0	0	-58,860	325,943	384,803
2025	Light Truck		40.8	40.6	0	-1,496,158	0	1,496,158
2026	Domestic Car	54.1	59.6	60.5	0	6,362,577	0	0
2026	Imported Car		59.8	420.7	0	974,430	0	0
2026	Light Truck		45.3	45.6	0	2,321,808	0	0
2027	Domestic Car	55.2	60.8	60.8	0	0	0	0
2027	Imported Car		61.1	79.8	0	50,864	0	0
2027	Light Truck		47.2	47.3	0	799,292	0	0
2028	Domestic Car	56.3	62.1	63.9	0	12,848,058	0	0
2028	Imported Car		62.3	79.5	0	46,784	0	0
2028	Light Truck		49.2	49.2	0	0	0	0
2029	Domestic Car	57.5	63.3	65.8	0	17,469,975	0	0
2029	Imported Car		63.6	79.3	0	41,762	0	0
2029	Light Truck		51.2	51.2	0	0	0	0

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[125] Note, however, Honda is also shown as carrying forward an additional 9,350 credits into their PC fleet in MY 2022, beyond what was required during that year. These credits are shown as subsequently being trasferred out (visible under the “Credits Out” column) and being deposited into the LT fleet in MY 2022 (although, from the table, while it is not immediately obvious that such a transaction occurred, readers can inspect the relevant "credits trades” log generated by the CAFE Model to view this specific credit transaction).

2030	Domestic Car	58.6	64.6	68.1	0	24,057,215	0	0
2030	Imported Car		64.9	79.0	0	36,942	0	0
2030	Light Truck		53.4	54.0	0	4,678,584	0	0
2031	Domestic Car	59.8	66.0	70.2	0	28,713,930	0	0
2031	Imported Car		66.2	78.7	0	32,625	0	0
2031	Light Truck		55.6	55.7	0	761,294	0	0
2032	Domestic Car	61.1	67.3	71.9	0	31,461,010	0	0
2032	Imported Car		67.6	77.7	0	26,361	0	0
2032	Light Truck		57.9	57.9	0	0	0	0

As in the previous two MYs, in MY 2024, Honda's DPC and LT fleets exceed their standard and generate credits that are banked for later use. Honda's IPC fleet generates a shortfall, which it again resolves with credits. Despite complying with their GHG standards in MY 2023, Honda's PC and LT fleets fail to comply in MY 2024. However, as in MY 2022, Honda once again has sufficient banked credits to offset the deficits in the PC and LT fleets.

In MY 2026, the single vehicle in Honda's IPC fleet is redesigned and exceeds its standard from that point forward. Honda's DPC and LT fleets continue to exceed their standards for the remainder of the analysis period as well. As in previous years, the CAFE Model attempts to use expiring credits to the fullest extent allowable but must allow some credits to expire. Since Honda can achieve compliance via the application of cost-effective technology, and even over-comply by large margins in some cases, any credit balances available from prior years (or generated by the model during analysis) will end up expiring. On balance, Honda's combined fleet exceeds its GHG constraint under Alternative PC2LT4, by either employing previously earned credits or through the benefits resulting from technology application. Starting with MY 2027, the simulation shows Honda generating large CAFE and GHG credit surpluses, which are attributed to application of significant amounts of cost-effective technology to the fleet. As the ZEV columns in Table 6-9 illustrate, some of the improvements in Honda's compliance position between MYs 2023 and 2032 are due to the increases in the ZEV requirements, which result in Honda producing additional BEVs to comply with the new ZEV targets that also influence compliance with CAFE and GHG standards.[126]

Table 6-9: Simulated GHG Compliance (Alternative PC2LT4), Honda

Model Year	Regulatory Class	Standard [g/mi]	Rating [g/mi]	Credits Earned	Credits Out	Credits In	ZEV Target	ZEV Credits
2022	Passenger Car	172	181	-1,381,552	9,350	1,390,902	0	0
2022	Light Truck	226	237	-1,659,350	0	1,659,350	0	0
2022	TOTAL	197	207	-3,040,902	9,350	3,050,252	94,453	0
2023	Passenger Car	165	161	613,833	0	0	0	0
2023	Light Truck	218	215	494,326	0	0	0	0
2023	TOTAL	191	187	1,108,159	0	0	115,415	203,569
2024	Passenger Car	157	159	-288,643	0	288,643	0	0
2024	Light Truck	207	213	-995,772	0	995,772	0	0
2024	TOTAL	182	186	-1,284,415	0	1,284,415	128,759	211,374
2025	Passenger Car	148	150	-275,714	295,684	571,398	0	0
2025	Light Truck	192	201	-1,520,684	0	1,520,684	0	0
2025	TOTAL	171	176	-1,796,398	295,684	2,092,082	143,314	244,535

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[126] The application of ZEV compliance logic and how it is applied in conjunction with the CAFE and GHG logic is discussed in Draft TSD Chapter 2.3.1.

2026	Passenger Car	131	129	276,190	0	0	0	0
2026	Light Truck	173	174	-174,805	0	174,805	0	0
2026	TOTAL	153	153	101,385	0	174,805	232,246	232,502
2027	Passenger Car	131	118	1,809,506	0	0	0	0
2027	Light Truck	173	155	3,249,578	0	0	0	0
2027	TOTAL	153	138	5,059,084	0	0	291,298	291,322
2028	Passenger Car	131	109	3,067,435	0	0	0	0
2028	Light Truck	173	145	5,116,667	0	0	0	0
2028	TOTAL	153	128	8,184,102	0	0	348,001	348,023
2029	Passenger Car	131	103	3,822,062	0	0	0	0
2029	Light Truck	173	134	7,046,283	0	0	0	0
2029	TOTAL	153	120	10,868,345	0	0	396,212	396,236
2030	Passenger Car	131	96	4,699,299	0	0	0	0
2030	Light Truck	173	122	8,982,191	0	0	0	0
2030	TOTAL	153	110	13,681,490	0	0	447,021	447,043
2031	Passenger Car	131	90	5,475,391	0	0	0	0
2031	Light Truck	173	114	10,145,030	0	0	0	0
2031	TOTAL	153	103	15,620,421	0	0	492,069	492,092
2032	Passenger Car	131	85	6,145,547	0	0	0	0
2032	Light Truck	173	105	11,592,638	0	0	0	0
2032	TOTAL	153	95	17,738,185	0	0	528,625	528,649

7. Simulating Consumers' Potential Responses and Related Impacts to Regulatory Alternatives

7.1. Impacts on Markets for New and Used Vehicles

Raising CAFE and fuel efficiency standards requires manufacturers to improve the fuel economy of some – and perhaps most – car, LT, and HDPUV models, and by doing so will increase manufacturers' costs to produce them. Manufacturers' higher costs to increase fuel economy and efficiency are the initial source of all costs and benefits that ultimately result from imposing higher standards. This chapter outlines the process by which costs to increase vehicles' fuel economy are transmitted through vehicle markets and ultimately generate various economic costs and benefits of alternative increases in CAFE and fuel efficiency standards.

First, new vehicles' purchase prices are likely to rise as manufacturers attempt to recover their costs for improving fuel economy and sustain their profitability. This will directly affect sales of new models, and indirectly affect the market value of used vehicles and the number of them kept in use. Imposing higher standards may also cause manufacturers to scale back or even forego planned improvements in vehicles' other features, as they attempt to comply with more demanding standards while minimizing any impact on their profitability. However, the agency's analysis assumes that manufacturers will not compromise other attributes of models whose fuel economy they improve, and instead will incur the incremental costs of technology necessary to meet higher standards without changing vehicles' other characteristics.[127]

The economic impact of meeting higher CAFE and fuel efficiency standards includes losses in consumer welfare to would-be buyers of new vehicles who elect not to pay the higher prices required to compensate manufacturers for their costs to improve fuel economy, as well as welfare gains to buyers who choose to purchase new vehicles even at those higher prices because of the savings in fuel costs they offer. It also includes any losses in manufacturers' profits ("producer surplus") stemming from their inability to recover increases in production costs to meet tougher standards by charging higher prices for new vehicles. Without detailed models of manufacturers' costs to produce vehicles with different combinations of fuel economy and other features, and how vehicles' prices and features affect sales and market shares of competing models, we are unable to estimate the actual economic cost of requiring manufacturers to meet more demanding standards.[128] Instead, the agency makes several simplifying assumptions that enable it to approximate the economic costs and benefits of imposing alternative CAFE and fuel efficiency standards for future model years.

First, we assume that vehicle manufacturers will be able to recover their full incremental costs for producing vehicles that meet higher fuel economy and fuel efficiency targets by raising selling prices for at least some new vehicles. The agency does not attempt to estimate price increases for specific car, LT, or HDPUV models, and instead simply assumes that their average price will rise sufficiently that increased sales revenue will fully cover manufacturers' increased costs. Our analysis does not attempt to project improvements in vehicles' other attributes that manufacturers would make if they were not compelled to meet higher targets, or to value welfare losses to buyers resulting from any sacrifices in those other features that producers make to meet more demanding standards. We make this simplification in order to focus our analysis on manufacturers' direct monetary costs for complying with stricter standards and the consequences of the resulting increases in prices for new vehicles.

NHTSA's analysis does not account for increases in the fuel economy of future vehicles that may occur as a result of new innovations in vehicle technology that occur even when CAFE standards remain unchanged. However, it does assume that learning effects reduce the costs of existing technology and enable gradual improvement in fuel economy under the baseline alternative, because additional technologies will repay their initial costs within the 30-month payback period buyers are assumed to demand. In addition, the agency

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[127] Gradual technological progress in vehicle design and production methods may enable manufacturers to improve vehicles' fuel economy slowly over time at no cost, thus reducing their incremental costs to meet higher targets, but the agency's analysis does not account for this potential effect and may thus overstate compliance costs slightly.

[128] Much of the information necessary to estimate cost increases, higher prices for specific models, and changes in thisr sales is closely held by manufacturers and not publicly available.

accounts for fuel economy improvements manufacturers voluntarily make in response to increasing FPs and their effect on new vehicle buyers' demands for higher fuel economy.

Manufacturers' use of more advanced technology to improve fuel economy may also increase owners' maintenance or repair expenses. Although some minor deterioration in vehicles' fuel economy as they age and accumulate use appears normal, owners must respond to unexpected deterioration beyond that normally expected by undertaking the maintenance or repairs necessary to preserve their expected savings in fuel costs. On the other hand, BEVs may require lower maintenance costs than ICE vehicles. This would tend to lower maintenance costs for these vehicles, but due to NHTSA's statutory constraints on considering the fuel economy of BEVs and the full fuel economy of PHEVs in determining maximum feasible CAFE standards, any reduction in maintenance and repair costs due to electrification would have a limited impact on NHTSA's analysis. Changes in the costs of maintenance and repairs to sustain vehicles' original fuel economy (and other capabilities) represent changes in the cost of requiring new vehicles to meet higher fuel efficiency targets, and while we do not attempt to estimate such expenses, doing so would affect the costs of meeting higher standards.

The agency's analysis first assembles data on sales, prices, fuel economy, and other attributes of the car and LT models each manufacturer produced during MY 2022 (the "reference fleet"). It then projects baseline values of these variables for future MY under the assumption that previously adopted standards remain in effect, including fuel economy improvements that manufacturers would make to "catch up" with prevailing standards, to respond to increased market demand for fuel economy, or to take advantage of normal improvements in technology that enable higher fuel economy. Using this regulatory baseline, the agency's CAFE Model simulates the improvements in fuel economy each manufacturer could make to specific models in its reference fleet that would minimize its total incremental costs for complying with alternative increases in CAFE and fuel efficiency standards proposed for future model years.

Because it does not allow for any fuel economy increases beyond technology that payback within 30 months or improvements in vehicles' other desirable attributes that normal technological progress under the baseline alternative would enable, the agency may overstate manufacturers' costs for improving the fuel economy of their reference fleets to meet higher standards. As noted above, however, our analysis does account for reductions in technology costs due to learning effects and the resulting increases in fuel economy, which offsets some or all of any tendency to overestimate compliance costs. At the same time, NHTSA's analysis omits any opportunity costs resulting from manufacturers' decisions to deploy additional technology to increase the reference fleet's fuel economy rather than to improve other vehicle features that buyers also value. It is difficult to anticipate the net effect of these omissions, but the agency's view is that on balance they are likely to have only modest effects on the true economic costs of meeting stricter standards.

7.1.1. Near-Term Effects in the Market for New Vehicles

This chapter describes how we estimate the effects of higher standards on new vehicle sales and the used car market. The changes in selling prices, fuel economy, and any other features of cars and LT produced during future MY will affect both sales of individual models and the total number of new vehicles sold. On balance, the agency believes that changes in prices and fuel economy resulting from manufacturers' efforts to comply with higher CAFE and fuel efficiency standards are likely to reduce total sales of new vehicles during future model years, because we assume that at the time, they decide which models to purchase, buyers value the required improvements in fuel efficiency at less than manufacturers' costs to make them.

The logic underlying this assertion is simple: if manufacturers believed that potential buyers valued higher fuel efficiency (and adjusted their purchasing decisions accordingly) sufficiently that improving it while raising vehicle prices to cover their incremental costs would increase sales, they would do so even in the absence of higher standards because their profits would rise. Conversely, the observation that manufacturers do not voluntarily provide the improvement in fuel economy even the least aggressive alternative considered here would require suggests that they believe that doing so would reduce their sales and profits.[129]

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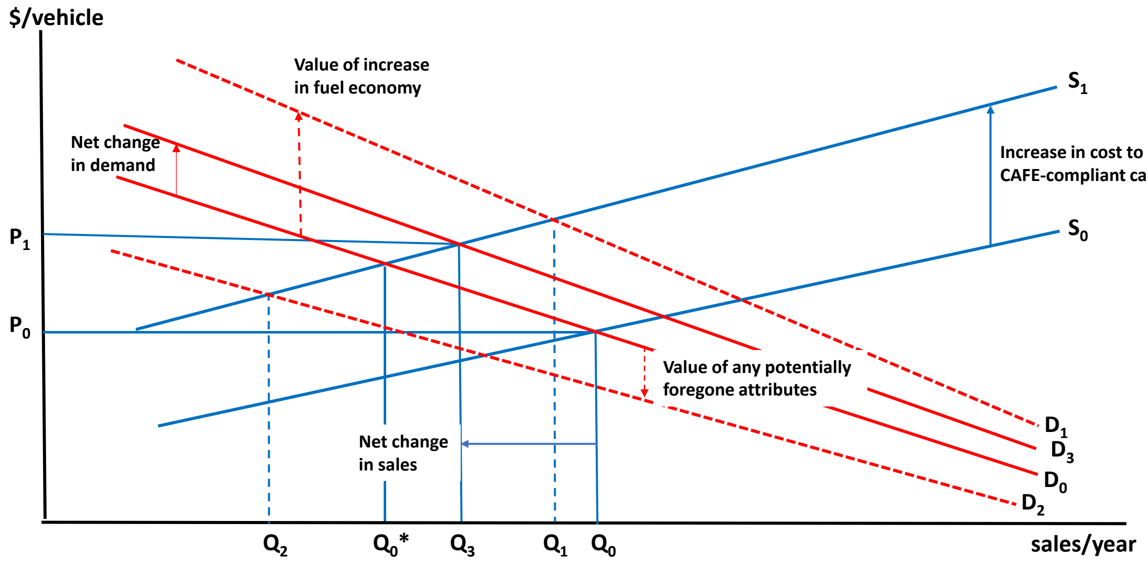
[129] Note that this could occur due to a variety of market failures, including short-termism among manufacturers, market power allowing manufacturers to focus on attributes that maximize their profits rather than those that would maximize consumer welfare, first-mover disadvantages among manufacturers with respect to experimenting with new fuel-efficiency technologies, as well as manufacturers' observation of consumer preferences as influenced by demand-side market failures and behaivoral biases.

However, the relative importance of prices, fuel economy, and vehicles' other attributes to potential buyers at the time they consider purchasing a new model and subsequently as they own and drive it is not fully understood. Their relative importance is also likely to vary widely among consumers, so their combined effect on sales of new vehicles and the market shares of individual models is difficult to anticipate. The following chapters detail our approach to estimating changes in new car, LT, and HDPUV prices, the response of sales to higher prices, and their implications for consumer welfare.

Figure 7-1 illustrates the likely near-term effect of requiring higher efficiency on total sales of new models. Under the baseline scenario, total demand for new vehicles is shown by the demand curve D_0, which relates the number that will be purchased to their average selling price. The industry-wide supply curve – which depicts the number produced during a model year and offered for sale at each price – is shown by S_0 in the figure; in the baseline alternative (where standards remain at previously-established levels), demand and supply interact to result in total sales of Q_0 vehicles at a price of P_0.

Increasing the amount of fuel economy-improving technology that manufacturers must employ by raising CAFE and fuel efficiency standards increases their costs to produce new vehicles, and this effect is shown as an upward shift in the industry-wide supply curve to S_1. To preserve their profitability, manufacturers seek to charge higher prices that reflect their increased costs (on average across their entire model lineups, if not for each individual model), and if there were no accompanying change in demand, annual sales would decrease to the level Q_0*.

Figure 7-1: Effect of Changes in Price, Fuel Economy, and Other Attributes on Demand and Sales of New Vehicles[130]



As indicated in the previous chapter, however, the fuel economy and potentially other features of some new models will also change, as their manufacturers employ more advanced technology to increase fuel efficiency and may potentially forgo some improvements they would otherwise have made in those models' other desirable features. Both changes will affect consumer demand for new vehicles, but they are likely to do so in opposite directions. On one hand, improving vehicles' fuel economy reduces their operating costs, which improves their appeal to potential buyers; by itself, this would shift demand for new vehicles upward – for illustrative purposes, to the level shown by the demand curve D_1 in Figure 7-1. The specific form of the upward shift in demand shown in the figure reflects a distribution of buyers' valuations of higher fuel economy, with those toward the upper (or left) end of D_1 willing to pay the most for increased fuel economy, and buyers showing progressively lower values of higher fuel economy moving down and to the right along D_1.

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[130] Note that this graph represents the impacts from today's proposed rule only does not show the impact of other policies such as the Inflation Reduction Act tax credits or California's ZEV mandate. To see how NHTSA has modeled these policies, please see Draft TSD Chapter 2.

In conjunction with price increases that reflect manufacturers' higher costs, the increase in demand caused by the improvement in fuel economy would limit the decline in sales to Q_1, if no other changes in vehicles' attributes occurred. At the same time, however, any accompanying sacrifice in improvements to other features that manufacturers make as part of their efforts to increase fuel efficiency could reduce new models' desirability to potential buyers; this would reduce market demand, as illustrated in Figure 7-1 by the downward shift in the demand curve to D_2.[131] In conjunction with higher prices that fully compensated manufacturers for their higher costs, the sacrifice in improvements to vehicles' other desirable features would reduce their sales to Q_2 if it were not accompanied by improved fuel efficiency.[132]

The net effect of these two changes on demand for new cars, LT, and HDPUVs is difficult to anticipate, because it depends on the specific changes in fuel economy and vehicles' other features that manufacturers make, as well as on the distributions of values that buyers attach to fuel economy and those other attributes. As Figure 7-1 shows, if buyers view the combination of higher fuel economy and more modest improvements in vehicles' other features (compared to the combinations of attributes manufacturers would have offered under the No-Action Alternative) as making future models more desirable on balance, demand for new vehicles will ultimately settle at a position such as D_3 and their price will rise to P_1. Consequently, sales will decline to the level Q_3 shown in the figure, because the effect of higher prices will outweigh the increase in new vehicles' overall desirability.

More generally, sales of new vehicles will decline as long as potential buyers find that the combination of higher prices and foregone improvements in vehicles' other features outweighs the value of their improved fuel efficiency, and the agency's assumption that buyers value only a fraction of the lifetime savings in fuel costs that purchasing a vehicle with higher fuel economy offers implies that this is the most likely response. Our analysis also assumes that the increase in new car and LT prices occurs at the outset of the model year when higher standards take effect, and that the resulting decline in their sales occurs throughout the period when that model year is on sale.

7.1.2. Near-Term Effects on the Used Vehicle Market

By affecting the fuel economy, selling prices, and other features of new vehicles, raising the standards will not only affect new vehicle sales, but will also change the demand for used models. This is because used vehicles – especially those produced during recent MY – offer a potential substitute for new models, so changes in prices and other attributes of new models will influence demand for used versions. This will affect the market value and selling prices of used vehicles, which in turn will influence some owners' decisions about whether to make the repairs necessary to keep their used models in service and how much to drive them.

Regulations on new cars can also affect their durability and retirement rates directly by changing their cost to repair and maintain, and thus affecting their owners' decisions about how long to keep them in use. Changes in the number of used vehicles kept in service and how much they are driven can have important consequences for fuel consumption, safety, and emissions of GHGs and criteria air pollutants, so it is important for the agency to consider how raising standards will affect the number and use of older vehicles. The indirect effect of regulations that raise prices for new vehicles on the size and utilization of the used vehicle fleet has been well documented and is the subject of extensive empirical research and is often referred to as the "Gruenspecht effect."[133]

Figure 7-2 illustrates the immediate effects of higher standards on the market for used cars, LT, and HDPUVs. Faced with higher prices for new models that feature improved fuel economy, some households and businesses will choose to rely on used cars or LT as an alternative to purchasing new ones. Their decisions

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[131] Note that NHTSA does not include any estimate of the foregone value of other vehicle attributes in the primary analysis of light-duty fuel economy standards or the the primary analysis of the HDPUV fuel efficiency standards.

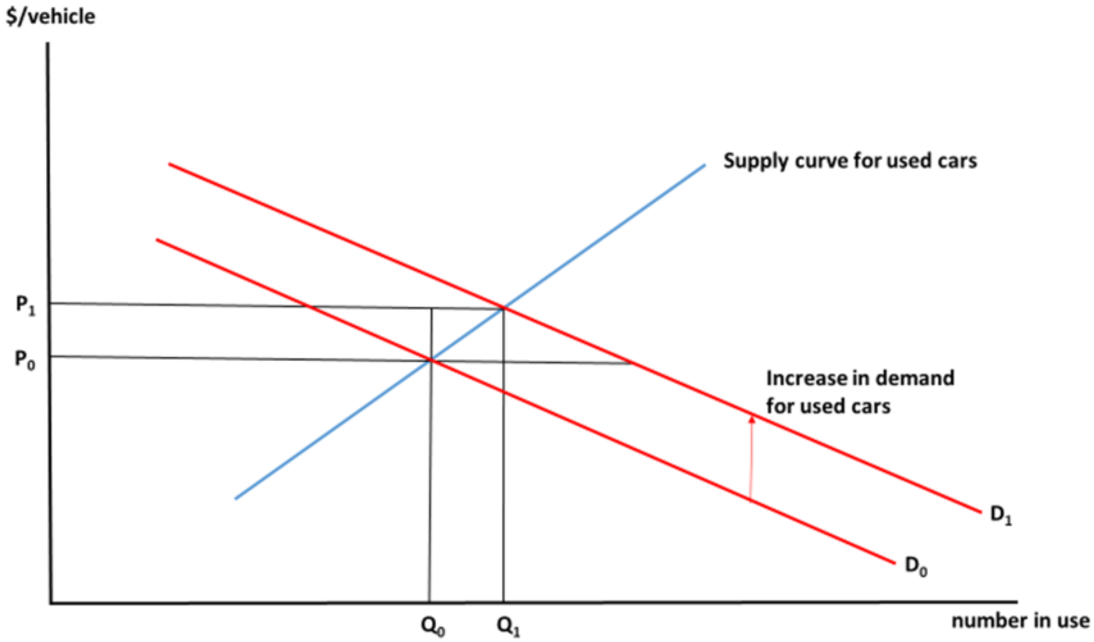
[132] NHTSA notes that some elements of performance are held constant across regulatory alternatives. Since we do not allow them to vary in response to changes in the standard, the CAFE Model does not provide a mechanism through which these tradeoffs can be directly analyzed. Thus it would be inappropriate for NHTSA to monetize any opportunity cost associated with those attributes. Similarly, there are other vehicle attributes that could trade off with fuel economies such as size, as heated seats, advanced entertainment systems, or panoramic sunroofs, which are amenities consumers value but are unrelated to the performance of the drivetrain (e.g. these attributes do not impact the engine's horsepower). Some of these attributes such as panoramic sunroofs are unlikely to to have a significant impact on fuel efficiency. Modeling these attributes goes beyond the scope of the model and so we do not assign an opportunity cost associated with these potential tradeoffs in the primary analysis.

[133] This reference is to the author who originally identified and analyzed this effect; see Howard Gruenspecht.

will increase demand for used vehicles, shifting the demand curve for used models in the figure from its original position at D_0 outward to D_1.

Shifts in demand for used vehicles of different ages in response to changes in the prices and attributes of new models are likely to mirror how closely they substitute for their new counterparts. Nearly new vehicles offer the closest substitute for new ones, so their demand is likely to be most responsive to changes in prices and other characteristics of new ones. In contrast, the outdated features and accumulated usage of older vehicles make them less satisfactory substitutes, so their demand is likely to be less responsive to higher prices for new models. Thus, demand for nearly new vehicles is likely to increase significantly when prices for new models rise, while increases in the demand for older vehicles are likely to be progressively smaller.

Figure 7-2: Effect of Increasing CAFE Standards on the Market for Used Vehicles



In Figure 7-2 the position of the supply curve for used vehicles reflects the initial size of the used vehicle fleet at the outset of the period, which in the agency's analysis is the current new-car model year and corresponding CY. Although the supply of used vehicles is likely to be relatively insensitive to changes in their price (or "inelastic"), it is not fixed. For example, owners can increase the number of vehicles that are available by spending more on the maintenance and repairs necessary to keep older models in service rather than retiring them. This is shown by the upward-sloping supply curve in Figure 7-2, which reflects the fact that the repairs and maintenance necessary to increase the number of used vehicles in usable condition are likely to become progressively costlier as more owners of those that would otherwise have been retired decide instead to keep them in use.

The interaction of increased demand for used models and their inelastic supply will cause their average market value and selling price to rise, from P_0 to P_1 in Figure 7-2. Some owners who would previously have retired their used vehicles will find that their higher market value justifies the expense of the added maintenance and repairs necessary to keep them in use longer, so the increase in their price will raise the number remaining in service, from Q_0 to Q_1. Because the market for used vehicles is very active – annual sales of used vehicles have averaged nearly 40 million in recent years, nearly three times the number of new models sold– these responses are likely to occur rapidly, probably within the same model year as those in the new car market shown previously in Figure 7-1.

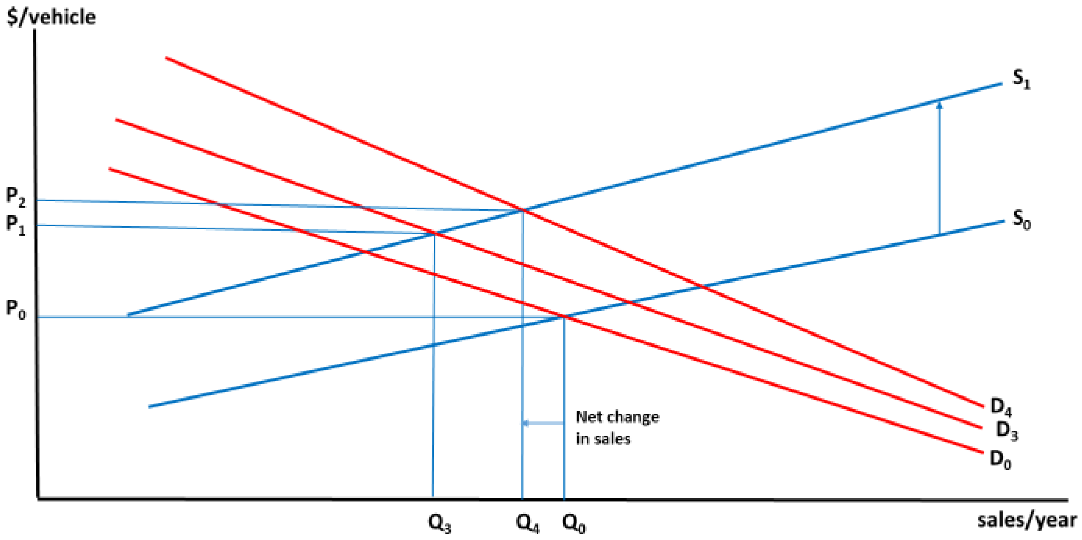
These indirect effects of raising CAFE and fuel efficiency standards on the used vehicle market will continue as long as those standards continue to be raised. In effect, this process will slow the "turnover" of the nation's vehicle fleet from its pace under the baseline, by reducing the rate at which models enter the fleet to replace the used vehicles that are retired each year. Coupled with the reduction in sales of new vehicles likely to result from raising standards, the resulting increase in the number of used models kept in service will in effect “transfer” some travel that would have been done in new vehicles to older models. As emphasized throughout this regulatory analysis, this shift of travel toward older cars and LT has important implications for fuel consumption, safety, and the environmental externalities associated with producing and consuming fuel.

7.1.3. Longer-Term Effects on New and Used Vehicle Markets

Because new and used vehicles can substitute for each other in meeting households’ and businesses’ demands for transportation services, the change in used vehicle prices will have secondary effects in the markets for new cars, LT, and HDPUVS, as Figure 7-3 illustrates. Higher prices for used vehicles in turn increase demand for new models, and this effect is shown in Figure 7-3 as a shift in demand for new vehicles outward from D_3, its final near-term position shown previously in Figure 7-1, to D_4. In conjunction with the upward-shifted supply curve shown previously in Figure 7-1, which reflects manufacturers’ increased costs to produce CAFE-compliant new cars and LT and new HDPUVs that meet higher standards for fuel efficiency, this secondary increase in demand raises their prices further from their ultimate level P_1 in Figure 7-1 to P_2 in Figure 7-3.

At the same time, however, the further outward shift in the demand curve for new vehicles mitigates the near-term decline in their sales; in Figure 7-3, new car and LT sales ultimately settle at Q_4, a level higher than their near-term equilibrium level Q_3 shown previously in Figure 7-1, although still lower than their baseline level Q_0. Thus, the longer-term effect of raising standards on sales of new vehicles is likely to be more modest than it would have been if new and used vehicles were not substitutable and there were no interactions between markets for the two. In contrast, the ultimate effect on prices for new vehicles may be larger than the immediate effect, although the secondary increase in response to higher used car prices is likely to be modest, as Figure 7-3 suggests.

Figure 7-3: Longer Term Effects on Sales and Prices of New Vehicles



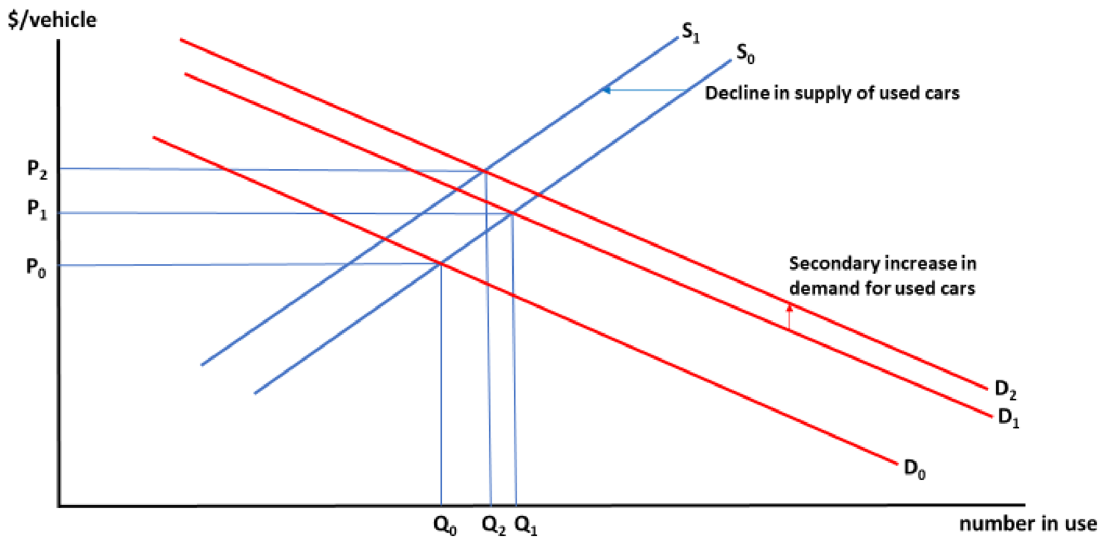
Finally, there are also likely to be important secondary impacts on the market for used vehicles. First, the secondary increase in prices for new vehicles will raise demand for their used counterparts, again because – within limits imposed by changes in their design over time and the effects of accumulated use – the two can substitute for each other in providing transportation services for households and businesses. At the same time, the decline in sales of new vehicles during the current model year reduces the supply of used models available in future years, and this effect accumulates over time, particularly if CAFE and fuel efficiency standards are raised year after year as has been the recent case.

This occurs simply because fewer new cars are initially produced and sold during each model year subject to higher standards, so fewer remain in use at the outset of any subsequent CY and thus available to be maintained in (or restored to) working condition when their market values rise. While the effect of higher new-car prices on demand for used vehicles is likely to be felt within the current model year, the reduction in their supply resulting from lower new vehicle sales will accumulate more gradually over time.

Figure 7-4 illustrates these longer-term effects. The secondary increase in prices for new vehicles increases demand for used cars further relative to the near-term effect of higher new car prices, shifting the demand curve from its previous position at D_1 in Figure 7-2 further outward to D_2 in Figure 7-4. At the same time, the reduction in sales of new models reduces the supply of used versions available in future years, and this effect – which accumulates over time, as noted above – is represented in Figure 7-4 as an inward shift in the supply curve for used vehicles, from S_0 to S_1. Increased demand and reduced supply of used vehicles interact to raise their average price further beyond its near-term increase to P_1 shown previously in Figure 7-2, to the higher level P_2 in Figure 7-4.

In response to this secondary increase in their market value, the number remaining in working condition adjusts further; depending on the relative magnitudes of the shifts in demand and supply, the final equilibrium size of the used vehicle fleet can be larger or smaller than in the nearer term. Figure 7-4 illustrates the case where the effect of reduced supply outweighs that of increased demand and the number of used vehicles in service (Q_2) declines relative to the near term (Q_1). However, the more certain and important effect is that the final equilibrium size of the used vehicle fleet (Q_2 in Figure 7-4) is larger than it would have been if CAFE and fuel efficiency standards were not raised and instead remained at their baseline levels (Q_0).

Figure 7-4: Longer Term Effects on Prices for Used Vehicles and the Number Remaining in Use



In theory, these reciprocal responses of new- and used-car demand to increasing prices for each other continue until markets for the two jointly reach a new equilibrium, although in practice these further adjustments seem likely to "dampen out" relatively quickly. It is difficult to anticipate exactly how long these complex adjustments will continue, but most of the ultimate change in new vehicle prices and sales should be largely complete within the same model year when higher standards take effect. However, the complete effects on prices and sales of used vehicles shown in Figure 7-4 are likely to require considerably longer to be fully felt, because they depend in part on the longer-term cumulative effect of lower new vehicle sales on the supply of used models.[134]

7.1.3.1. Estimating Impacts in the New and Used Vehicle Markets

We use an econometric model that captures the historical relationship of new car and LT sales to the number of U.S. households, disposable personal income, and other economic variables to project future sales of new vehicles under the baseline alternative. To estimate the effect of increased costs to produce new vehicles and the resulting higher prices when CAFE standards for future MY are raised, NHTSA applies a price elasticity of new vehicle sales of -0.4, which implies that for example, a 10 percent increase in new vehicles' average price causes a 4 percent decline in their total sales.[135] The agency estimates the shares of future sales accounted for by cars and LT starting with EIA fleet share projections and modeling changes across alternatives based on relatively changes in regulatory costs between cars and light-trucks. Finally, NHTSA uses a combination of historic compliance data, EIA's forecast of HDPUV sales reported in that agency's 2022 AEO, and, like LDVs, the change in regulatory costs across alternatives to model HDPUV sales for this analysis. Development and use of these forecasts are described in detail in Chapter 4.2 of the Draft TSD accompanying this proposed rule.

To estimate the effects of raising new vehicle standards on the used vehicle fleet, we use a detailed econometric model relating prices, fuel economy, and other characteristics of new vehicles to age-specific retirement rates for each vintage of used vehicles making up the current year's fleet. This model also controls for the increasing durability of new vehicles over time, FPs, macroeconomic conditions, maintenance and repair costs, and other factors that influence year-to-year variation in used vehicles' retirement rates. Our development and use of this model is described in Chapter 4.2.2 of the Draft TSD accompanying this proposed rule.

7.1.4. Welfare Effects in the New and Used Vehicle Markets

The likely decline in sales of new vehicles during future MY when stricter CAFE and fuel efficiency standards take effect produces two potential sources of economic costs. Figure 7-5 illustrates these costs for the simplified case where demand for new vehicles increases (from D_0 to D_1) as their manufacturers improve fuel economy to comply with stricter standards but make no accompanying sacrifices in their models' other attributes. Although the upward shift in the demand curve in response to improved fuel economy by itself would increase sales, higher prices – which rise from P_0 to P_1 as producers attempt to recoup their higher costs for producing vehicles meeting the stricter standard – suppress sales by more than enough to offset this gain. On balance, sales of new cars and LT decline to Q_1.

On one hand, this example provides a conservative estimate of costs, because if manufacturers forego any improvements in vehicles' other features as part of their effort to increase fuel economy, the decline in sales will be larger than Figure 7-5 shows, as the discussion accompanying Figure 7-1 above indicated. On the other hand, the assumption of "perfectly elastic" supply (indicated by the horizontal supply curve shown in the figure) may slightly exaggerate the increase in prices. Under the perhaps more realistic assumption of something less than perfectly elastic supply of new vehicles, manufacturers would absorb some of their increased costs to meet a stricter standard, so the increase in prices and resulting decline in sales would be slightly smaller than Figure 7-5 shows.[136]

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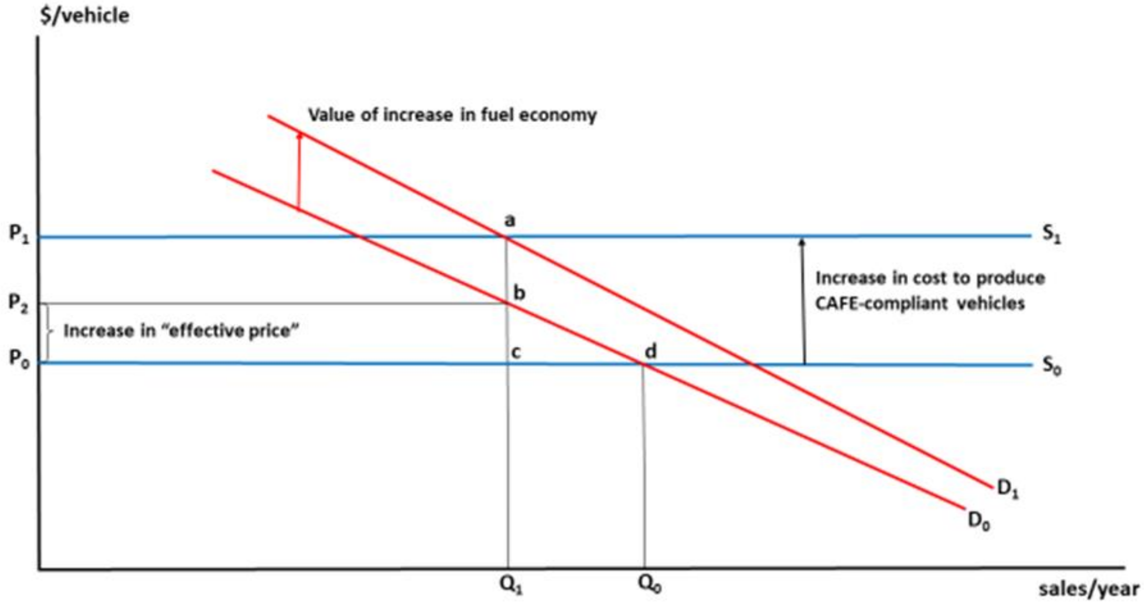
[134] For more information on this effect, see U.S. EPA. Assessment and Standards Division. The Effects of New-Vehicle Price Changes on New- and Used-Vehicle Markets and Scrappage. RTI International. EPA Contract No. EP-C-16-021, Work Assignment No. 4-28. Technical Report EPA-420-R-21-019. August 2021.

[135] This estimate is drawn from *ibid*., Chapter 7.

[136] Of course, in that case there would also be a reduction in producer surplus, which represents a welfare loss to manufacturers and those owning a financial interest in them.

Figure 7-5: Welfare Effects in the Market for New Vehicles



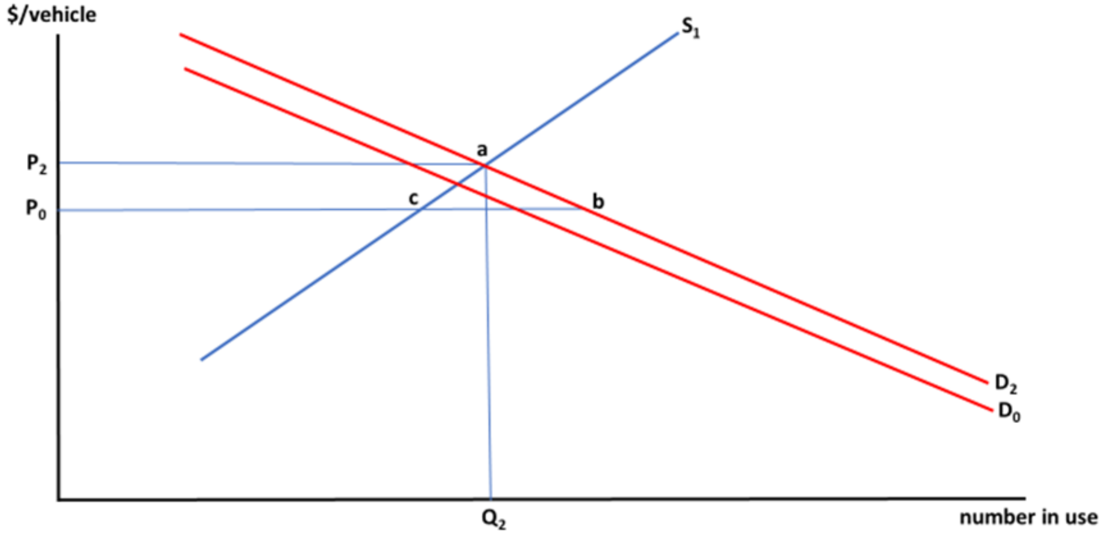
First, although buyers who purchase new vehicles even at their increased price are likely to be those with the highest values of improved fuel economy, they collectively experience some loss in welfare from the combination of higher prices and improved fuel economy. Their net loss in welfare is measured by their increased outlays to purchase Q_1 new vehicles, shown as rectangle P_1acP_0 in Figure 7-5 (its area is the increase in price multiplied by the number that continue to be sold), minus the value they attach to the savings in fuel costs that result from higher fuel economy.

This latter value is the smaller rectangle P_1abP_2, since its area equals the value of improved fuel economy (the distance ab, or the upward shift in the demand curve) multiplied by the number of new vehicles that continue to be sold (Q_1). Together, these partly offsetting impacts leave net losses to continuing buyers equal to rectangle P_2bcP_0. Another way to view this result is that the "effective price" of new vehicles – the difference between the actual increase in their price and the increase in their value due to their higher fuel economy – increases only from P_0 to P_2, so the loss to "continuing" buyers is equal to the product of this effective price increase and the number of vehicles that continues to be sold, which is again rectangle P_2bcP_0.

Second, some buyers who would have purchased new vehicles under the baseline standard will decide not to do so once stricter CAFE and fuel efficiency standards take effect, and these buyers experience smaller losses in welfare. Their valuation of higher fuel economy is slightly lower than those who continue to purchase new vehicles, and consequently the increase in average prices deters their purchases and reduces the number sold from Q_1 to Q_0. The welfare loss to buyers who forego purchases they would otherwise make because of new vehicles' higher "effective price" averages one-half of those to continuing buyers of new vehicles, or $\frac{1}{2}*(P_2-P_0)$, and their total loss is represented by triangle bcd in Figure 7-5.

The previously discussed consequences of higher standards in the used vehicle market for economic welfare are complex. Higher prices for used vehicles result in a loss of consumer surplus to their potential buyers, which is shown in Figure 7-6 below (a simplified version of the previous Figure 7-4) as the area P_2abP_0. However, much of this loss is simply a transfer to suppliers of used cars and LT, who are a combination of retail dealers and individual owners selling used vehicles on the private market. Collectively, they experience a gain in "producer surplus" equal to area P_2acP_0 in Figure 7-6, which offsets much of the loss in consumer surplus to buyers; the remaining uncompensated loss in consumer surplus is the triangle abc. Estimating the value of this loss would require detailed data on prices for used cars and LT of different ages, together with estimates of both the elasticity of their supply (which would also be expected to vary with age) and the "cross-elasticities" of demand for used cars and LT of varying ages with respect to the prices of new models. The agency lacks such detailed information.

Figure 7-6: Welfare Effects in the Market for Used Vehicles



As discussed previously, however, the increase in used vehicle prices that creates these welfare effects in the used vehicle market also causes an increase in demand for new cars and LT, which will ultimately be incorporated in the longer-run upward shift of the new-car demand curve (D_4) shown previously in Figure 7-3. Although not shown explicitly there, the further increase in new-car demand that occurs in response to higher prices for used vehicles acts much like the improvement in new cars' fuel economy, by limiting the decline in their sales and the accompanying loss in consumer surplus to their would-be buyers. Under reasonable assumptions, this reduction in the welfare loss to new vehicle buyers will approximately offset the net loss in welfare in the market for used vehicles.[137] Hence our analysis omits both effects, under the assumption that including them would have little effect on the comparison of total costs and benefits from imposing higher standards.

7.2. The Effect of Higher Standards on Vehicle Use

The fuel economy rebound effect – a specific example of the well-documented energy efficiency rebound effect for energy-consuming capital goods – refers to the tendency of motor vehicles' use to increase when their fuel economy is improved and the cost of driving each mile declines as a result. Increasing CAFE and fuel efficiency standards will lead to higher fuel economy for new cars, LT, and HDPUVs, thus reducing the amount of fuel they consume per mile. The resulting decline in the cost to drive each mile will lead to an increase in the number of miles they are driven over their lifetimes. For its analysis of this final rule, we use a value of 10 percent for the fuel economy rebound effect, which implies that a 10 percent increase in fuel economy will produce a 1 percent increase in average annual driving.

7.2.1. The Fuel Economy Rebound Effect and Vehicle Use

Figure 7-7 illustrates the effect of new vehicles' higher fuel economy on the number of miles they are driven annually. As it shows, vehicles' per-mile operating costs include the cost of fuel they consume, the expected cost associated with potential crashes, maintenance and repair outlays, operating costs other than fuel (oil, tire wear, etc.), and the value of their occupants' travel time. Requiring new vehicles to achieve higher fuel

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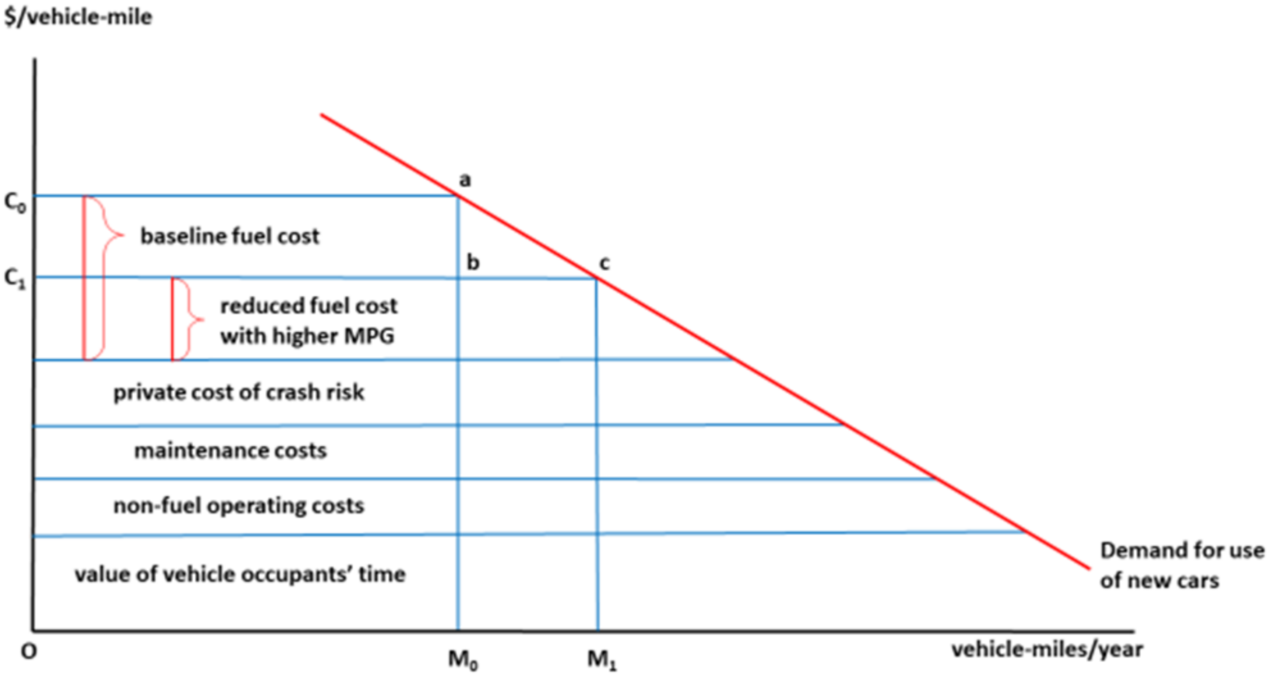
[137] Boardman, Anthony E., David H. Greenberg, Aidan R. Vining, and David L. Weimer. 2001. Cost-Benefit Analsyis: Concepts and Practice, 2nd edition. Upper Saddle River NJ, Prentice Hall Inc.; Mohring, Herbert. 1993. Maximizing, Measuring, and Not Double-Counting Transportation Improvement Benefits: A Primer on Closed- and Open-Economy Cost-Benefit Analysis. Chapter 5. Transportation Research, Vol. 27 No. 6, pp. 413-424.

efficiency reduces the amount of fuel they consume each mile they are driven and lowers their per-mile driving cost, shown in the figure as a reduction in the total cost of driving each mile from C_0 to C_1. If the use of new cars and LT remained unchanged, their owners' total savings in fuel costs would be the rectangle C_0abC_1, whose area is the product of the reduction in per-mile fuel costs and the number of miles driven. However, the decline in driving costs leads to a downward movement along the demand curve for vehicle use, increasing the average number of miles that new cars and LT are driven annually from M_0 to M_1.

Figure 7-7: Effect of Increasing CAFE Standards on New Vehicle Use



While this increase in driving offsets a small fraction of the fuel savings that would otherwise result, it also creates additional economic benefits (as well as a variety of indirect economic benefits and costs, which are discussed in subsequent chapters). First, vehicle buyers' annual outlays for fuel will decline throughout the lifetimes of the models they purchase, as raising standards leads to higher fuel economy levels and reduces fuel consumption. The magnitude of this benefit depends on how much new vehicles' average fuel economy increases when future standards are raised, how much they are driven each year, and future retail prices for fuel.

During the year they are initially sold, it is measured by the difference between drivers' annual driving costs with higher standards in effect, area C_1cM_1O in Figure 7-7, and their driving costs with the lower baseline standards in effect, or C_0aM_0O. This difference – which is negative, indicating that it represents a net savings – is also equal to the cost of fuel consumed by the additional driving (area bcde) minus the savings in fuel costs on the amount of driving that would have been done under the baseline that results from improved fuel economy (area C_0abC_1).

The agency estimates the savings in new vehicles' annual fuel costs using improvements in the fuel economy of individual car, LT, and HDPUV models projected to result from raising CAFE and fuel efficiency standards, estimates of how much they will be used with and without the increased driving due to the rebound effect of higher fuel economy, and forecasts of FPs from the EIA's AEO 2022. As indicated above, this savings declines over vehicles' lifetimes as they are driven less and gradually retired from use, although their annual value also varies in response to forecast changes in FPs. The savings in fuel costs for a new vehicle produced during each future model year required to meet higher CAFE and fuel efficiency standards will equal this same area during the year it is initially sold and decline similarly over its lifetime in the fleet.

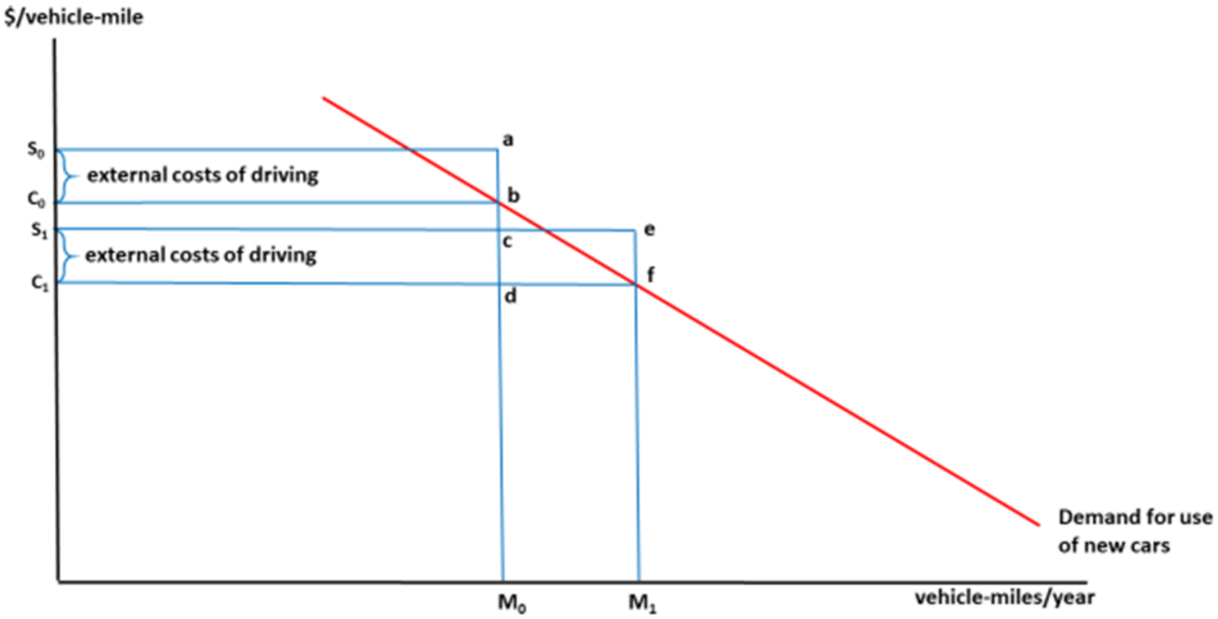
Second, the additional mobility associated with increased driving provides some benefits to new vehicle buyers. These benefits must be more than sufficient to offset the costs of their additional driving, including expenses for fuel, vehicle depreciation, other operating costs, maintenance, the value of travel time, and the increased safety risks they assume; if they were not, no additional driving would occur. In Figure 7-7, mobility benefits from increased driving are equal to the area M_0acM_1, which exceeds the total cost of the additional driving, area M_0bcM_1. The amount by which they do, which is shown as the area abc in Figure 7-7, measures the net benefit (or gain in "consumer surplus") to buyers of new vehicles trucks from their additional driving. Following the usual procedure, we estimate the dollar value of this welfare gain assuming the demand curve for vehicle use is linear over the relevant range, so its annual value can be calculated as one-half of the product of the decline in driving costs ($C_0 - C_1$) and the increase in vehicle use ($M_1 - M_0$).

7.2.2. Externalities from Increased Rebound-Effect Driving

Additional vehicle use generates external costs via increased traffic congestion and roadway noise, more exposure to accident risks, adverse health effects from air pollution, and climate-related damages caused by emissions of GHGs. The increase in driving that vehicle operators may choose to do with new vehicles are required to achieve higher fuel economy can offset some of the health and climate benefits from lower fuel consumption, while also increasing traffic congestion and roadway noise. Although setting more stringent fuel economy standards will on balance reduce adverse health effects from air pollution and climate related damages caused by GHG emissions, the increases in external costs caused by added rebound-effect driving represent additional costs of setting higher fuel economy targets that must be accounted for.

Figure 7-8 illustrates how NHTSA estimates these costs; like the preceding figure, it shows the demand for travel using new vehicles and illustrates the effect of the reduction in per-mile driving costs on their increased use that occurs when their fuel economy improves. For simplicity, however, Figure 7-8 omits the detailed breakdown of total driving costs shown previously, and instead shows the combined external costs imposed by new vehicles' contributions to traffic congestion, road noise, injuries and property damage from crashes, air pollution, and climate-related damages. We assume that the per-mile value of these costs is unaffected by the change in vehicle use that occurs in response to improved fuel economy.

Figure 7-8: Externalities Caused by Increasing Use of New Vehicles



As in Figure 7-7 previously, Figure 7-8 denotes private costs as C_0 prior to the increase in fuel economy and C_1 with improved fuel economy; per-mile external costs are added to these to estimate the total SCs associated with each mile driven, denoted S_0 and S_1. At the level of new vehicle use with the baseline standards in effect, these external costs are equal to the product of their per-mile value (shown as the distance $S_0 - C_0$ in Figure 7-8) and the initial level of vehicle use M_0, or the rectangular area S_0abC_0. With the increased level of driving that occurs when fuel economy increases (M_1 in Figure 7-8), the total cost of these externalities is again the product of their per-mile value ($S_1 - C_1$) and this higher level of use M_1, or the rectangular area S_1efC_1.

If the per-mile value of these externalities is unaffected by the increase in new vehicles' use, as the figure illustrates (that is, the distances $S_1 - C_1$ and $S_0 - C_0$ are equal), total external costs will increase by the area of the rectangle cefd, which is equal to the increase in the number of miles driven ($M_1 - M_0$), multiplied by the per-mile value of external costs ($S_1 - C_1$). In words, this additional cost is the difference between the total cost of driving-related externalities caused by new cars and LT with higher CAFE and fuel efficiency standards in effect, and the value of those costs if the baseline standards had remained in effect. It is a direct consequence of the additional driving estimated to result from the fuel economy rebound effect.

The agency's analysis calculates the increase in each of these external costs resulting from more intensive use of new cars and LT separately. The increase in GHG emissions from additional driving and fuel use is already reflected in the net reduction in total GHG emissions from raising standards, since this net reduction reflects the decline in fuel production and use after accounting for the additional fuel consumed by increased driving. Increases in emissions of criteria air pollutants are calculated from the increased number of miles driven in new cars, LT, and HDPUVs, together with per-mile emission factors for future model year vehicles of these three types derived from EPA's Motor Vehicle Emission Simulator (MOVES) model (which reflect future changes in emission standards).

Increases in costs of congestion and road noise are calculated using incremental per-mile contributions of car and LT use to delays and noise originally estimated by the FHWA and updated for this analysis. Finally, we assume that drivers consider only 90 percent of the added risk of injuries and property damage in crashes they create when they elect to travel more, so 10 percent of the increase in these costs also represents an external cost of added rebound-effect driving.

7.3. Safety Implications of Higher Standards

In setting standards, there are secondary effects on vehicle safety resulting from changes in fuel economy. NHTSA, as a safety agency, has long conserved the potential effects of CAFE standards on safety when establishing new CAFE standards. The safety consequences considered include all impacts from motor vehicle crashes, including fatalities, nonfatal injuries, and property damage.

The safety analysis includes the comprehensive measure of safety impacts from three factors:

1. Change in Vehicle Mass: Change in vehicle mass affects the prevalence of injuries and fatalities on roadways. Increases in vehicle mass might confer additional safety to vehicle occupants while also reducing safety for pedestrians, cyclists, and other vulnerable road users, as well as for road users with lower mass vehicles.
2. Impacts of Vehicle Prices on Fleet Turnover: Advanced Driver Assistance Systems (ADAS) reduce the frequency (and severity) of certain crash types. As manufacturers adopt these technologies and as the technologies improve, newer vehicle models confer additional safety benefits. Since standards can affect the price of vehicles, changes in standards can affect the turnover of vehicles in the fleet and thus the prevalence of ADAS technologies in the vehicle fleet.
3. Increased Driving from Improved Fuel Economy (Rebound Effect): More stringent standards lower the marginal cost of operating a vehicle and if the perceived value of driving remains stable across time, then vehicle operators may choose to drive additional miles because of increased fuel economy. The additional driving of new vehicles from this rebound effect translates into additional fatalities and injuries.[138]

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[138] Chapter 7 of the Draft TSD describes the modeling of future fatalities and injuries from a safety baseline, the modeling of specific ADAS technologies on safety, the modeling of the impact of weight reduction on safety, and the modeling of the impact of the rebound effect on safety.

The contribution of the three factors described above generate the differences in safety outcomes among regulatory alternatives.[139] The agency's analysis makes extensive efforts to allocate the differences in safety outcomes between the three factors. Fatalities expected during future years under each alternative are projected by deriving a fleet-wide fatality rate (fatalities per vehicle mile traveled) that incorporates the effects of differences in each of the three factors from baseline conditions and multiplying it by that alternative's expected VMT. Fatalities are converted into the societal cost by multiplying fatalities with the DOT-recommended value of the statistical life (VSL) supplemented by the economic impacts that are external to VSL measurements. Traffic injuries and property damage are also modeled directly using the same process and valued using the costs that are specific to each injury severity level.[140]

7.4. Effects of Higher Standards on Fuel Consumption

Raising standards for the fuel economy of new cars and LT and the fuel efficiency of HDPUVs will significantly reduce demand for transportation fuels. Because gasoline and diesel – which account for the vast bulk of energy consumed by these vehicles – are refined from petroleum, U.S. demand for petroleum will decline, and this will be reflected in some combination of reduced U.S. production and imports of crude oil or fuels refined outside the U.S. Extracting and refining petroleum and distributing fuel for retail sale produces additional emissions of criteria air pollutants and GHGs beyond those from vehicles' consumption of fuel, so reducing the volume of fuel supplied will generate additional benefits in the form of reductions in the climate and health damages these emissions cause. Finally, reduced spending for fuel by drivers of new vehicles will lower tax revenues to both Federal and state governments, which typically fund spending on transportation infrastructure or other programs, and this will offset part of those drivers' savings in retail outlays for fuel.

7.4.1. Impacts on Fuel Use and Spending

Imposing more stringent CAFE and fuel efficiency standards will reduce U.S. demand for petroleum-based transportation fuels, shown in Figure 7-9 as a downward shift in the demand curve for fuel. Vehicles subject to the higher standards will save fuel throughout their lifetimes, while added rebound-effect driving and the shift of some driving to used cars will partly offset this savings, but on balance total fuel demand will decline. The U.S. domestic supply of refined transportation fuels appears to be extremely "price-elastic" – that is, increasing production does not exert significant upward pressure on refining costs and FPs – so reducing demand is not expected to lower FPs, as the figure indicates. Because of lower demand, total fuel consumption will decline from G_0 to G_1 in Figure 7-9, and spending on fuel will be reduced by the rectangular area G_1beG_0. The dollar value of this area is equal to the retail price of fuel per gallon, labeled P_{retail} in the figure, multiplied by the decline in the number of gallons consumed, or $G_1 – G_0$.

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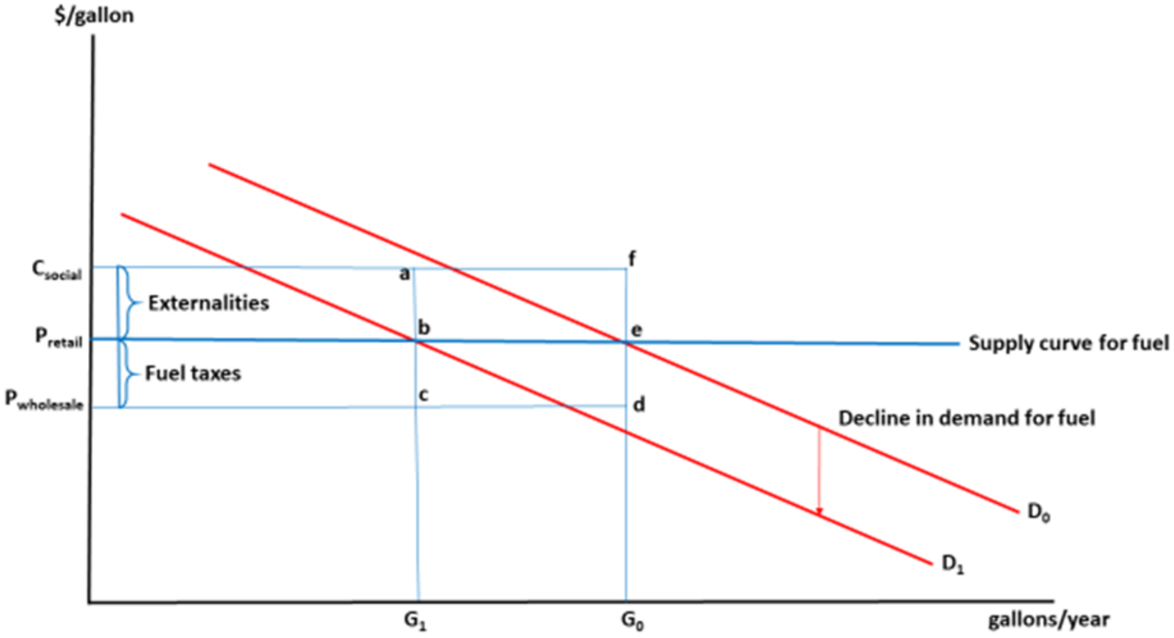
[139] The terms safety performance and safety outcome represent different related concepts. Safety performance refers to intrinsic safety of a vehicle based on its design and features. Safety outcome describes whether a vehicle has been involved in a crash and the severity of the crash. Safety outcomes are influence by safety performance, and other factors such as behavioral characteristics of vehicle operators or driving environment.

[140] For additional descriptions on the valuation of safety impacts please refer to Chapter 7.7 of the Draft TSD.

Figure 7-9: Effect of Proposed Standards on Fuel Consumption and Spending



The agency's analysis measures savings in fuel spending by car, LT, and HDPUV owners using retail FPs, which include a significant tax component – Federal, state, Tribal, and some local governments impose taxes on gasoline and diesel that together average approximately $0.50 per gallon. Thus, some fraction of drivers' savings in fuel costs – shown as the rectangle c, b, e, and d in Figure 7-9 – represents lower tax payments; their yearly dollar value is the product of average fuel taxes per gallon and the decline in the number of gallons consumed annually. However, the loss in benefits from lower spending on programs funded from fuel tax revenue is exactly offset by the part of drivers' savings in retail fuel costs that represents lower fuel tax payments, so on balance it leaves net social benefits from requiring higher fuel economy unaffected.

7.4.2. Externalities from Refining and Consuming Fuel

Extracting and transporting crude petroleum, refining it to produce transportation fuels, and distributing fuel generate additional emissions of GHGs and criteria air pollutants beyond those from vehicles' use of petroleum-derived fuels. By reducing the volume of fuel produced and consumed, adopting higher CAFE and fuel efficiency standards mitigates global climate-related economic damages caused by accumulation of GHGs, as well as the more immediate and localized health damages caused by exposure to criteria air pollutants. Because they fall broadly on the United States – and globally, in the case of climate damages – population and economy, reducing them represents an external benefit from requiring higher fuel efficiency.

In Figure 7-9, the economic cost of climate and health damage externalities is shown as the difference between the SC of supplying fuel C_{social} and its retail price P_{retail}, and these costs are assumed to be constant on a per-gallon basis. The reduction in economic costs of climate and health damages resulting from lower fuel consumption is the rectangular area labeled bafe in the figure, which is equal to the product of their per-gallon value and the reduction in the number of gallons of fuel supplied and consumed.

We calculate the reduction in GHG emissions throughout the global fuel supply chain ("upstream" emissions) directly from the estimated savings in the volume of fuel refined and consumed, using emission rates derived from Argonne's GHGs, Regulated Emissions, and Energy Use in Transportation (GREET) model and procedures described in Chapter 5.2 of the Draft TSD accompanying this proposed rule. As with GHG emissions from fuel use itself, the agency uses unit damage costs of GHG emissions reported in recent draft guidance issued by the Federal IWG on the Social Costs of Greenhouse Gases to convert these reductions in GHG emissions to economic benefits.

Our evaluation also accounts for benefits from reducing domestic emissions of criteria air pollutants that occur during fuel refining and distribution, again using emission rates for different fuels derived from Argonne's GREET model. Although the U.S. population may also be exposed to criteria emissions from Canadian and Mexican fuel production, this is not estimated as part of our analysis. Health damage costs resulting from increased population exposure to harmful accumulations of these pollutants were obtained from recent EPA analyses; these costs differ between vehicle and upstream emissions, reflecting differences in their geographic dispersal, accumulation, and resulting population exposure. Detailed descriptions of the sources used to develop these inputs appear in Chapter 6.2 of the Draft TSD.

7.4.3. Effects on Petroleum Consumption and U.S. Energy Security

Reducing U.S. fuel consumption will reduce the nation's demand for crude petroleum, and the United States accounts for a large enough share of global oil consumption that lower domestic demand could reduce total petroleum demand enough to lower its global price. This would reduce the transfer of revenue from consumers of petroleum products to global oil producers, since consumers worldwide would pay lower prices; some analysts assert that this transfer is an economic externality resulting from domestic consumption of petroleum products, and that reducing it represents an additional economic benefit from raising U.S. CAFE standards. In the case where large oil producers (e.g., OPEC, Russia) can exercise market power to sustain global prices above competitive levels, a reduction in price caused by decreased U.S. oil consumption would also contribute to greater potential economic growth.

Reducing U.S. petroleum consumption via higher fuel economy will also reduce the exposure of U.S. consumers to sudden increases in oil prices. If households and businesses that use petroleum products do not bear all of these costs (that is, if they are partly "external" to consumers), reducing them could provide wider benefits to the U.S. economy. Finally, reducing U.S. demand for imported petroleum and reducing the exposure of U.S. consumers to global oil shocks might also enable reductions in military spending to secure oil supplies from unstable regions of the globe, particularly as demand reductions from successive increases in fuel efficiency standards accumulate over time.

These three effects are usually referred to collectively as "energy security externalities" caused by U.S. petroleum consumption and reducing them is often cited as a potential economic benefit of lowering U.S. oil demand. Thus, each of these effects represents another potential benefit of adopting the more stringent CAFE and fuel efficiency standards analyzed here. Chapter 6.2.4 of the Draft TSD assesses the extent to which lowering domestic gasoline use will directly reduce each of these effects, whether reducing it represents a net economic benefit, and whether and how such benefits could be measured. Briefly, it concludes that only reducing potential external costs from sudden increases in petroleum prices, which U.S. consumers have experienced repeatedly in recent decades, represents a potentially significant and measurable economic benefit from tightening standards. We thus include reducing the probability-weighted or "expected" value of external costs from petroleum consumption to measure the improvement in U.S. energy security from imposing stricter CAFE and fuel efficiency standards but exclude any reduction in revenue transfers from lower prices or savings in U.S. military spending.

8. Effects of Regulatory Alternatives for the LDV Fleet

8.1. Overview

CAFE Model Files Referenced in this Chapter

Below is a list of CAFE Model Files referenced in this chapter. See TSD Chapter 2.1.9 Where can I find the internal NHTSA files? for a full list of files referenced in this document and their respective file locations.

- CAFE Model Documentation
- Parameters Input File
- CAFE Model Output File

Fuel economy and fuel efficiency standards produce wide-ranging effects in the vehicle market, society, and the environment, and NHTSA considers such impacts when making decisions about new standards. This proposal considers several regulatory alternatives for LDVs across MYs 2027 through 2031, and augural standards for MY 2032 and alternatives for HDPUV standards for MY 2030 and beyond. The CAFE Model explicitly estimates manufacturers' responses to each set of alternatives in each fleet and quantifies numerous effects of these alternatives throughout the lifetimes of vehicles in both the LD and HDPUV fleets. The analysis supporting this proposal should be interpreted not as a forecast, but rather as an assessment—reflecting in some cases best judgments regarding different and often uncertain factors—of impacts that could occur. The light-duty fleet analysis is conducted subject to a set of constraints as outlined in EPCA/EISA that include the prohibition of considering the fuel economy of dedicated AFVs when determining maximum feasible standards and a number of limitations on the transfer and use of compliance credits. These constraints are in place for the analysis discussed in this chapter. In addition to the results of the central analysis case discussed below, the agency conducted a sensitivity analysis to assess a variety of potential changes in key analytical inputs (e.g., FPs, macroeconomic forecasts, technology assumptions). This sensitivity analysis is included in Chapter 9 of this PRIA.

This chapter describes the effects of each of the four LD and three HDPUV alternatives in relation to each fleet's No-Action Alternative scenario (described in detail in Chapter 3 of this PRIA and in Chapter 1.4 of the Draft TSD). The discussion in this chapter is split into parts, first by fleet (i.e., LD and HDPUV), and then by the space the proposed standards affect: (i) vehicle manufacturers, (ii) new vehicle buyers, (iii) society as a whole, and (iv) the physical environment. Effects for vehicle manufacturers include compliance outcomes (e.g., achieved average fuel economy and fuel efficiency levels), technology application choices, costs associated with technology adoption and compliance, and changes to sales and sector employment. Assessment of new car and truck buyer impacts include vehicle price changes, fuel savings, and other mobility-related benefits (i.e., consumer benefits from additional travel from reduced expenditure on fuel). The analysis of social impacts includes effects that accrue to vehicle purchasers and non-purchasers alike. Examples of social impacts are the monetized value of changes in GHG emissions, congestion, and road noise, as well as energy security consequences, and safety-related outcomes. This proposal also directly affects the physical environment by altering overall vehicle use (e.g., VMT), fuel consumption, GHG emission quantities, and criteria pollutant and toxic air pollutant emission quantities).

As discussed in the Draft TSD, the underlying CAFE Model explicitly accounts for each MY from 1983 to 2050, simulating fleet turnover and mileage accumulation until all these vehicles are projected to have been scrapped (i.e., through CY 2089, when the last of the MY 2050 vehicles are projected to be in service). For CAFE standards, this proposal considers alternatives for each MY between 2027-2031, and augural standards for MY 2032. Therefore, many impacts are most meaningfully understood by considering the vehicles produced in those *MYs*. On the other hand, an understanding of the rule's physical impacts over time can also be important in some contexts. For example, when the U.S. reports progress toward goals adopted under the United Nations Framework Convention on Climate Change (UNFCCC), it reports annual inventories of GHG emissions, which would correspond to a "CY" approach rather than a "model year" approach. Accordingly, today's analysis presents most physical impacts on a *CY* basis—that is, showing projected total or incremental quantities through CY 2050, accounting for all vehicles projected in service in each CY (including vehicles produced during MYs 2033-2050). Because fuel efficiency standards for HDPUV vehicles remain in place until new standards are set, HDPUV market benefits and costs are reported on a CY basis (i.e., CYs 2022-2050).

Underlying CAFE Model Output Files are available (along with input files, model, source code, and documentation) on NHTSA's website.[141] A comprehensive appendix of detailed tables (e.g., results by manufacturer) is also available in Appendix I LDV Data Book for the LD fleet and Appendix III HDPUV Data Book for the HDPUV fleet.

An additional and more detailed analysis of the environmental impacts of the CAFE LD regulatory alternatives is provided for in the accompanying Draft EIS. Results presented here for the CAFE standards differ slightly from those presented in the Draft EIS. While EPCA/EISA requires that the Secretary (by delegation, NHTSA) determine the maximum feasible levels of CAFE standards in a manner that, as presented here, sets aside the potential use of CAFE credits or application of alternative fuels toward compliance with new standards,[142] the National Environmental Policy Act (NEPA) does not impose such constraints on analysis presented in corresponding EISs, and the Draft EIS presents results of an "unconstrained" analysis that considers manufacturers' potential application of alternative fuels and use of CAFE credits. Detailed manufacturer and MY tables of results for the Draft EIS are available in Appendix II EIS Data Book.

Throughout this chapter, figures and tables report outcomes for a three percent and seven percent DR, as directed by OMB Circular A-4. And while those DRs are applied to all social and private benefits and costs in the analysis, the SC-GHG, and corresponding SCs of high global warming potential (GWP) gases (CH_4 and nitrous oxide, in particular), are discounted at rates recommended by the IWG. NHTSA stresses that it does not have a primary estimate for the DR for the SC-GHG and instead presents non-GHG related impacts of the final rule discounted at three and seven percent alongside estimates of the SC-GHG valued at each of the DRs recommended by the IWG. This approach was selected because, as NHTSA noted in previous rulemaking documents, the IWG does not specify a single recommended DR for use as an agency's primary estimate, and NHTSA agrees that all three values provide useful information to decision-makers.

The agency's analysis showing our primary non-GHG impacts at three and seven percent alongside climate-related benefits discounted at each rate recommended by the IWG may be found in Chapter 8.2 for LD and Chapter 8.3 for HDPUV. For the sake of simplicity, most tables throughout today's analysis pair both the three percent and the seven percent DRs with a three percent value for the SCs of GHGs.[143] The DRs referenced in this chapter refer to the social DR applied to non-GHG cost streams. Unless otherwise noted, the compliance simulation portion of the LD analysis is limited to all MYs up to MY 2032; for tables and figures in this chapter, costs and benefits are reported in 2021$ and are associated with MYs 1983-2032 under the model year perspective, and CYs 2022-2050 under the CY perspective; and, results assume a 3 percent social DR and a 3 percent DR for climate-related benefits.

This chapter proceeds by summarizing costs and benefits of the regulatory alternatives relative to the No-Action Alternative. It then examines modeled compliance outcomes before exploring each of the above-mentioned impacts categories in detail.

8.2. LD Fleet

8.2.1. Summary of Benefits and Costs

To assess the effect of the regulatory alternatives, NHTSA aggregates outputs of the CAFE Model and compares the resulting cost and benefit values for each simulated alternative to those of the No-Action Alternative. Figure 8-1 presents the outcome of this calculation for MYs 1983 through 2032 at both a three

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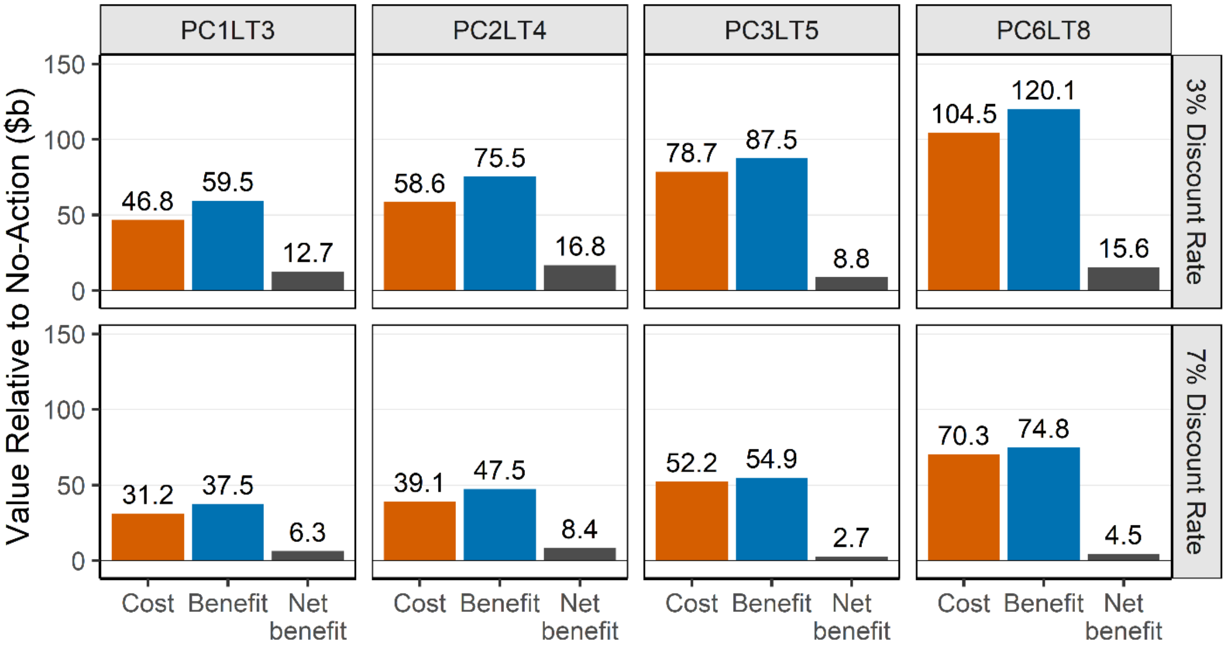
[141] NHTSA. 2022. CAFE Compliance and Effects Modeling System: The Volpe Model. Last Revised: 2022. Available at: https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-compliance-and-effects-modeling-system. (Accessed: May 31, 2023).

[142] 49 U.S.C. 32902(h).

[143] These rates are consistent with recommendations from the IWG on the Social Cost of Greenhouse Gases, as discussed in Preamble Section II.G.2.b(1)(a).

and seven percent social DR.[144,145] Costs and benefits increase across alternatives, corresponding with increased stringency. Relative to the No-Action Alternative, program net benefits are positive across all alternatives.

Figure 8-1: Costs and Benefits for the LD Vehicle Fleet, MYs 1983-2032



Chapter 8.2.4 outlines the main categories of costs and benefits aggregated to produce Figure 8-1. The largest component of these estimated costs is the technology cost that manufacturers pay to improve fleet fuel economy and meet the CAFE targets under each alternative. Reductions in fuel costs for consumers who purchase more fuel-efficient vehicles is the largest private benefit component; SC-GHG reductions make up the largest external benefit category.

8.2.2. Effects on Vehicle Manufacturers

The CAFE Model produces industry-level achieved fuel economy values, as plotted in Figure 8-2 (all fleets) and Figure 8-3 (by regulatory class). These figures report achieved fuel economy relative to the proposed standards; the figures also include the achieved levels computed without AC and OC credits or the PEF. For this analysis, to ensure that simulation of each action alternative begins from the same baseline, the CAFE Model copies the compliance result for the No-Action Alternative for MY prior to the first standard setting year. The result of this approach is displayed in Figure 8-2 and Figure 8-3; standards and achieved average fuel economy values are identical across all solutions for MYs 2022-2026. In these model years, manufacturers generally meet—and in some cases exceed—the standards with AC/OC included. Initial over-compliance in these cases is driven in part by manufacturer redesign schedules and cost-based decisions regarding technology application. In practice, manufacturers may modify vehicle lines at the time of scheduled redesigns, as opposed to making incremental technology upgrades in the specific years in which fuel

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[144] The reporting includes vehicles as far back as MY 1983 because it seeks to account for all vehicles in the on-road fleet, because new CAFE standards can affect how all of these vehicles are driven – as one example, higher costs for new vehicles may lower their sales and shift VMT to older vehicles, with consequent effects on fuel consumed and pollution rates. After 40 years, fewer than 2 percent of initial sales of a given model year tend to remain on the road, so NHTSA assumes that vehicles of a given model year vintage may still be on the road for up to 40 years, and any remaining vehicles at that point are assumed to be scrapped.

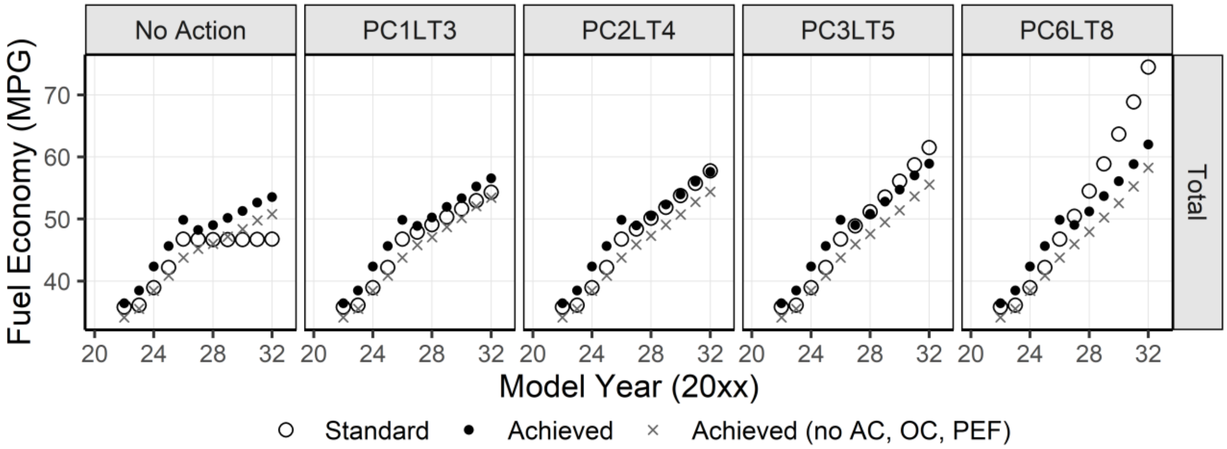
[145] Results are presented for SC-GHG DRs of 3 percent. Benefit summaries for alternate SC-GHG DRs are included in Chapter 8.2.4.1, Table 8-13.

economy requirements change, which might be more expensive than making changes at a redesign. The CAFE Model allows for such an approach, and this can drive some amount of overcompliance.[146]

Examining achieved and target efficiency levels by regulatory class, Figure 8-3 shows that the domestic car fleet consistently exceeds compliance targets across all scenarios, while the imported car fleet achieved fuel economy remains very close to each alternative's corresponding targets in scenarios PC2LT4 and PC3LT5. The LT fleet is unable to comply under the most stringent scenarios of PC3LT5 and PC6LT8 but is capable of compliance under the No Action scenario and PC1LT3 scenario; the LT fleet, however, is unable to comply (by a small margin) under the PC2LT4 scenario. Under the No Action alternative, all vehicles strongly over-comply in MYs 2026-2032. For scenario PC1LT3 there is over compliance after MY 2026 for the domestic and import car fleets, while the LT fleet barely complies over the same time frame.

While some of this over-compliance results from the projected "inheritance" of technologies (e.g., changes to engines shared across multiple vehicle model/configurations) applied in earlier MYs, FPs also play a role. As in all past rulemakings, over at least the last decade, NHTSA assumes that beyond fuel economy improvements necessitated by CAFE standards, EPA-GHG standards, and ZEV mandates, manufacturers could also apply fuel economy improvements that, given projected FPs, would pay for themselves within the first 30 months of vehicle operation. The resultant relative role of FPs is greatest when standards are the least stringent (and, of course, when FPs are the highest).

Figure 8-2: Fleet Modeled Fuel Economy



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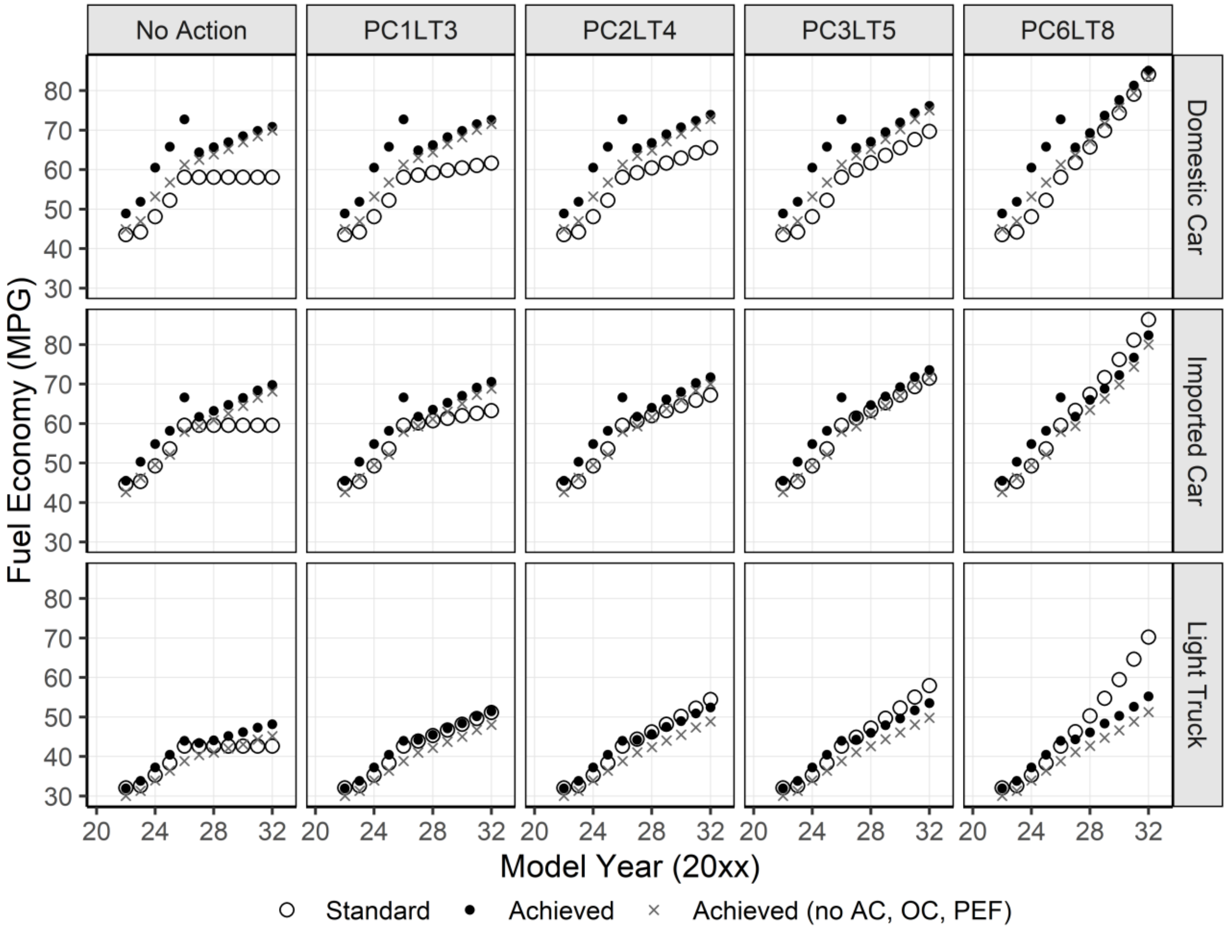
[146] The No-Action Alternative includes increasing standards through MY 2026 based on standards from the 2022 Final Rule. Standards for MY 2027 and beyond are then held fixed at MY 2026 levels. Because the model applies a multi-year planning algorithm, and allows manufacturers to "reach back" to prior model years (e.g., to take advantage of model refresh and redesign years), some overcompliance during the MY 2022-2026 period is the result of manufacturers' compliance actions in MYs beyond 2026. However, because standards are held constant at MY 2026 levels in the No-Action Alternative, and this solution is then carried over to all action alternatives, overcompliance across all alternatives in MYs 2022-2026 is not the result of anticipated stringency increases for any of the action alternatives. Note as well that the decision algorithm can only apply technology in anticipation of future changes in targets; it cannot delay compliance decisions in response to future technology price decreases or changes in compliance simulation constraints (e.g., removing limits on availability of vehicle electrification).

Figure 8-3: Fleet Modeled Fuel Economy by Regulatory Class



These are industry-wide, fleet-level results, and we note that results vary considerably among specific manufacturers. Figure 8-4 presents manufacturer-level differences between achieved and required fuel economy levels on a fleet-wide basis. Lighter colored shading represents manufacturer-years with small, estimated deviations between standards and achieved efficiency levels. Regions shaded blue indicate manufacturer fleets that are more efficient than required and those shaded red fall short of their compliance thresholds.[147] Manufacturers do not have to meet their fuel economy targets exclusively through technology application in any given model year. Manufacturers may make up deficits between their target and achieved fuel economies through the use of over-compliance credits from another fleet (e.g., PC to LT and vice versa), model year (subject to carry forward restrictions) or civil penalty payments.[148] The vertical black line in the figure indicates MY 2027, the first period of the proposed standards.

Figure 8-4 illustrates how all the manufacturers in the fleet comply with CAFE requirements. Most manufacturers see overcompliance by MY 2030 in the No Action Alternative, some by a significant margin.[149] Unsurprisingly, manufacturers that exclusively produce BEVs exceed their regulatory requirements for each fleet in each alternative analyzed under this proposal (PC1LT3 through PC6LT8) for all years. Subaru and Toyota meet all regulations under all alternatives apart from Toyota in the final year of scenario PC6LT8. Volvo initially over-complies, and in MY 2027, suddenly starts to rapidly fall behind in requirements; this is

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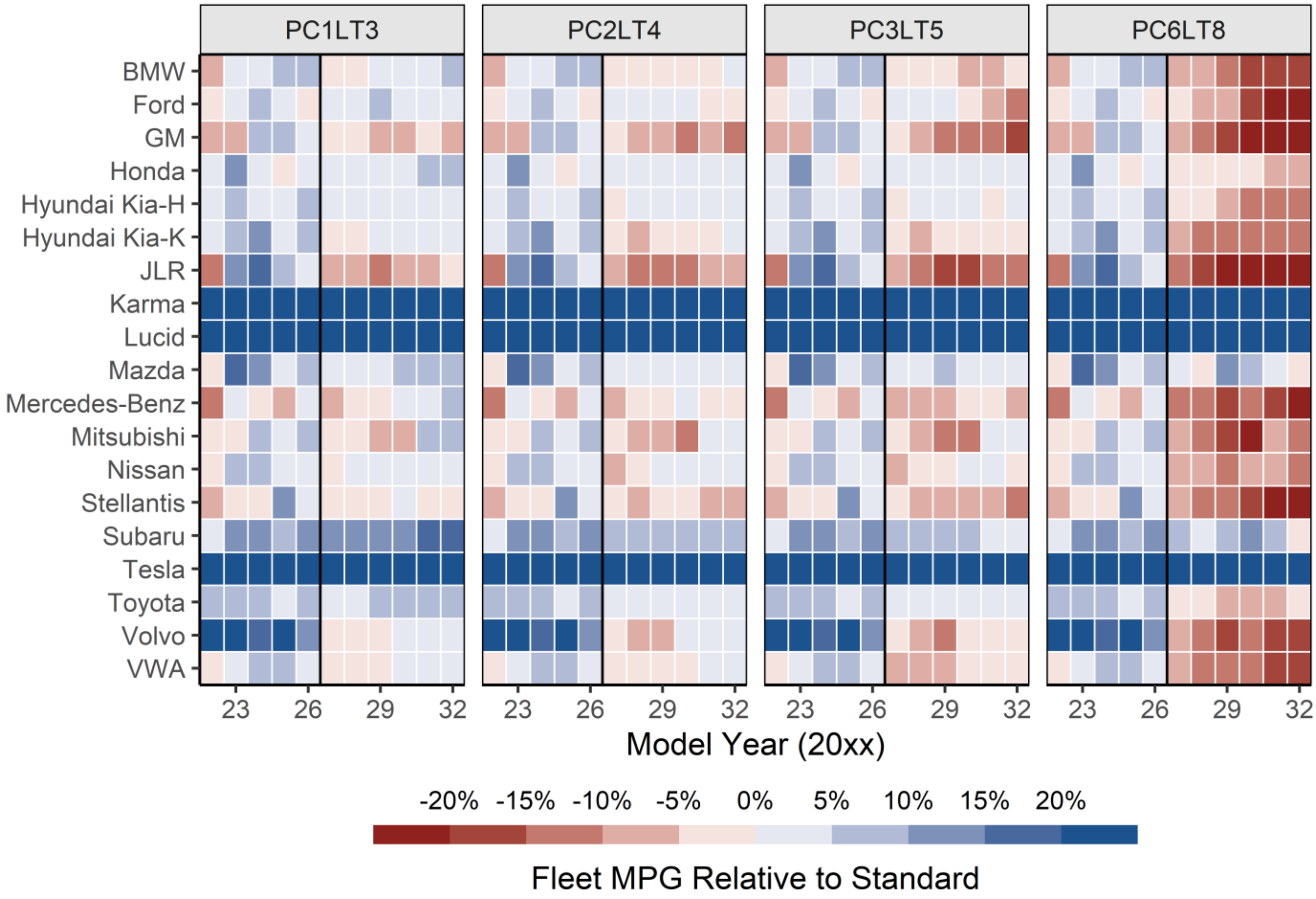
[147] To preserve the color gradient in Figure 8-4 and Figure 8-5, compliance that exceeds standards by more than 20 percent (or falls short by more than 20 percent) falls into the highest (lowest) color category. Karma, Lucid, and Tesla exceed the proposed standards by a wide margin in all alternatives due to their BEV-only fleets; these manufacturers are excluded from Figure 8-5.

[148] Additional detail on alternative compliance flexibilities is included in Section VI.B.1.b. and Section VI.B.1.c of the preamble. In the CAFE Modeling framework, the current approach to modeling over-compliance credits allows credit carry forward and credit transfers within a manfaucturer but does not allow trades among manufacturers. For additional detail, see Draft TSD Chapter 2.2.2.3. and the CAFE Model Documentation.

[149] Note that the No-Action Alternative holds standards at the MY 2026 level in the absence of new regulation. In the No-Action Alternative, this figure measures compliance relative to that (flat) standard.

especially true in the most stringent alternatives: PC3LT5 and PC6LT8. Manufacturers such as Ford, Honda, Hyundai, Kia, Nissan, and Mazda always stay close to the regulatory line (sometimes above, sometimes below) for all the scenarios except for after 2027 with the most stringent alternative (PC6LT8). Note the dark, maroon-colored boxes – Jaguar Land Rover (JLR), Stellantis, and (to a lesser extent) General Motors (GM) rarely meet CAFE compliance under any of the alternatives or time frames subject to the statutory constraints reflected in the reference case (RC). Except for the manufacturers that only produce BEVs, the only manufacturer that meets compliance under the most stringent alternative (PC6LT8) is Subaru.

Figure 8-4: Modeled Fleet-wide Achieved CAFE by Manufacturer



Within manufacturer fleets, there is heterogeneity in modeled response by regulatory class. Figure 8-5 separates achieved fuel economy levels by manufacturer and fleet and shows relative compliance in each action alternative. Each individual panel represents a manufacturer's achieved fuel economy levels relative to the standard within a regulatory class. White cells indicate a manufacturer has no presence in a given regulatory class. Examining results across columns in the figure illustrates that some manufacturers achieve vastly different levels of compliance across regulatory classes. BMW, for instance, can over-comply with its imported car fleet but struggles to comply with its LT fleet. Hyundai over-complies to a significant extent with its domestic car fleet and, on-average, complies with its import car fleet and with LTs. Toyota, Subaru, and Mazda show generally consistent performance across regulatory classes and stringency alternatives.

In some cases, in Figure 8-5, there is a significant change in the level of compliance in manufacturer fleets between MY 2026 and MY 2027. While some of this change may be due to increasing standards, the updated PEF value also has notable effects on manufacturers' computed compliance levels.[150]

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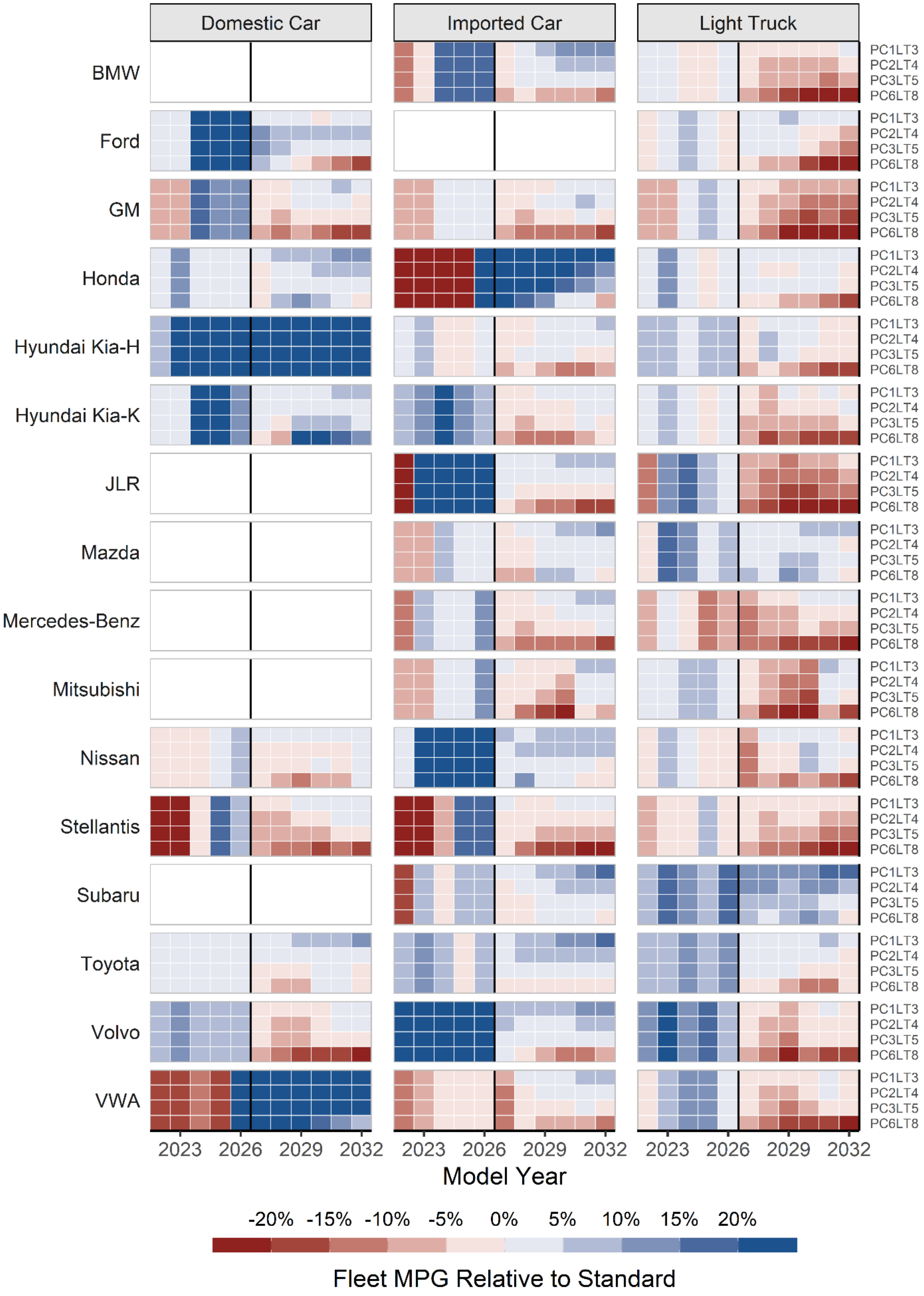
[150] The PEF is a scalar, set by DOE, that modifies the computed fuel economy values for electric operation and is used to convert a vehicle's "rated" fuel economy value to it's "compliance" value. The average achieved fuel economy level includes BEVs for all years (that occur in the fleet for reasons other than CAFE standards) and PHEVs for standard-setting years (standard setting years include PHEV gasoline operation only). For additional discussion on the use of the PEF in the CAFE analysis, see Chapter 2, Section 5.1 of the CAFE Model Documentation. See Chapter 9.2.5.4 of this document for model results under an alternative PEF scenario that retains the value used in the 2022 Final Rule.

Figure 8-5: Modeled Achieved CAFE Levels by Manufacturer and Regulatory Class



8.2.2.1. Technology Application

To meet the required CAFE standards under each regulatory alternative, the CAFE Model simulates compliance in part by applying various technologies to vehicle models in a given manufacturer's regulated fleet. As shown in Figure 8-6, most of this tech application occurs prior to and during the proposal time frame.[151] As expected, the quantity of technology application varies across action alternatives with higher stringency alternatives seeing more fuel economy technology applied. Some technology changes occur after the period of increasing fuel economy targets as the model continues to apply cost effective technologies to the fleet and considers the constraints of manufacturer redesign schedules.[152]

Figure 8-6: Timing of Technology Application in Response to Regulatory Alternatives

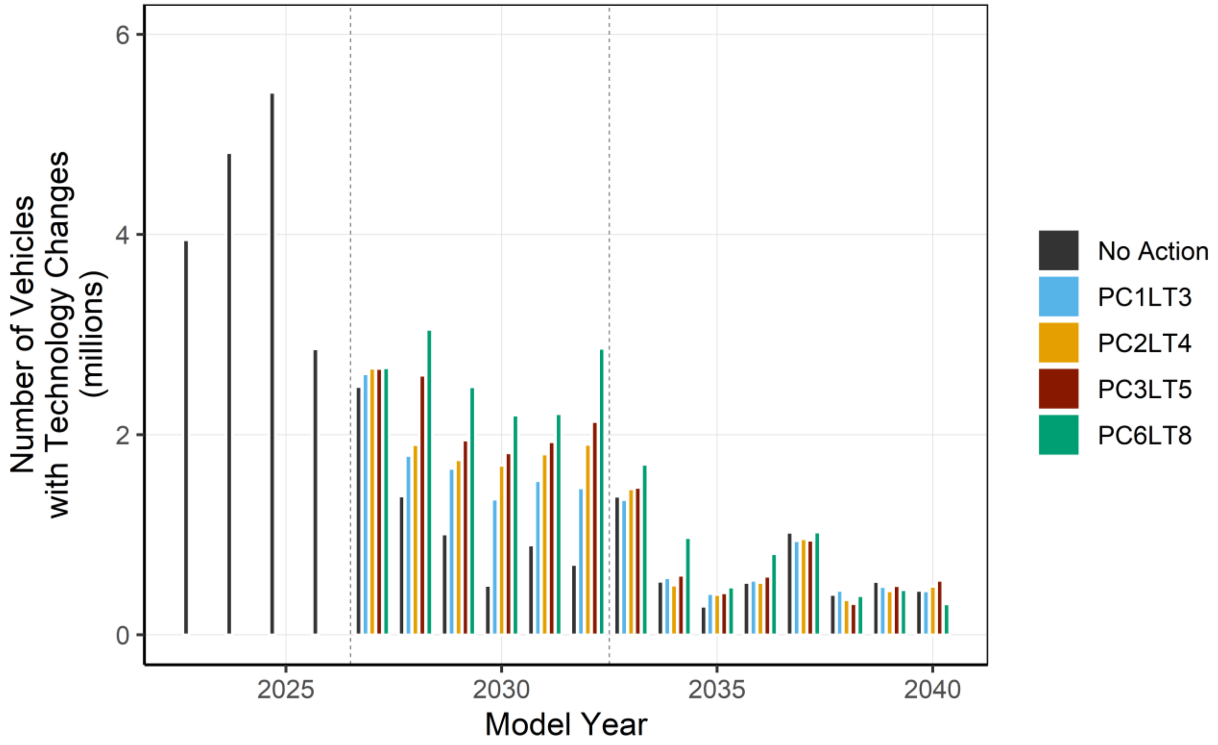


Figure 8-7 through Figure 8-11 present the resulting industry-wide technology penetration rates across scenarios. Each horizontal line segment in the figure represents the change in technology penetration between MY 2022 (represented by a short vertical line segment) and MY 2032 (represented by a circle). Arrows indicate the direction of the change and line colors represent the regulatory alternative. Between MY 2022 and MY 2032, CAFE Model estimates reveal several trends, including:

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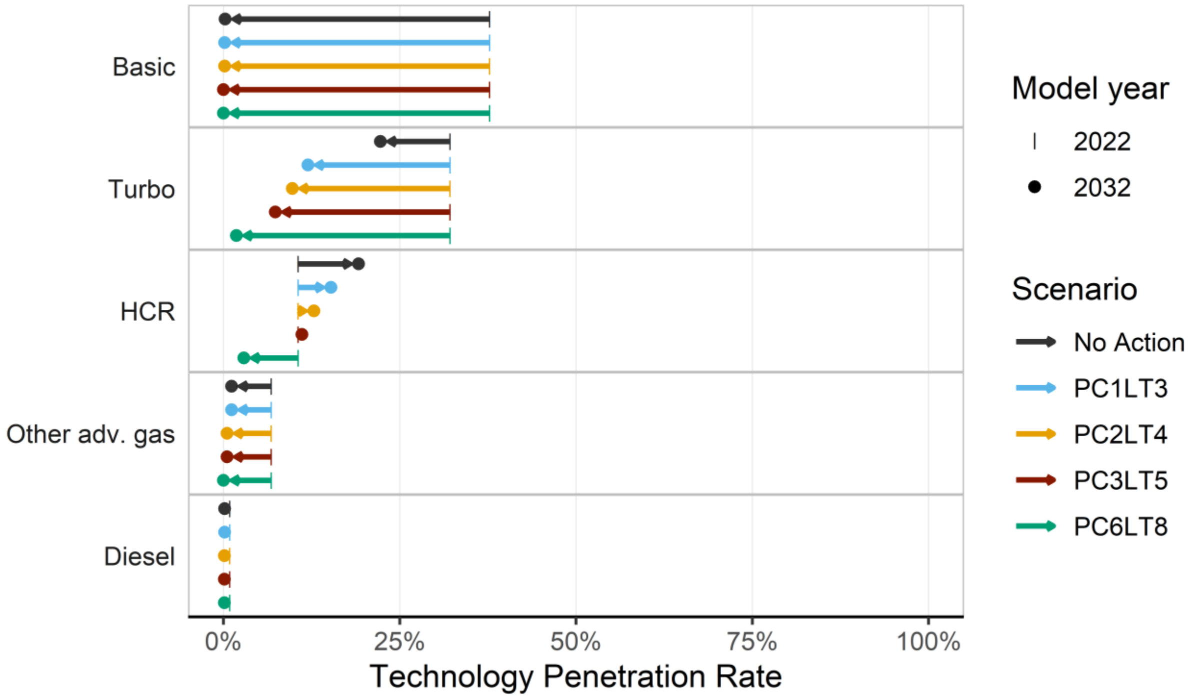
[151] Figure 8-6 includes values for the No-Action Alternative only for MYs 2023-2026. As noted previously in Chapter 3.1, technology application in the action alternatives prior to MY 2027 is identical to the No-Action Alternative by construction.

[152] The model makes these technology application decisions based on technology cost-effectiveness and not in an effort to generate over-compliance credits to address complaince shortfalls in prior model years.

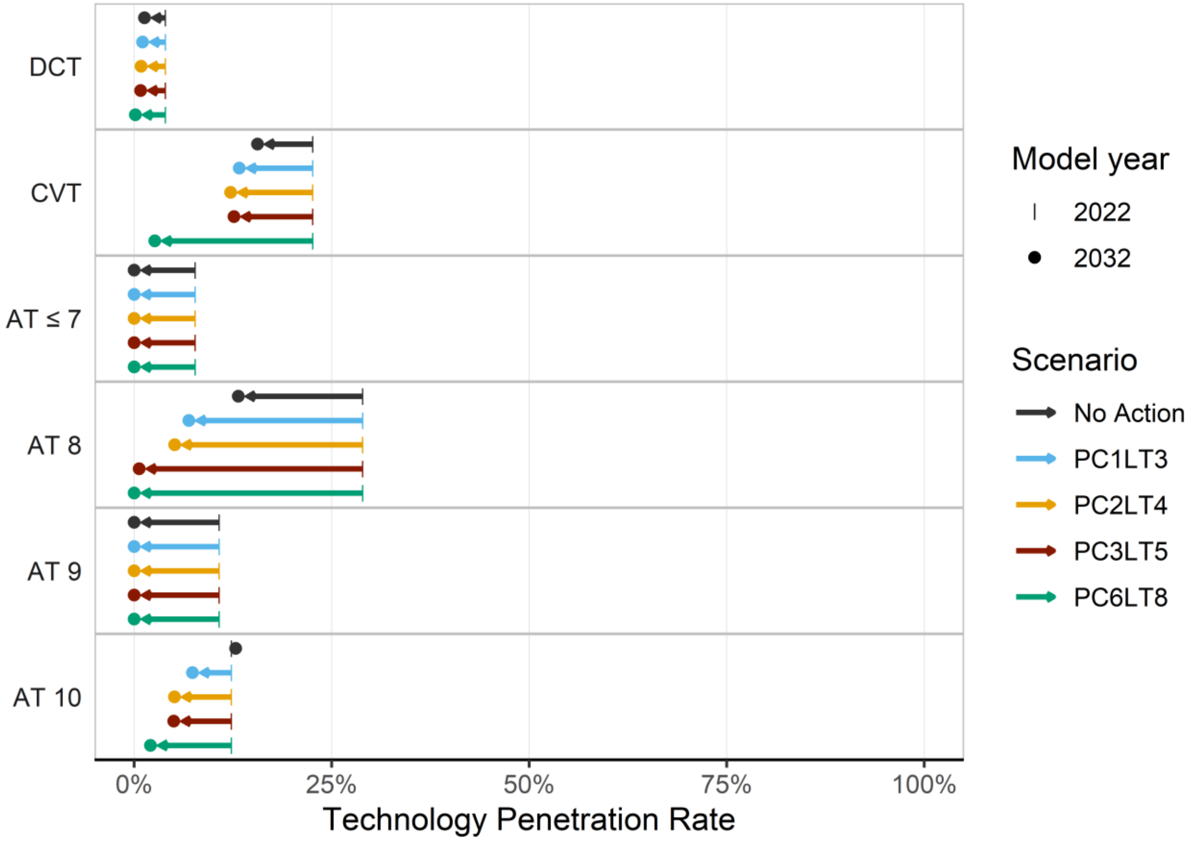
Figure 8-7: Prevalence of Engine Technology in the Fleet Under Different Regulatory Alternatives



Engine technology Figure 8-7:

- Basic engine technology (including SOHC, Dual Overhead Cam (DOHC), variable valve lift (VVL), cylinder deactivation (DEAC), and stoichiometric gasoline direct injection [SDGI]) decreases to 0% penetration rate between the base MY 2022 fleet and MY 2032 across all alternatives.
- Internal combustion (IC) engine advancements including Turbo and other advanced gas technologies (VCR, variable turbo geometry (VTG), and variable turbo geometry (electric) [VTGE]) all decrease between MY 2022 and MY 2032 in each of the simulated alternatives, though higher stringency alternatives see lower penetration rates by MY 2032.
- Use of High Compression Ratio (HCR) engine technology increases under all scenarios except for the most stringent (PC6LT8). In this case, the modeled increase in SHEVs to meet the higher proposed stringency levels drives this decline in HCR prevalence.
- Diesel engines see limited adoption in all scenarios in MY 2032.

Figure 8-8: Prevalence of Transmission Technology in the Fleet Under Different Regulatory Alternatives



Transmission technology (Figure 8-8):

- All multi-speed transmissions (including Continuously Variable Transmissions [CVTs]) decrease in penetration for all scenarios from MY 2022 until MY 2032. The one exception is AT10, which slightly increases in penetration under the No-Action scenario.
- Penetration of Dual-clutch Transmission, AT6, AT7, and AT9 decline to near zero percent by MY 2032. Other automatic transmission options see similar declines in the higher-stringency alternatives (e.g., AT8 and AT10 in PC6LT8). This comes as a result of a decline in conventional powertrain technologies and a shift to powertrain technologies that tend to rely more often on CVT or single-speed transmissions.

Figure 8-9: Prevalence of Electrified Powertrain Technology in the Fleet Under Different Regulatory Alternatives

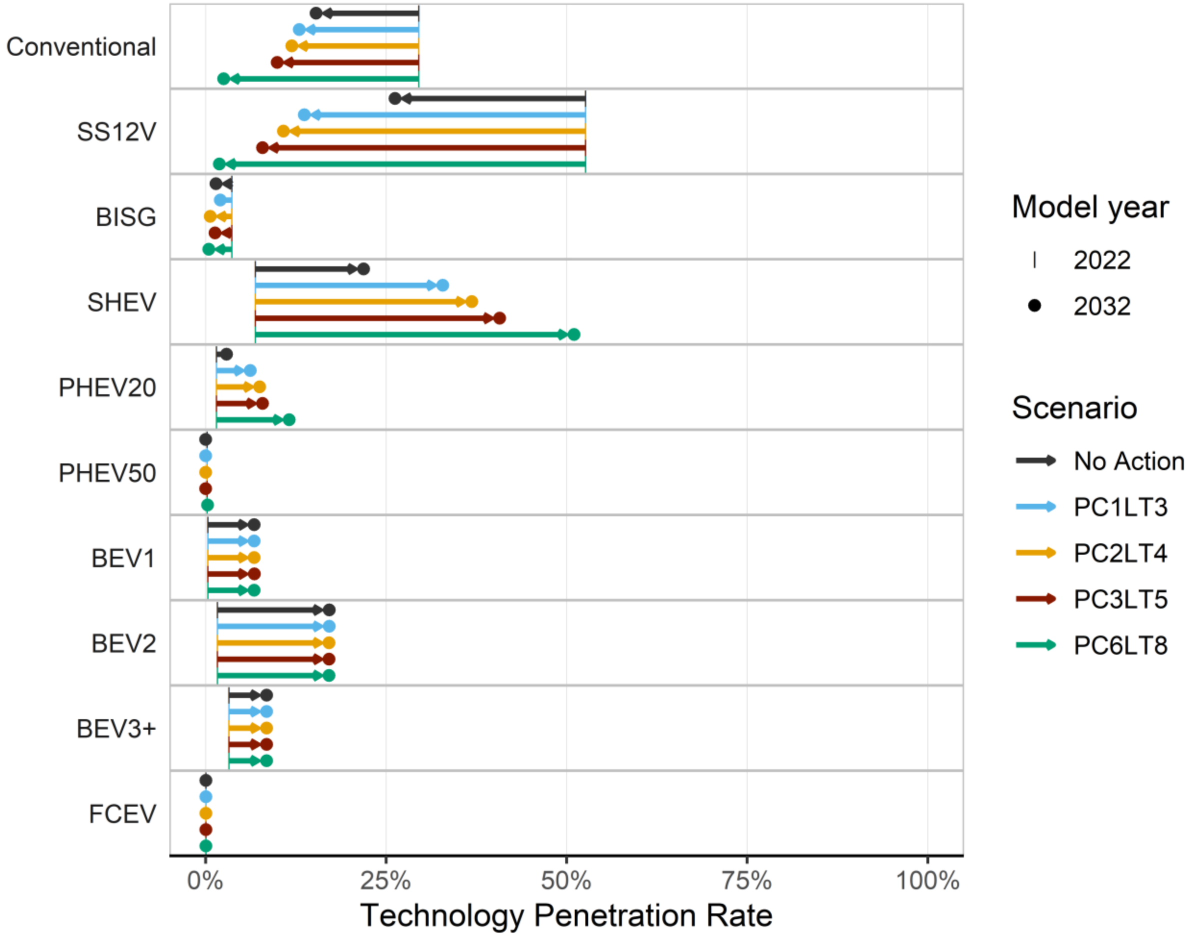
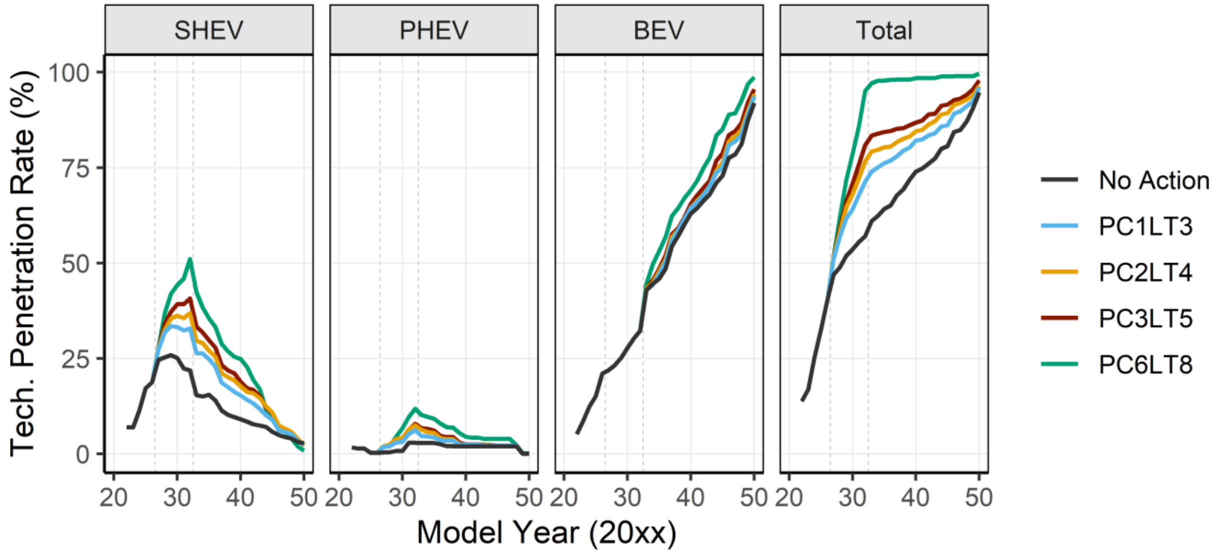


Figure 8-10: Electrified Powertrain Technology Penetration Rates by Model Year



Powertrain technology (Figure 8-9 and Figure 8-10):

- Penetration of SHEV and PHEV technology increases from MY 2022 penetration and peaks in between MY 2029 and MY 2032. After MY 2032, their penetration rates decline rapidly.
    - BEV penetration rates do not differ between No-Action Alternative and the action alternatives during the proposal timeframe due to statutory constraints on modeling.
    - During the standard-setting years, penetration rates of SHEVs and PHEVs increase.[153]
    - SHEV technology and PHEV technology penetration rates decline when the constraints imposed on standard-setting years are removed and prevalence of these technologies drops to nearly zero percent by 2050.
- All scenarios show nearly complete adoption of electric powertrain technology by 2050.
- All technologies associated with ICE powertrains (e.g., conventional, SS12V, BISG) decrease over the course of the simulation, with these declines accelerating in the action alternatives beyond MY 2027.

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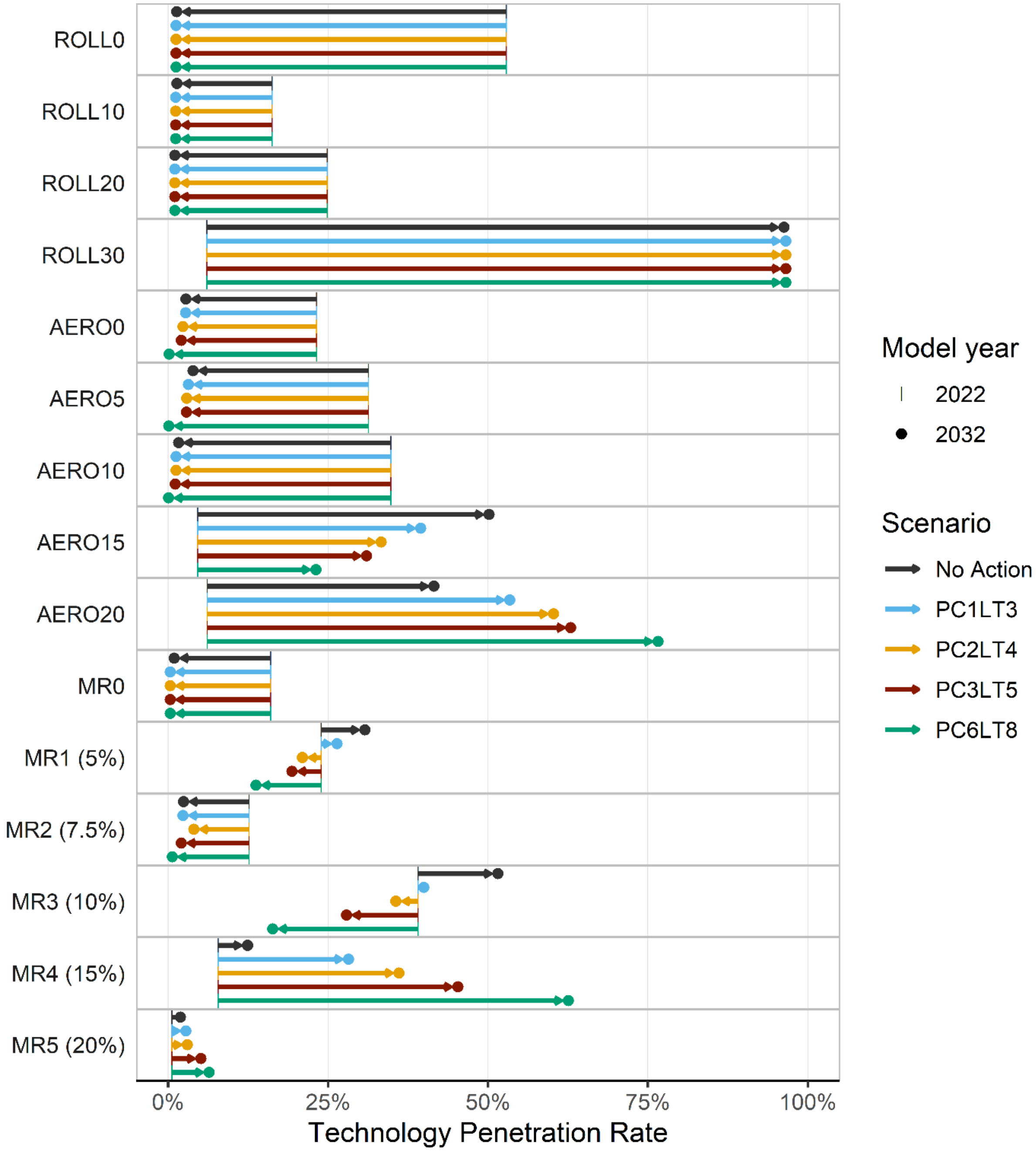
[153] Note that for the purposes of computing manufacturer compliance, the model only counts the gasoline operation component of PHEVs.

Figure 8-11: Prevalence of Tire Rolling Resistance, Aerodynamics, and Mass Reduction Technologies in the Fleet Under Different Regulatory Alternatives



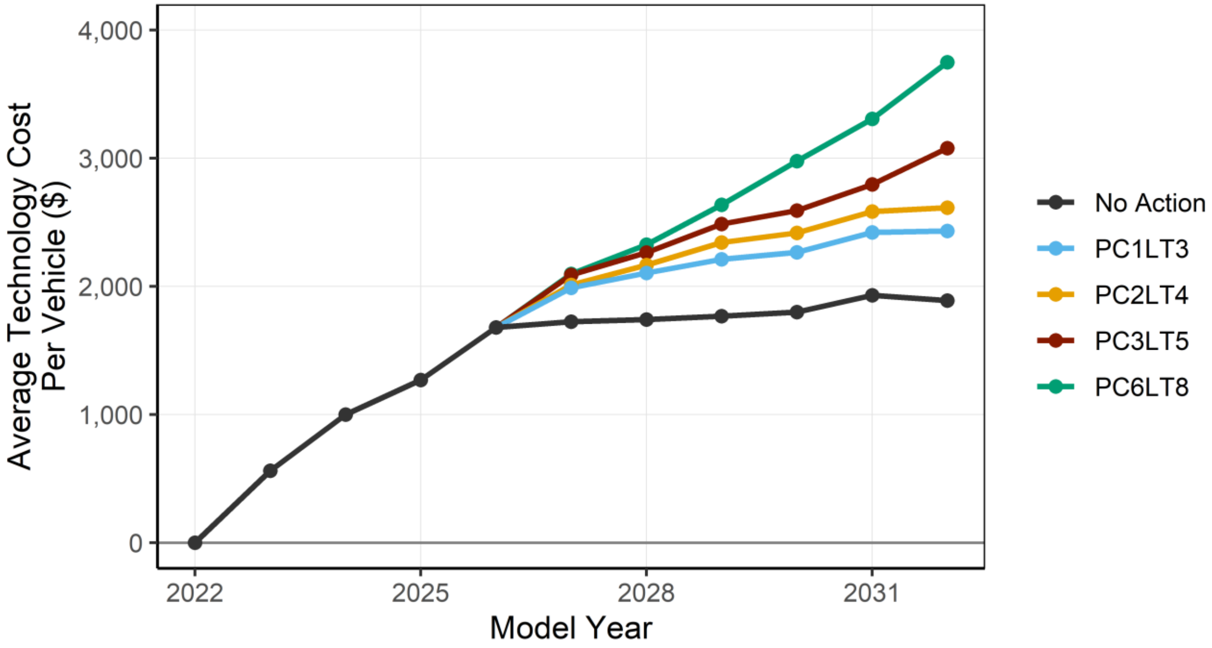
- Rolling Resistance:
    - Results are very similar across scenarios.
    - With few exceptions, ROLL30 is applied to all models by MY 2032.
- Aerodynamics:
    - The amount of AERO0 through AERO10 applied is reduced in favor of applying AERO15 and AERO20.
    - At higher stringency alternatives, aerodynamic improvement technologies are applied more aggressively.

    - Under the most stringent scenario – PC6LT8 – the CAFE model applies AERO20 at a penetration rate over 75%.
- Mass Reduction (MR):
  - The amount of MR0 through MR3 applied is reduced in favor of of MR4 and, to a lesser extent, MR5.
    - MR5 penetration rates are relatively minor but do increase with stricter stringencies.
  - The penetration rates of MR technologies vary across scenarios from MY 2022 until MY 2032.
  - MR greater than or equal to 20 percent is applied sparingly in all scenarios, due in part to modeled cost parameters and limits imposed on application due to feasibility concerns; still, a few manufacturers select MR at this level.

8.2.2.2. Compliance Costs

Manufacturers can comply with CAFE regulations by applying fuel-economy-improving technologies and/or over-compliance credits (whether earned or purchased), or alternatively, paying civil penalties for cover deficits. The CAFE Model computes both aggregate and per-vehicle values of these costs. Model outputs report regulatory costs (i.e., the combination of technology costs and total civil penalties across all regulatory classes) as well as technology costs alone; technology costs are a major contributor to regulatory costs. Figure 8-12 reports industry-wide, model year trends in per-vehicle technology costs.

Figure 8-12: Average Per-Vehicle Technology Cost



Per-vehicle technology costs vary widely by manufacturer and across alternatives, in-part, due to estimated technology application choices. Additionally, NHTSA does not model compliance via fully-electric powertrains, consistent with statutory restrictions. Manufacturers are always free to comply using any technologies they choose, including ones cheaper and more cost-effective than those modeled here.

Figure 8-13 presents baseline per-vehicle technology costs for a MY 2032 vehicle. Gray bars in the figure are costs in the No Action Alternative. Total No Action Alternative costs are listed in the data labels in the “No Action” panel. The portions of the bar in color represent the changes in manufacturer technology costs for each action alternative. For example, average per-vehicle technology costs for Volkswagen Group of America (VWA) in the No Action Alternative are $2,080. Under scenario PC1LT3, these costs increase by $390 per vehicle to $2,470. Under scenario PC2LT4, technology costs increase by $660 to $2,740. Manufacturers including Mazda, Hyundai, and Kia substantially increase per-vehicle technology costs under scenarios PC3LT5 and PC6LT8. Relative to the No Action scenario, PC1LT3 represents an average industry-wide increase in per-vehicle technology costs of $540 — an increase of 29 percent. Industry average technology costs increase by $730 per vehicle in scenario PC2LT4 (39 percent over the No Action Alternative), $1,190 in scenario PC3LT5 (63 percent), and $1,860 per vehicle in scenario PC6LT8 (a 98 percent increase).

Figure 8-13: Per-Vehicle Technology Cost, MY 2032 Vehicle

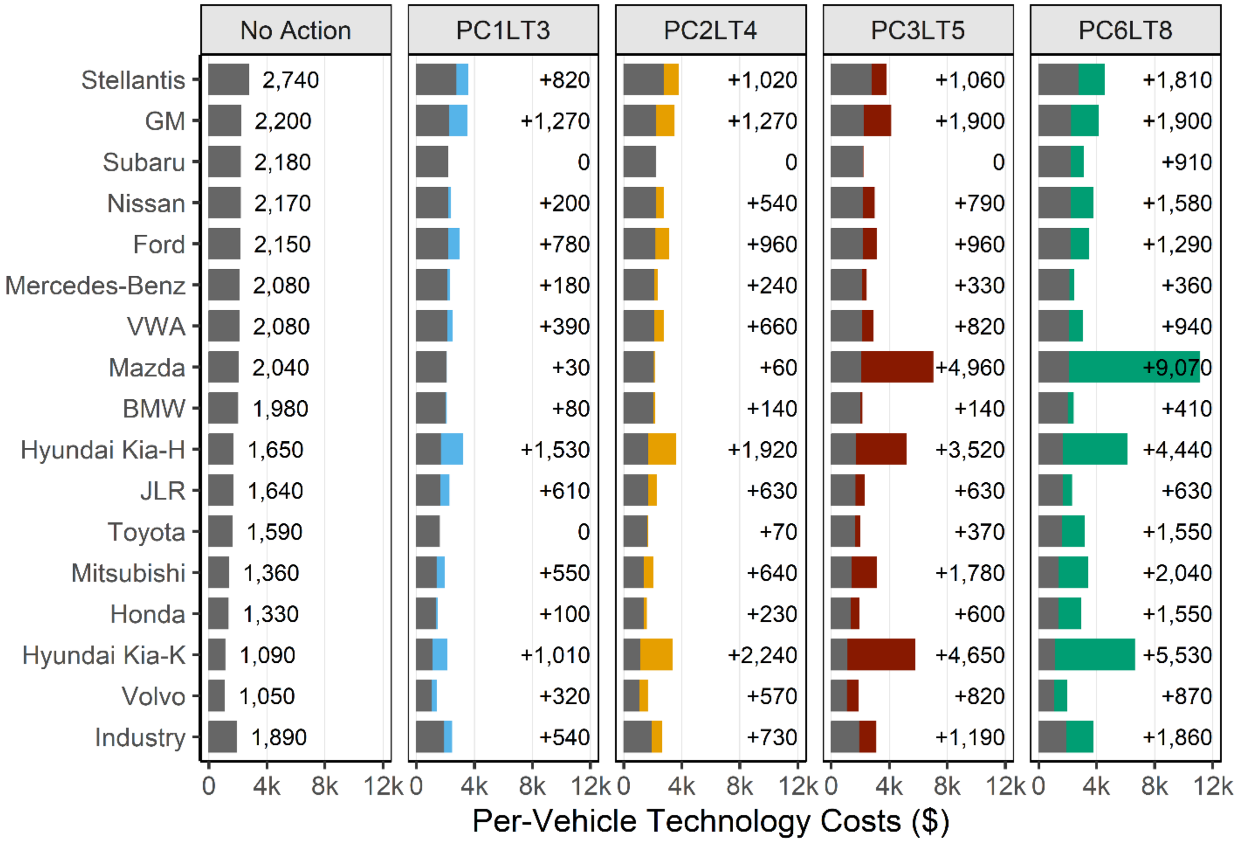


Figure 8-14 reports total technology costs for MYs 2022 through 2032. Gray bars in the figure are costs in the No Action Alternative. Total No Action Alternative costs are listed in the data labels in the “No Action” panel. The portions of the bar in color represent the changes in manufacturer technology costs for each action alternative. In most cases, differences in manufacturer rankings between Figure 8-13 and Figure 8-14 are the result of production-scale variation (e.g., and importantly, Ford’s large production volumes means it has the second largest total technology cost even though Ford’s average per-vehicle costs place it in the middle of the manufacturer ranking in Figure 8-13). However, in a few instances, differences in technology application play a significant role in determining aggregate manufacturer costs. This causes a portion of the estimated increases in cost between the action alternatives and the No-Action Alternative and can be seen by examining technology changes and associated costs for particular manufacturers. For example, Mazda’s per vehicle cost increases from $60 in PC2LT4 to $4,960 in PC3LT5. Mazda’s fleetwide application of high-level AERO and MR technology (AERO20 and MR5) increase substantially across these alternatives. Between PC3LT5 and PC6LT8, Mazda’s compliance pathway includes additional increases in these technologies as well as MR4 and a number of PHEV conversions.[154] Price increases for Hyundai and Kia jump in the higher stringency action alternatives as a result of similar technology application decisions (i.e., high level aero and MR).

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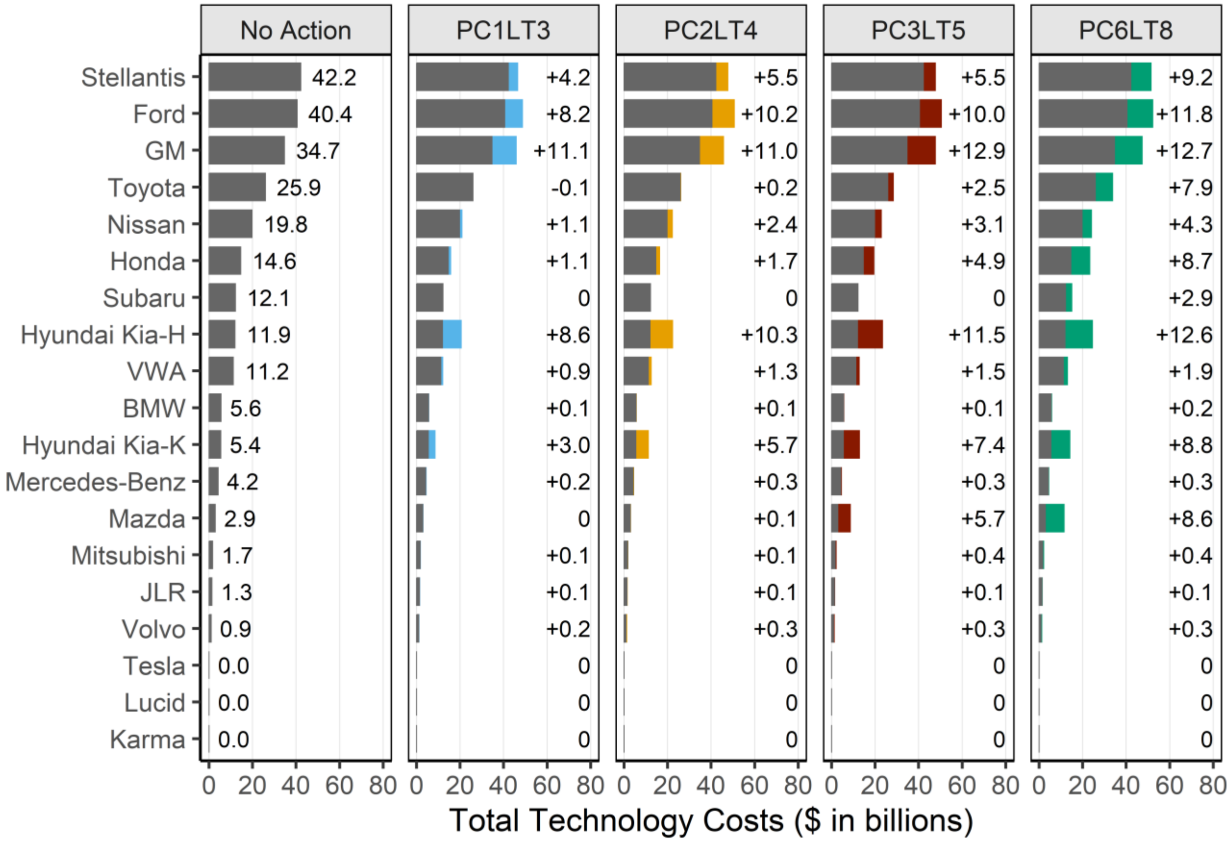
[154] Mazda is one example of a manufacturer with a signficant amount of paltform sharing and this can large movements in technology application. For additional detail, see the discussion of platform sharing and stranded capital in Draft TSD Chapter 2.6.

Figure 8-14: Technology Costs by Manufacturer, MYs 2022-2032



8.2.2.3. Sales and Employment Impacts

As manufacturers modify their vehicle offerings and utilize fuel-economy-improving technologies in response to CAFE standards, vehicle costs increase. The analysis assumes that these cost increases are passed on to consumers and higher retail prices decrease vehicle sales. Because the additional technology cost in each of the action alternatives exceeds the value of expected fuel savings in the first 30 months, sales decline in each alternative relative to the No-Action Alternative.[155] Figure 8-15 illustrates the magnitude of this effect in the context of total sales. Readers should note that the increase in total sales in MY 2023 represents a recovery from the sales shock caused by the Coronavirus Diseased of 2019 (COVID-19) pandemic.

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[155] Sales differences among alternatives are dictated by the assumed price elasticity of demand and the change in vehicle price net of future fuel savings. For this analysis, the assumed price elasticity is -0.4 and the model assumes new vehicle buyers value the first 2.5 years of future fuel savings. For a detailed discussion of these assumptions, see Draft TSD Chapter 4.2.

Figure 8-15: Industry-wide Sales

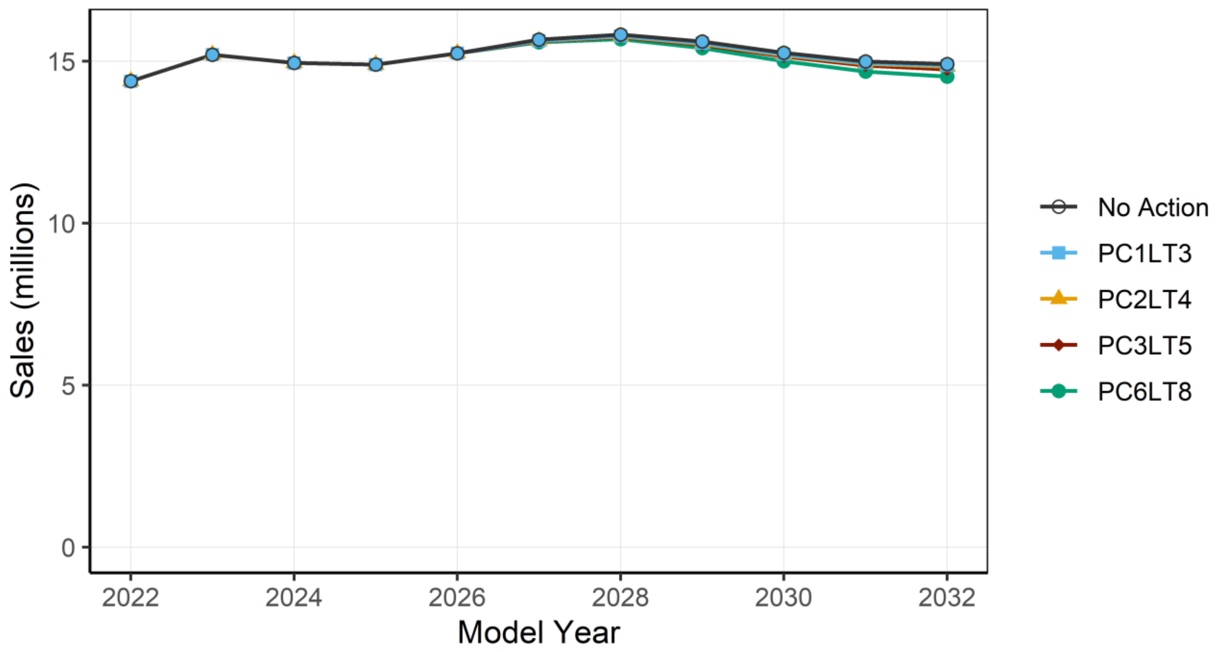


Figure 8-16 shows the simulated sales differences for the current analysis at the industry level across alternatives relative to the baseline through MY 2050. For all scenarios, sales stay constant relative to the No Action scenario through MY 2026, after which the model begins applying technology in response to the action alternatives. Beginning in MY 2027, sales begin to decline in all scenarios compared to the No-Action Alternative. As stringency levels increase across scenarios and tech costs increase, the sales overall magnitude of the response increases as well. Sales declines relative to the No-Action Alternative in the most stringent scenario (PC6LT8) are almost twice the declines in the next most stringent scenario (PC3LT5). This initial sharp decline in sales moderates beyond the mid-2030s. Excluding the most stringent case, LDV sales differ from the No-Action Alternative by approximately one percent or less through MY 2050.

Figure 8-16: Percentage Change in Sales, by Alternative

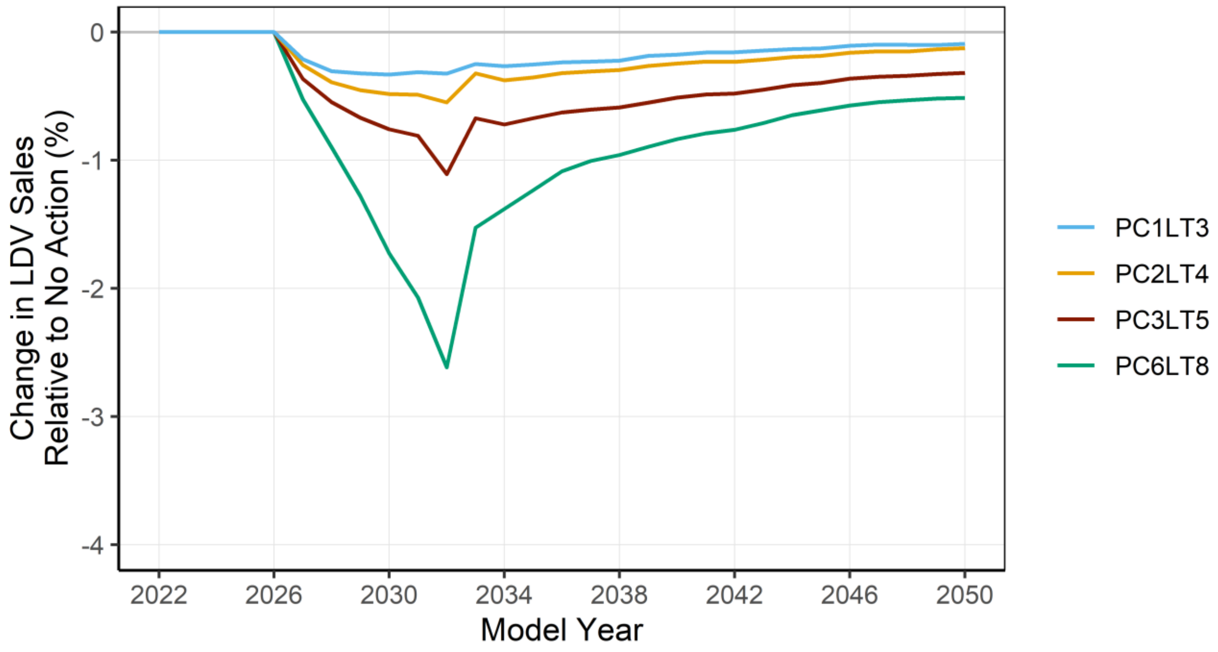
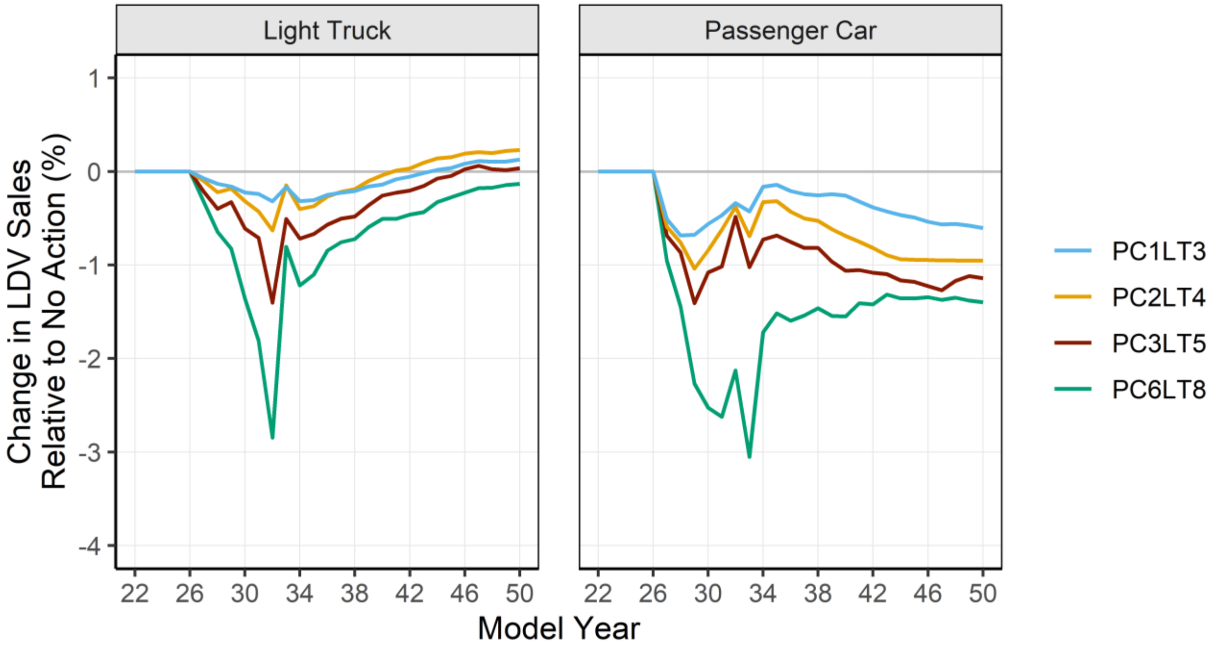


Figure 8-17 presents heterogeneity in sales response across regulatory classes. In the central analysis case presented here, the general trend in sales declines during the standard setting years holds across regulatory alternatives for the LT fleet. The trend in the PC fleet is different. For all regulatory alternatives other than PC6LT8, the percent decline in PC sales relative to the No-Action Alternative increases initially, before reversing course after MY 2029. This change is present in alternative PC6LT8 beyond MY 2031. This temporal pattern is driven by two elements of the sales model. First, regulatory costs increase relative to the No-Action Alternative as lower-cost technology is applied first, leaving more expensive technologies as the available compliance options in later model years. This increase in vehicle cost (price) interacts with the sales elasticity to reduce aggregate sales. Second, the fleet share elasticity changes sales quantities by regulatory class in response to changes in average vehicle value (where value is defined as costs net of fuel savings and vehicle incentives). In general, since the relative cost net of fuel savings and incentives of PCs to LTs increases in the regulatory alternatives, the PC share decreases relative to the No-Action Alternative. For further discussion of the sales model method and assumptions, see Draft TSD Chapter 4.2. The fleet share elasticity mechanism is isolated in a set of sensitivity analysis included in Chapter 9.

Beyond the standard-setting years, the decrease in LT market share becomes smaller, and in some alternatives (e.g., PC2LT4) increases relative to the No-Action Alternative; car share maintains declines of 0.5 to 1.5 percent relative to the No-Action Alternative across all action alternatives. The relative changes in sales for these two regulatory classes feeds into the analysis of on-road fleet and aggregate vehicle use explored in more detail in Chapter 8.2.5.1.

Figure 8-17: Percentage Change in Sales, by Alternative and Regulatory Class



When fewer vehicles are sold, manufacturers require fewer labor hours to satisfy demand. Hence, the decline in sales shown in Figure 8-15 reduces industry-wide labor hours. However, development and deployment of new fuel-economy-improving technologies increases demand for labor. Overall estimated CAFE program impacts on employment utilization depend on the relative magnitude of these two factors. Table 8-1 reports total employment utilization in full-time equivalent job units (i.e., the number of individuals working a full-time position that are required to meet new vehicle demand). Chapter 6.2.5 of the Draft TSD offers further detail on this measure and how it is calculated. In the No-Action Alternative, net employment utilization increases until it peaks in 2028 and then declines through 2032. This mirrors the pattern of total sales in Figure 8-17. Employment utilization increases in each action alternative relative to the No-Action Alternative, but these increases are small relative to their baseline levels. The most stringent, PC6LT8 adds the least to the No-Action scenario. On average, the third scenario, PC3LT5 adds the most to the baseline.

The fact that overall labor utilization follows the general trend of the No-Action Alternative but increases slightly over the baseline in each of the action alternatives indicates that technology effects ultimately outweigh sales effects. The fact that the additional jobs for the first three alternatives (i.e., PC1LT3, PC2LT4, and PC3LT5) are greater than those for the most stringent alternative (PC6LT8) may indicate that the sales declines are eroding some of the labor-related benefits of additional fuel-economy-improving technology in the latter case.

Table 8-1: Industry-wide Labor Utilization Effects (in Full-time Equivalent Jobs)

Model Year	No Action Alternative	Difference from No-Action			
		PC1LT3	PC2LT4	PC3LT5	PC6LT8
2022	889,223	0	0	0	0
2023	958,999	0	0	0	0
2024	954,900	0	0	0	0
2025	961,923	0	0	0	0
2026	997,446	0	0	0	0
2027	1,027,684	2,767	2,808	2,948	1,446
2028	1,039,834	3,322	3,196	3,341	996
2029	1,027,165	4,733	5,462	5,287	916
2030	1,006,042	5,083	5,923	5,772	3,050
2031	991,822	5,667	6,183	6,616	4,496
2032	986,394	6,241	6,773	9,199	5,796

8.2.3. Effects on New Car and Truck Buyers

8.2.3.1. Vehicle Purchasing Price

The CAFE Model uses vehicle-level MSRP values provided in the input fleet as the starting point for modeling light-duty vehicle purchase prices. These initial MSRPs are revised over successive MY to produce final MSRP values that incorporate the regulatory cost of compliance. The prices do not include the effects of EV and battery tax credits passed through to consumers.[156] Figure 8-18 displays trends in these MSRPs for MYs 2022 through 2032 and reports values separately for LTs and PCs. For both regulatory classes, Alternative PC6LT8 produces the largest deviation from the No-Action Alternative, an increase of approximately 5.3 percent on average for MY 2027 through MY 2032 PCs and 4.5 percent for LTs. For Alternative PC2LT4, the deviation is 1.6 percent for both fleets. Because these prices are influenced in large part by technology costs, the overall price trends are similar to those found in Chapter 8.3.2, which presents average technology cost per vehicle. After MY 2029, sales-weighted MSRP values for PCs either flatten or decline slightly in the less stringent alternatives. Most manufacturers apply technologies to respond to the proposed CAFE standards in the first few years, and then vehicles retain these technologies. Additionally, the associated costs of these technologies gradually decline over the modeling period due to the model's assumed technology learning rates. The observed MSRP declines in the PC fleet do not carry over to the LT fleet, where the average MSRP increases after 2030 in each alternative. This is due to the additional technology required to comply with standards that increase at a higher rate in the LT fleet. This trend is present in the PC fleet in the most stringent alternative, where technology costs continue to increase into the early 2030s.

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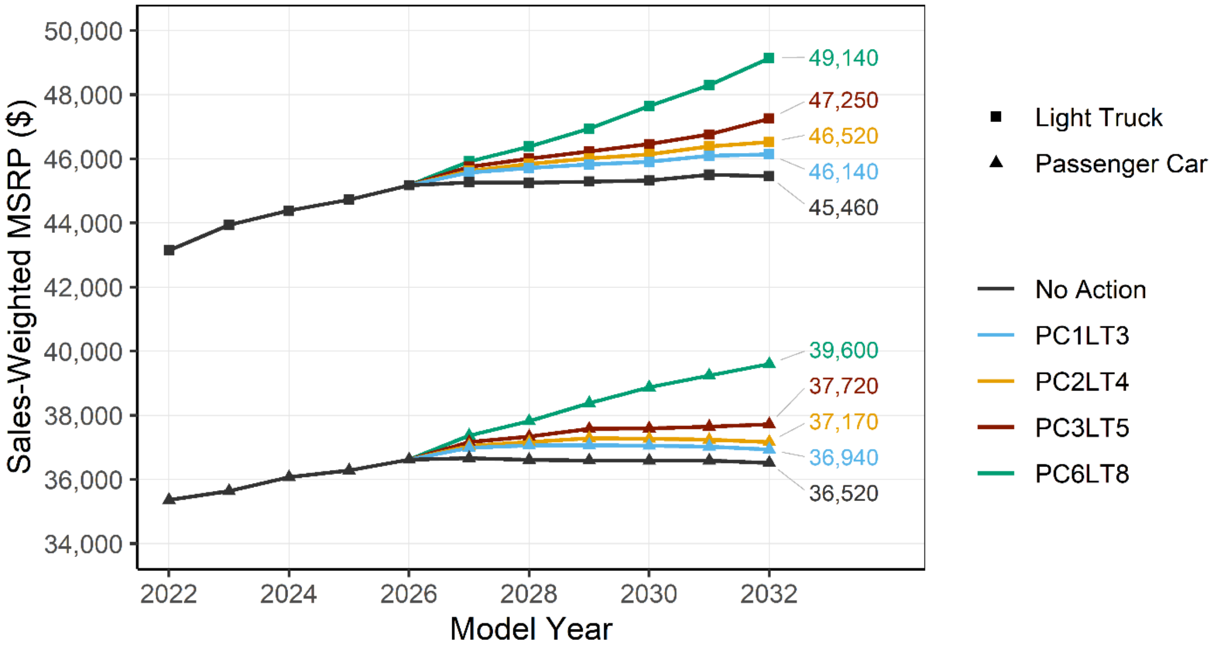
[156] While the MSRP reported here does not include the value of tax credits passed through to consumers, these credits are included in the sales model as discussed in Chapter 4 of the Draft TSD.

Figure 8-18: Sales-weighted MSRP by Regulatory Class



8.2.3.2. Additional Consumer Purchasing Costs and Benefits

In addition to vehicle price effects, the CAFE Model computes various categories of consumer costs and benefits.[157] Table 8-2 summarizes these cost and benefit categories for MY 2032 vehicles. The table includes per-vehicle aggregate values for the No-Action Alternative and differences from the No-Action Alternative for each of the regulatory alternatives.[158] Insurance cost and vehicle taxes and fees are all derived as a portion of modeled MSRP levels and hence vary directly with MSRP across alternatives. Regulatory costs are composed primarily of compliance costs due to technology application or civil penalties, and therefore increase as alternative stringency increases. As shown in Table 8-2, this regulatory cost component increases by nearly 30 percent over the No-Action Alternative for Alternative PC1LT3 and nearly doubles for PC3LT5 in MY 2032.

Estimated private benefits include decreased fuel expenditures, time saved due to less frequent fueling, additional value derived from reallocated vehicle miles, realized benefits from rebound travel miles, and any EV tax credits and battery tax credits that are passed on to consumers. As presented in Table 8-2, fuel savings benefits are the largest component of estimated consumer benefits. Estimates for the No-Action Alternative indicate average retail fuel outlay costs of approximately $13,727 per vehicle in 2032. Fuel-economy improvements ranged from $784 in PC1LT3, the least stringent alternative, to more than $2,000 per vehicle, around 15 percent of total fuel costs, in the most stringent alternative. Tax credits increase with the stringency of the alternative. This is due to greater production of PHEVs in these alternatives. The effect of these vehicles on compliance in the CAFE Model is based on their gasoline fuel economy. Overall, the incremental net benefits are higher in the less stringent alternatives for MY 2032. This reflects the difficulties that some manufacturers have complying with the most stringent alternatives in the initial years following the proposed changes to CAFE standards, as compliance costs increase by a factor of about 6, while retail fueling benefits to consumers increase by a factor of 2.6. Relative to the No-Action Alternative, net benefits to the consumer in the two least stringent alternatives are positive in MY 2032, while they are negative in the two more stringent alternatives.

Examining consumer benefits and costs by regulatory class Table 8-3 highlights the difference between PCs and LTs. In MY 2032, the ratio of consumer benefits to costs is roughly constant, around 0.5 for PCs in the

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[157] This chapter considers only private consumer costs and benefits. Chapter 8.2.4 presents model results for costs and benefits attributable to society as a whole.

[158] Results for additional regulatory fleet aggregations and DRs is included in Appendix I and II.

three most stringent action alternatives. For LTs, this same ratio is greater than one for alternatives PC1LT3, PC2LT4, and PC3LT5 and only drops below one for the most stringent alternative. This is driven in large part by the alternative standards causing a larger decrease in fuel-cost-per-mile in the LT fleet. This is related to both the higher rate of increase in stringency for LTs and the non-linear relationship between fuel economy and cost-per-mile.

Table 8-2: Per-vehicle Consumer Costs and Benefits, MY 2032 (2021$, 3 Percent DR)

	No Action	Relative to No Action			
		PC1LT3	**PC2LT4**	**PC3LT5**	**PC6LT8**
Consumer costs					
Regulatory cost	2,077	601	932	1,602	3,485
Insurance cost	4,017	57	87	150	327
Ownership taxes and fees	2,325	33	51	87	190
Foregone consumer sales surplus	0	1	2	7	41
Implicit opportunity cost	0	0	0	0	0
Total consumer costs		691	1,072	1,846	4,043
Consumer benefits					
Retail fuel cost	13,727	-784	-1,043	-1,296	-2,002
Refueling time cost	1,767	-38	-52	-61	-95
Mobility benefit	573	65	83	106	149
EV tax credit	826	76	107	115	200
EV battery tax credit	392	13	18	19	33
Reallocated mileage benefit	0	17	23	41	75
Total consumer benefits		993	1,326	1,638	2,555
Net benefits		302	254	-207	-1,489

Note: Negative retail fuel cost and refueling time cost relative to the No-Action alternative indicate net savings (i.e., benefits) from the consumer perspective and hence enter consumer benefit totals as positive values.

Table 8-3: Per-vehicle Consumer Costs and Benefits by Regulatory Class, MY 2032 (2021$, 3 Percent DR)

	Passenger Car					**Light Truck**				
	No Action	**Relative to No Action**				**No Action**	**Relative to No Action**			
		PC1LT3	**PC2LT4**	**PC3LT5**	**PC6LT8**		**PC1LT3**	**PC2LT4**	**PC3LT5**	**PC6LT8**
Consumer costs										
Regulatory cost	1,312	419	654	1,205	3,080	2,438	687	1,064	1,795	3,680
Insurance cost	3,445	39	61	113	290	4,288	65	100	169	347
Ownership taxes and fees	1,994	23	36	66	168	2,482	38	58	98	201
Foregone consumer sales surplus	0	1	2	7	41	0	1	2	7	41
Implicit opportunity cost	0	0	0	0	0	0	0	0	0	0
Total consumer costs		482	753	1,392	3,580		790	1,224	2,069	4,270
Consumer benefits										
Retail fuel cost	9,705	-153	-302	-529	-1,426	15,627	-1,083	-1,389	-1,643	-2,263
Refueling time cost	1,841	-7	-14	-24	-68	1,732	-53	-69	-80	-108
Mobility benefit	513	13	25	46	115	601	89	111	135	165
EV tax credit	951	0	0	-2	18	767	112	158	170	286
EV battery tax credit	394	0	0	0	3	391	19	26	28	48
Reallocated mileage benefit	0	12	17	30	53	0	19	26	47	85
Total consumer benefits		185	358	628	1,683		1,374	1,779	2,102	2,955
Net benefits		-296	-395	-764	-1,897		584	555	33	-1,315
Reg. class share of sales (absolute terms, %)	32.1	32.1	32.1	32.3	32.1	32.1	67.9	67.9	67.7	67.8

Note: Negative retail fuel cost and refueling time cost relative to the No-Action alternative indicate net savings (i.e., benefits) from the consumer perspective and hence enter consumer benefit totals as positive values.

Figure 8-19 reports net benefits per vehicle from MY 2022 through MY 2050. Across model years, private net benefits vary significantly. In early model years, net consumer benefits are negative across alternatives, as technology application costs of compliance outweigh consumer benefits. As technology costs decline after the initial compliance period, residual consumer benefits from reduced fuel expenditure, refueling time, and additional drive time continue to accrue. This produces positive net private benefits in later model years. Net benefits become positive in MY 2029 for Alternative PC1LT3, and all are positive across all the alternatives by MY 2034. Net benefits taper off in the late-2030s when applied technology in the No-Action Alternative begins to limit the fuel cost savings achieved by vehicles in the regulatory alternatives. Chapter 9 of this document explores the sensitivity of these results to alternate modeling assumptions.

Figure 8-19: Private Consumer Net Benefits, Light-Duty Vehicles, 3 Percent Social DR

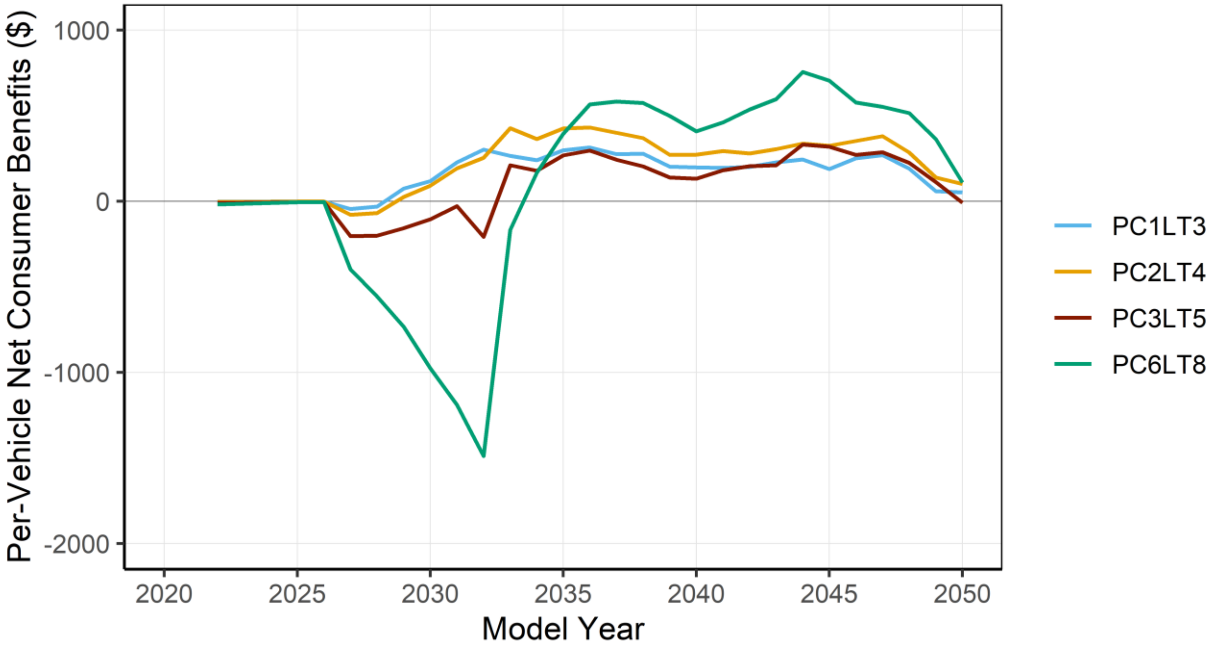


Figure 8-20 plots trends in each of the consumer cost components that are directly tied to vehicle MSRP. As expected, patterns of these costs track each other and MSRP trends (i.e., sharp initial increases followed by more gradual increases and leveling off at costs slightly higher than the baseline in later years for the less stringent alternatives, and steadier increases throughout the time period for the more stringent alternatives). Figure 8-21 breaks out the other cost and benefit components of the private net benefit calculation. Fluctuations in foregone consumer sales surplus, refueling time cost, and reallocated value are relatively small compared to the retail fuel outlay and drive value magnitudes. As expected, retail fuel outlay and drive value move in opposite directions over time, retail fuel outlay decreasing with more efficient fleets and drive value increasing with a larger number of rebound miles traveled. Note, as above, private consumer benefits due to avoided retail fuel costs are substantial across all the alternatives, however in later years these savings are significantly higher in the most stringent scenario as manufacturers must continue to apply additional technology to comply with higher standards.

Figure 8-20: Light-duty Vehicles MSRP-based Consumer Costs, 3 Percent Social DR

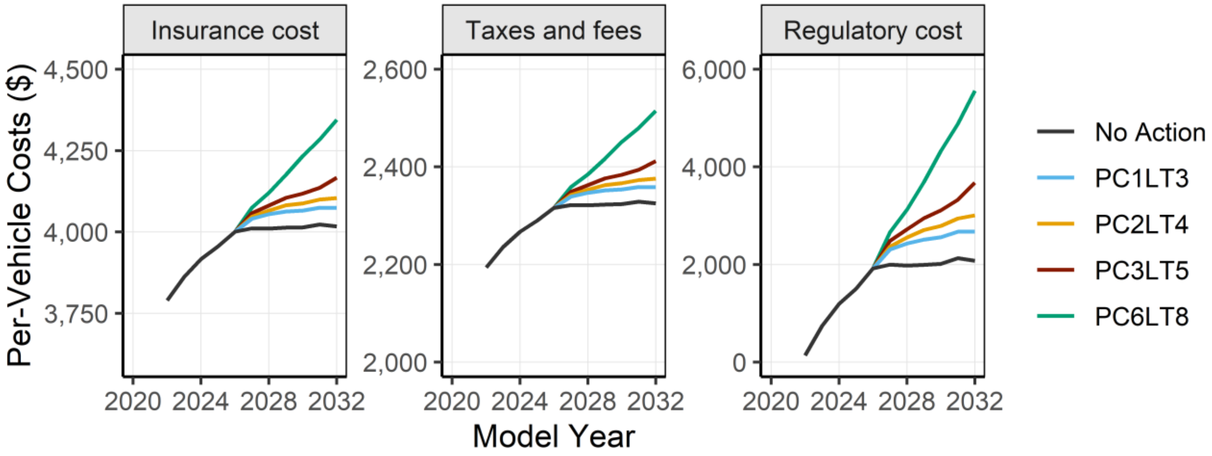
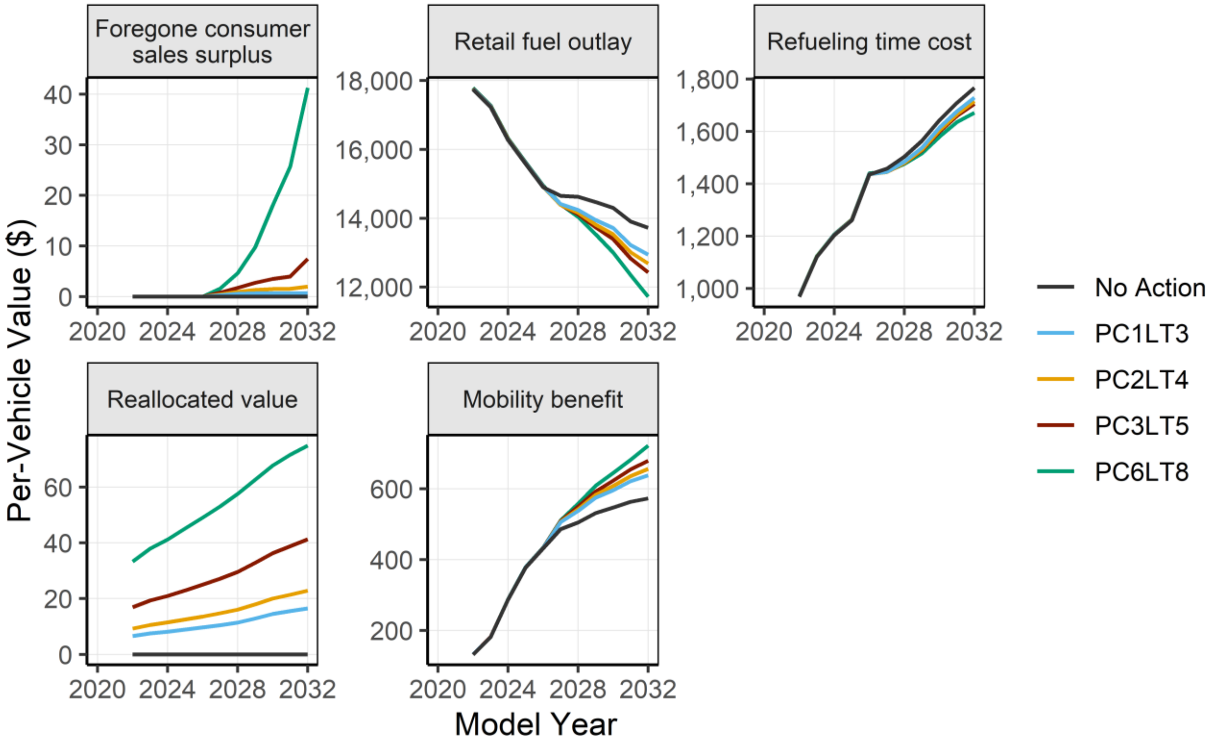


Figure 8-21: Light-duty Vehicle Consumer Costs and Benefits, 3 Percent Social DR



8.2.3.3. Total Cost of Ownership Payback Period

An alternative metric for evaluating relative costs and benefits of fuel economy regulations is to compute the time required for fuel economy improvements to produce positive returns from resulting fuel savings. To estimate the payback period for total cost of ownership (TCO) changes, the model aggregates regulatory costs—including the cost of applied technology and civil penalties net of any tax credits passed through to consumers. It then compares these to a running total of fuel savings and ownership cost changes (e.g., vehicle taxes and fees, finance and insurance costs) relative to the initial state of a given vehicle.[159] The

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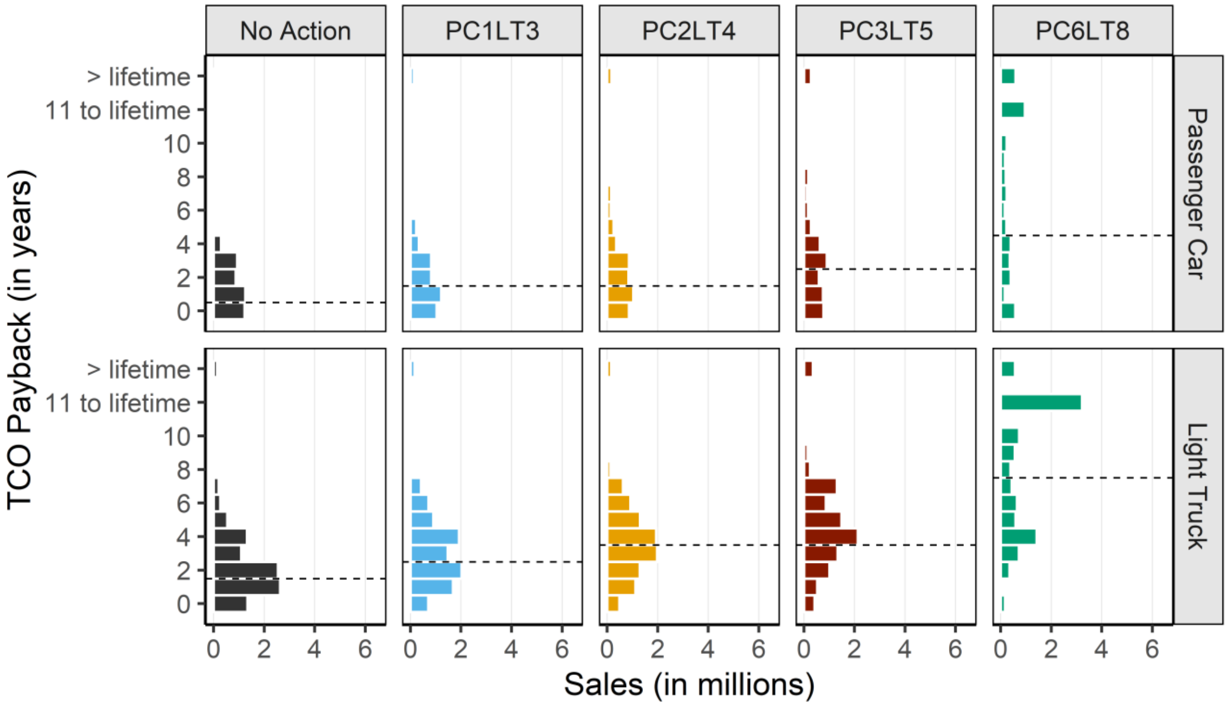
[159] The “initial state” of each vehicle is based on the vehicle’s technology status in MY 2022.

vehicle age at which estimated benefits outweigh estimated costs is the payback period. Figure 8-22 illustrates the distribution of payback periods across all modeled vehicle sales.

Figure 8-22: Light-duty Vehicle Distribution of Vehicle TCO Payback, MY 2032



Dashed line represents the median value.

Figure 8-22 summarizes payback periods for undiscounted costs from the CAFE Model's vehicles report.[160] Across the regulatory alternatives, average PC payback periods are slightly shorter than LT payback periods in MY 2032. Overall, payback times are longer in the more stringent alternatives due to larger regulatory costs that are required for compliance. Table 8-3 summarizes these results, and shows that in the No-Action Alternative LTs tend to take longer to pay back the costs of applied technology and fines. In the regulatory alternatives, where standards increase at a faster rate for trucks than PCs, the incremental increases in payback times are on average larger, although the difference narrows in the most stringent alternative.

Table 8-4: Light-duty Vehicle Payback Times, MY 2032 by Regulatory Class (in Years)

	No Action	PC1LT3	PC2LT4	PC3LT5	PC6LT8
Mean TCO Payback					
Passenger Car	1.7	0.3	0.6	1.2	5.4
Light Truck	2.3	0.8	1.4	2.1	5.7
Median TCO Payback					
Passenger Car	0.5	1.0	1.0	2.0	4.0
Light Truck	1.5	1.0	2.0	2.0	6.0

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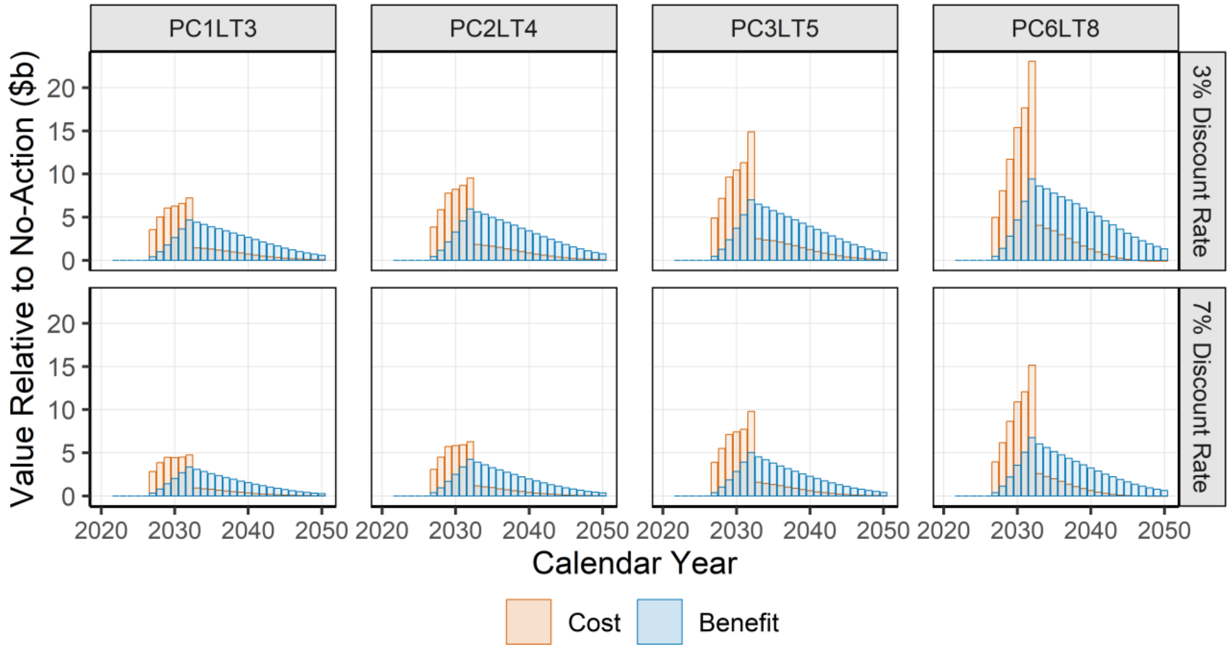
[160] In instances where costs outweigh benefits over the full vehicle lifetime, the payback period for individual models is reported as 99 years in the CAFE Model outputs. Because these values do not represent the full payback period, they were excluded from mean and median calculations in Table 8-2. As presented in Figure 8-22, vehicles with payback periods longer than their assumed lifetime represent a small fraction of overall sales, though this fraction does increase across alternatives. Including these values in the calculation of the mean increase's payback periods. For example, for MY 2032 PCs, the baseline average TCO payback period is 1.7 years and increases to 5.4 years in Alternative PC6LT8. As this payback value is censored at 99 years, average and median payback periods presented above underestimate true fleet-wide payback, though the fraction of total vehicles with long payback periods is small.

8.2.4. Effects on Society

This chapter discusses social benefits and costs associated with the different rulemaking alternatives, including purely external benefits and costs pertaining to the following: GHGs, criteria pollutant emissions, congestion, noise, energy security, and safety. The following chapters (8.2.4.1-8.2.4.6) discuss the external effects to society. Chapter 8.2.4.6 summarizes the full accounting of both these external costs and benefits and the costs and benefits experienced by society as a whole, including the effects on consumers and manufacturers described in Chapter 8.2.2 and Chapter 8.2.3.

The CAFE Model records costs and benefits for particular MY but also reports these measures over the lifetime of the vehicle. Examining program effects through this lens illustrates the temporal differences in major cost and benefit components. Figure 8-23 displays values for MYs 1983 through 2032 vehicles over their lifetimes. Across all alternatives and both DRs, for CY 2032 and earlier, costs exceed benefits, driven mostly by costs for applying efficiency-improving technologies. From 2033 onward, benefits exceed costs. The costs values increase as the alternatives become more stringent, with the highest costs occurring under Alternative PC6LT8, which also accrues the highest levels of benefits.

Figure 8-23: Annual Costs and Benefits of Model Years 1983-2032 (Total fleet), on a CY Basis[161]



This chapter presents some results from both the model year and CY perspectives – particularly where the external nature of the cost or benefit more readily lends itself to a CY accounting structure.[162] Figure 8-24 aggregates annual cost and benefit streams to produce cumulative net benefits, by CY, for the four modeled alternatives. Estimated program compliance and outcomes indicate the industry reaches cumulative positive net benefits for Alternatives PC1LT3 and PC2LT4 in 2042 using a 3 percent DR (2042 and 2041 using a 7 percent DR). Using the 3 percent DR, Alternative PC3LT5 and Alternative PC6LT8 reach this threshold in 2047 and 2046, respectively (2045 at the 7 percent DR). As shown in Figure 8-23 net benefits first become positive for MY 2033 vehicles. In Figure 8-24 this can be seen by the change in slope from negative to positive for cumulative net benefits in the mid-2030s. While the depth of the decline in cumulative net benefits is greater for Alternative PC6LT8 than any of the others, the net benefits also grow at a faster rate once they turn positive. Using a 7 percent DR, the cumulative net benefits are greatest under PC6LT8 by 2050, but under the 3 percent DR, Alternative PC2LT4 and Alternative PC6LT8 have similar net benefits by CY 2050, with the benefits under Alternative PC2LT4 only slightly smaller. This figure illustrates the prior note regarding

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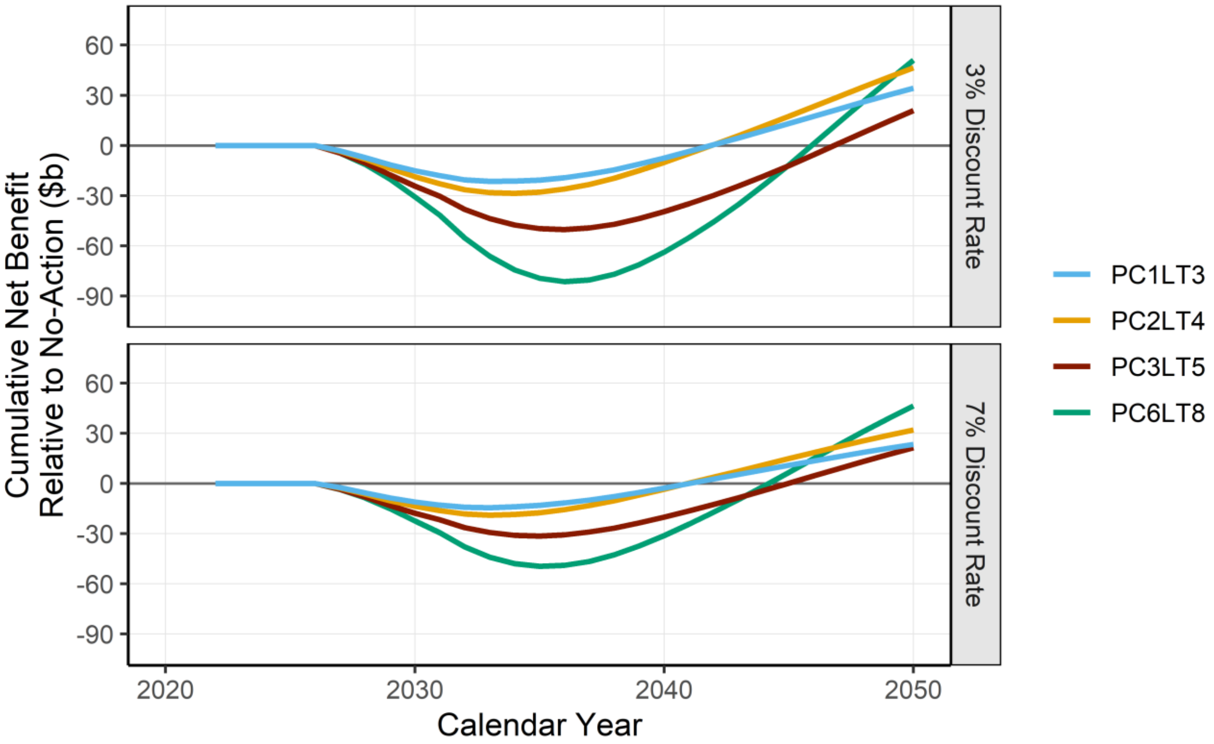
[161] For exposition, the figure truncates costs and benefits at 2050. Some costs and benefits accrue out to 2071, though these values are relatively small.
[162] See Chapter 5.3 of this PRIA for the differences between CY and model year reporting.

the CY accounting perspective; the years closest to the action years look different from years much later, but those later years can be sufficient to dominate the calculation of net benefits (particularly at the 3 percent DR).

Figure 8-24: Cumulative Net Benefits, CY 2022-2050



The graphs in this chapter present certain effects in absolute terms, while others show incremental costs and benefits relative to the No-Action Alternative. Both model year and CY perspectives are used in this chapter depending on the effects discussed. Unless otherwise stated, the model year perspective includes MYs 1983-2032 and the CYs that correspond to the full lifetimes of models produced in those model years, while the CY perspective measures effects that accrue to the on-road fleet in CYs 2022-2050 only.

8.2.4.1. Social Benefits of Reducing GHG Emissions

NHTSA has determined that the best available and most appropriate values for estimating climate effects are the interim values published by the IWG in February 2021 to represent the SC per ton of CO_2, CH_4, and N_2O.[163] See Chapter 6.2.1 in the Draft TSD for discussion of how these values were integrated into the CAFE Model inputs.

The CAFE Model multiplies the per-ton cost values for each of the three GHGs considered by the total emissions of each. Chapter 5 of the Draft TSD describes the calculation of these total emissions, from both upstream and downstream sources.[164] The CAFE Model reports the monetized values of the total GHG emissions in its output reports. All reported cost values in this chapter are in 2021 dollars. Table 8-5 lists the total costs of GHG emissions by alternative, for MYs 1983-2032, based on the four different SC-GHG

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[163] Interagency Working Group on Social Cost of Greenhouse Gases, U.S. Government. 2021. Technical Support Document: Social Cost of Carbon, Methane, and Nitrous Oxide Interim Estimates under Executive Order 13990. Available at https://www.whitehouse.gov/wp-content/uploads/2021/02/TechnicalSupportDocument_SocialCostofCarbonMethaneNitrousOxide.pdf. (Accessed: May 31, 2023).

[164] At the time of NHTSA's analysis, the latest upstream emission factors (EFs) available were from GREET 2022, which are based on AEO 2022 forecasts of the electricity generation mix. We understand AEO 2023 forecasts assume faster rates of grid decarbonization than previous releases and include some recent IRA and BIL provisions that are expected to impact emissions results associated with future CAFE standards, in particular including provisions that would reduce SO2 emissions from upstream sources. For these reasons, we anticipate updating our upstream analyses with projections from GREET 2023 and AEO 2023 or other relevant forecasts as the final rule schedule permits.

DR/damage level combinations. All values in Table 8-5 are in absolute terms, monetizing the incurred costs of emissions. SC-GHG decrease for all GHGs as stringency increases across the alternatives.[165]

Table 8-5: Total Costs of GHG Emissions across Alternatives (2021$, in billions, MYs 1983-2032)

	No Action	PC1LT3	PC2LT4	PC3LT5	PC6LT8
5% SC-GHG discount rate					
CO_2	$309.9	307.4	306.7	306.2	304.8
CH_4	$20.9	20.8	20.7	20.7	20.6
N_2O	$4.7	4.7	4.7	4.7	4.7
3% SC-GHG discount rate					
CO_2	1,190.3	1,179.9	1,177.0	1,175.1	1,169.2
CH_4	53.0	52.6	52.5	52.4	52.1
N_2O	16.5	16.4	16.4	16.3	16.3
2.5% SC-GHG discount rate					
CO_2	1,808.8	1,792.7	1,788.4	1,785.3	1,776.2
CH_4	71.3	70.7	70.5	70.4	70.0
N_2O	24.8	24.7	24.6	24.6	24.5
95th percentile at 3% SC-GHG discount rate					
CO_2	3,606.9	3,575.0	3,566.4	3,560.3	3,542.4
CH_4	140.6	139.5	139.1	138.9	138.2
N_2O	43.8	43.5	43.4	43.4	43.2

Figure 8-25 and Figure 8-26 show the SC-GHG emissions in the No-Action Alternative for CYs 2022-2050, illustrating the relative magnitudes of each pollutant's monetized costs. Although CH_4 and N_2O have substantially higher SCs per ton compared to CO_2, the quantity of CO_2 emissions is much higher (see Chapter 8.2.5), accounting for the large difference between the three total SC amounts. Comparing the two figures shows the extent to which DRs matter for these emissions costs; using the highest SC estimate (95th percentile values discounted at 3 percent), damage costs due to GHG emissions peak at over 240 billion dollars per year and then decline from there. In contrast, the lowest estimates (discounted at 5 percent) amount to slightly over 20 billion dollars per year at their highest point, and then decline in future years.

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[165] Climate benefits are based on changes (reductions) in CO_2, CH_4, and N_2O emissions and are calculated using four different estimates of the SCC, SC-CH_4, and SC-N_2O (model average at 2.5 percent, 3 percent, and 5 percent DRs; 95th percentile at 3 percent DR). We emphasize the importance and value of considering the benefits calculated using all four estimates. For simplicity, most tables throughout this analysis pair the 3 percent and 7 percent social DRs of non-GHG related effects with a 3 percent DR for the SCs of GHGs.

Figure 8-25: Social Costs of CO_2, CH_4, and N_2O under the No-Action Alternative for CYs 2022-2050, 3 and 5 Percent Discount Rate (2021$, billions)

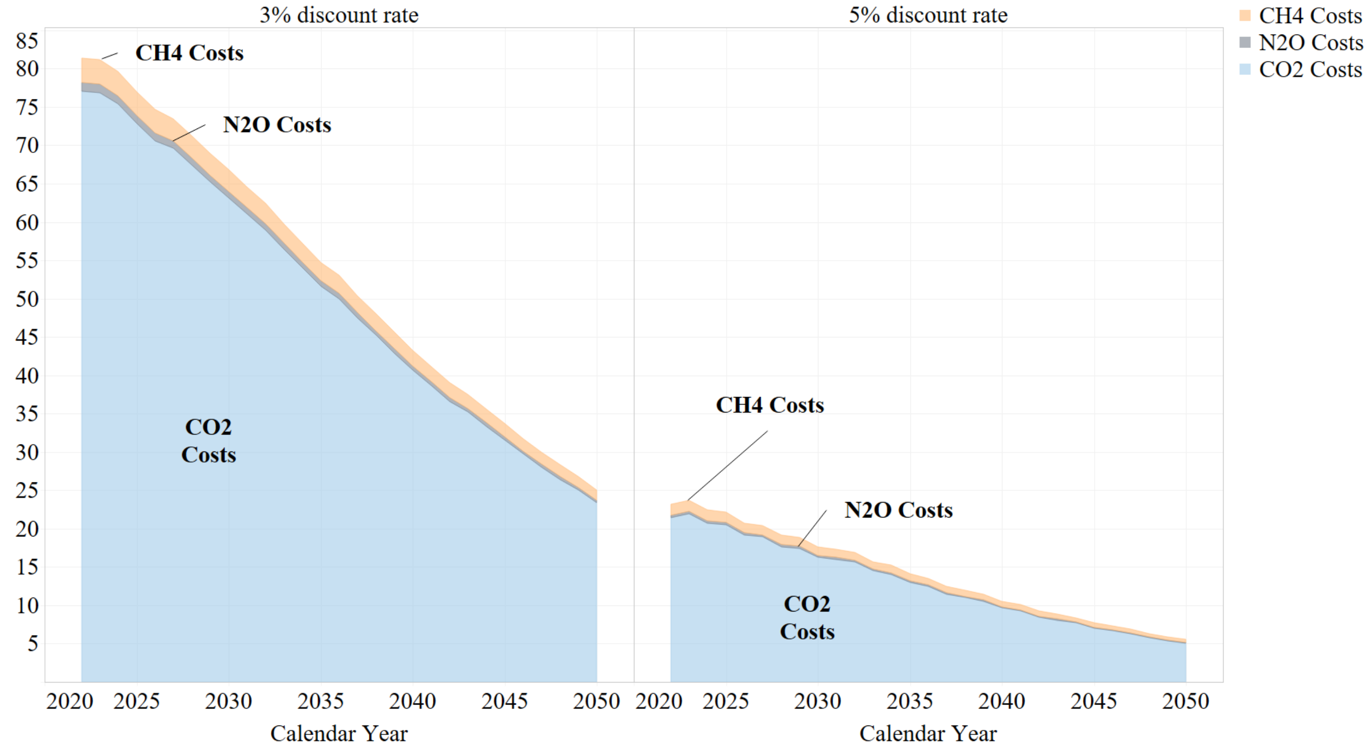

Figure 8-26: Social Costs of CO_2, CH_4, and N_2O under the No-Action Alternative for CYs 2022-2050, 95th Percentile and 2.5 Percent Discount Rates (2021$, billions)

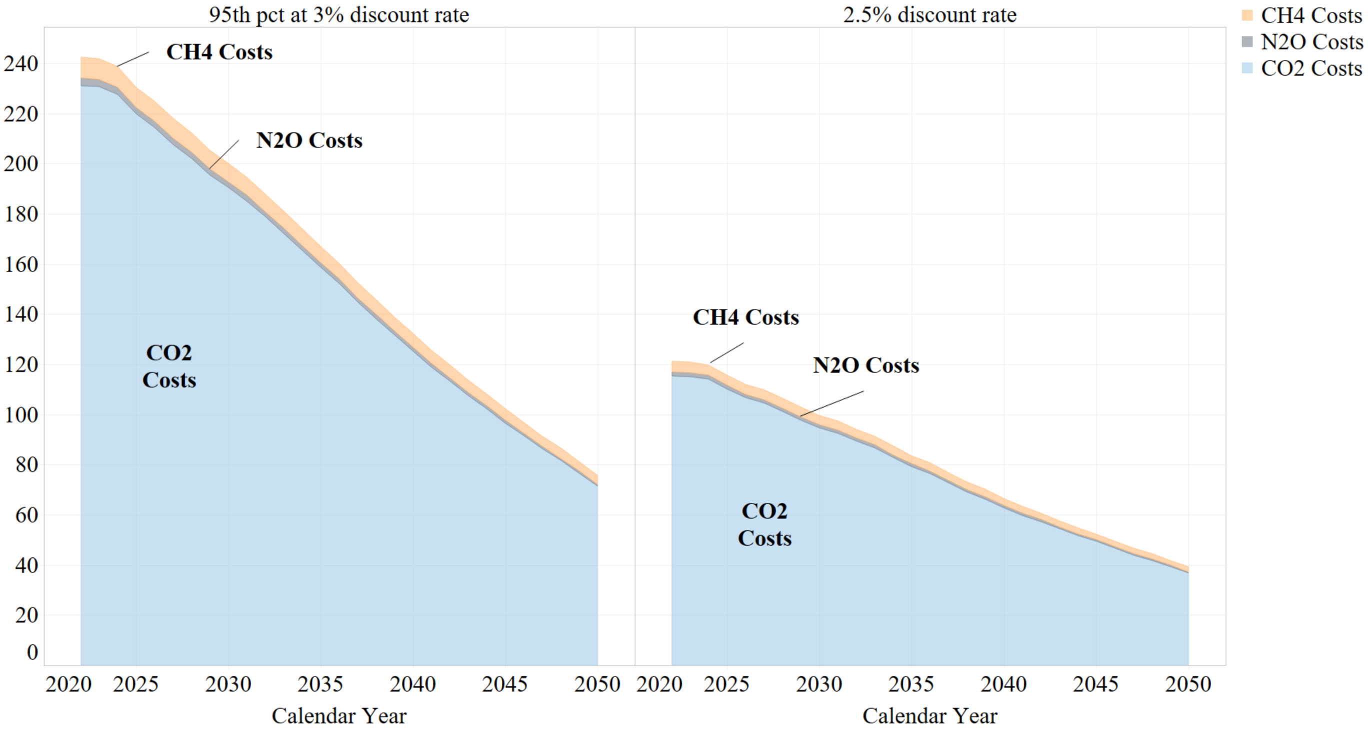

Table 8-6 presents the SC-GHG emissions in terms of incurred costs.[166] This table reports GHG costs by SC-GHG DR. The GHG emission costs in the baseline are shown in absolutes, while the costs in each alternative is shown in terms of incremental reduced costs relative to the baseline. For instance, using the 3 percent DR, Alternative PC1LT3 reduces costs by approximately $11 billion relative to the No-Action levels (about 0.9 percent of the baseline total), while Alternative PC6LT8 reduces costs by $22.2 billion from the No-Action levels (approximately 1.8 percent of the total baseline costs). Alternative PC2LT4 reduces costs by approximately $14 billion.

Table 8-6: Total GHG Costs by SC-GHG Discount Rate for MYs 1983-2032 (2021$, billions, 3% social DR)

SC-GHG Discount Rate	No Action	Relative to No Action			
		PC1LT3	PC2LT4	PC3LT5	PC6LT8
5 percent	335.62	-2.73	-3.47	-3.99	-5.50
3 percent	1,259.85	-10.99	-13.96	-16.04	-22.23
2.5 percent	1,904.87	-16.84	-21.40	-24.60	-34.12
95th percentile at 3 percent	3,791.31	-33.35	-42.37	-48.71	-67.51

Figure 8-27 and Figure 8-28 focus on these reduced costs relative to the baseline, presenting them as benefits in positive terms (avoided costs). Unlike in the previous graphs, this figure shows the distribution of GHG benefits across CYs, dividing the benefits into three decades: 2022-2030, 2031-2040, and 2041-2050. Through this perspective, we see that most of the monetized benefits of reducing GHG emissions occur after 2030, and the highest benefits, in every alternative, occur in the period between 2041-2050.

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[166] Negative incurred costs relative to the baseline are GHG costs that are avoided due to the action alternatives (i.e., reduced fuel consumption reduces GHG emissions). These avoided costs appear in figures and tables later in this chapter as positive values, as they enter the cost-benefit analysis as external social benefits.

Figure 8-27: Avoided GHG Costs Relative to the No-Action Alternative (2021$, billions, 3 and 5 percent DRs, CYs 2022-2050)

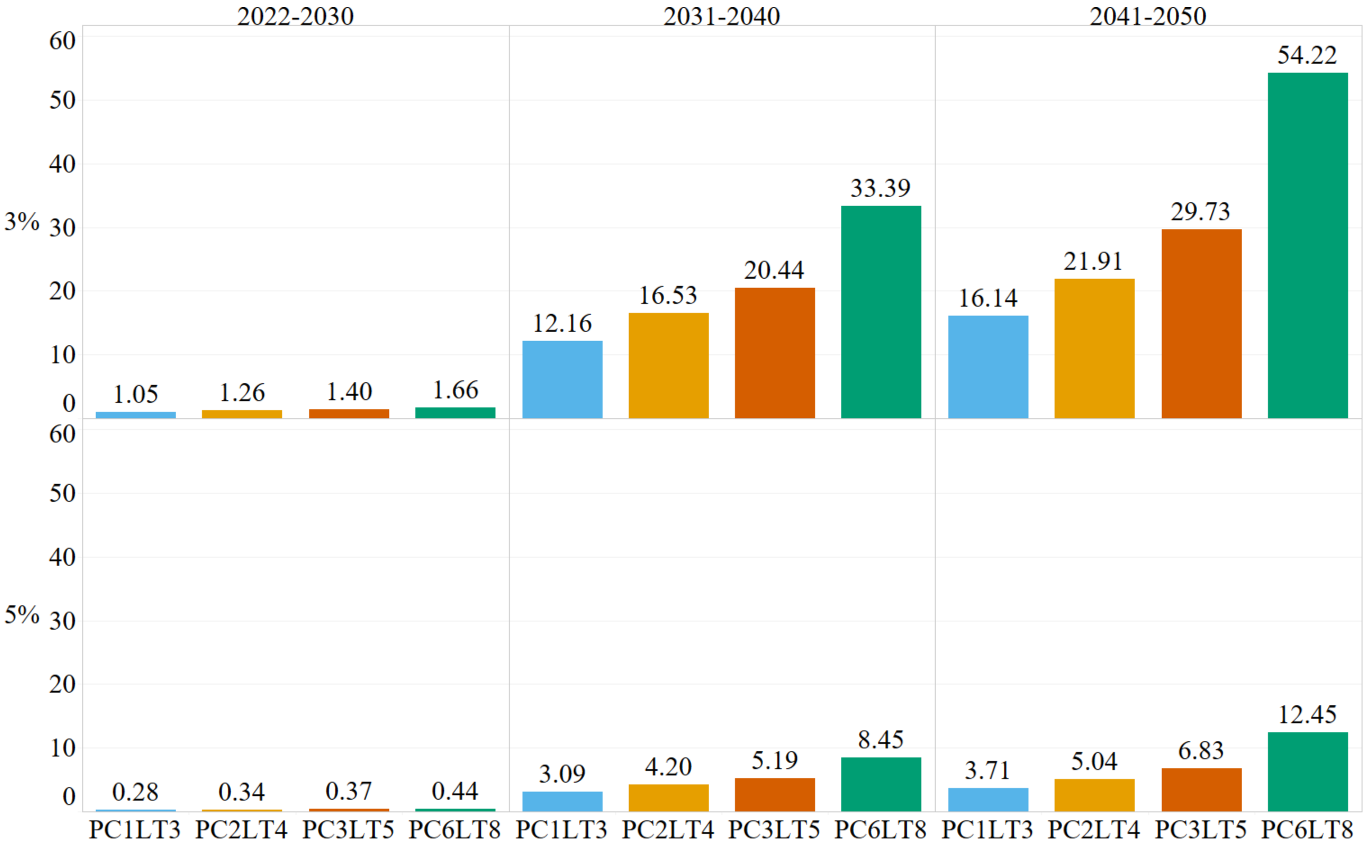
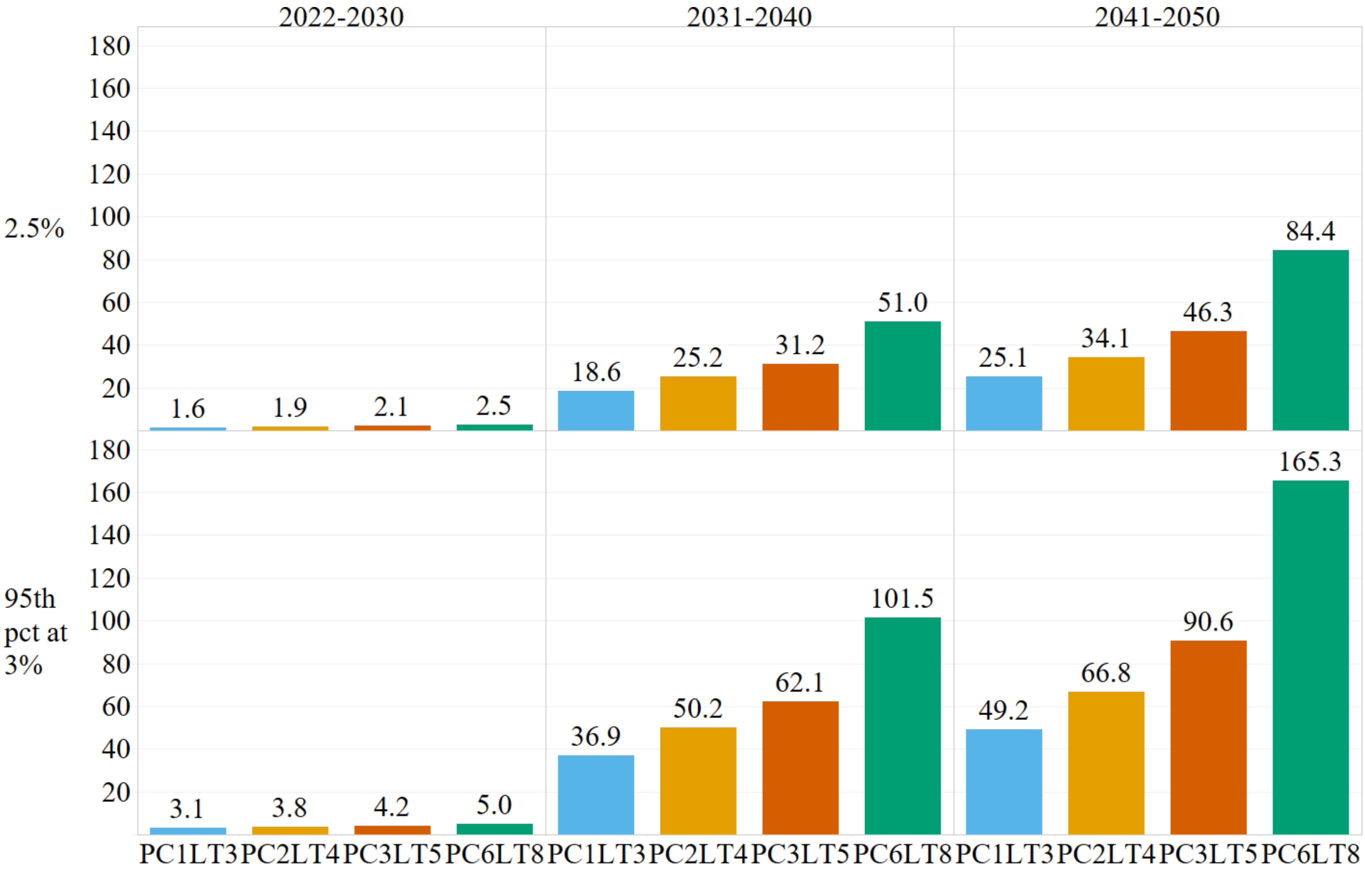


Figure 8-28: Avoided GHG Costs Relative to the No-Action Alternative (2021$, billions, 2.5 percent and 95th percentile at 3 percent DRs, CYs 2022-2050)



8.2.4.2. Social Benefits of Reducing Criteria Pollutant Emissions

The criteria pollutant emissions computed by the CAFE Model—nitrogen oxides (NO_X), sulfur oxides (SO_X), particulate matter 2.5 microns or less in diameter ($PM_{2.5}$)—are linked to various health impacts (see Draft TSD Chapter 5.4).[167] The model contains per-ton monetized health impact values corresponding to these health impacts (see Draft TSD Chapter 6.2.2). The CAFE Model calculates the total criteria pollutant emissions associated with the fleet in different alternatives, based on the emissions inventory discussed in Draft TSD Chapter 5, and the monetized health impact values per ton are then multiplied by the total tons in the emissions inventory. The resulting total costs associated with criteria pollutant emissions can be found in the CAFE Model Output Files. For further information pertaining to these criteria pollutant emissions, see also Chapter 4 in the Draft EIS.

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[167] The morbidity health impacts included in the per-ton monetized values are: acute bronchitis, asthma exacerbation, cardiovascular hospital admissions, lower respiratory symptoms, minor restricted activity days, non-fatal heart attacks, respiratory emergency room visits, respiratory hospital admissions, upper respiratory symptoms, and work loss days.

Table 8-7: Total and Incremental Costs of Criteria Pollutants, by Alternative and Social DR, MYs 1983-2032 (2021$, billions)

	No Action		PC1LT3		PC2LT4		PC3LT5		PC6LT8	
	3%	7%	3%	7%	3%	7%	3%	7%	3%	7%
NOx	44.7	31.2	0.06	0.03	0.07	0.04	0.07	0.04	0.12	0.07
SOx	66.9	42.7	0.15	0.09	0.18	0.11	0.06	0.05	0.17	0.11
$PM_{2.5}$	299.9	193.0	-0.38	-0.17	-0.55	-0.25	-0.38	-0.16	-0.67	-0.26

Table 8-7 shows the total and incremental health costs attributable to the three criteria pollutants under each rulemaking alternative, using the model year perspective (MYs 1983-2032), discounted at 3 and 7 percent. In the No Action column, we present these costs in absolute terms. Incremental costs are presented relative to the baseline in each action alternative. These SCs increase slightly for NO_X and SO_x relative to the baseline total, due to a number of factors described below, including electrification in some alternatives causing slightly higher upstream emissions, and for downstream emissions, some decreases in sales causing older vehicles to be driven longer, and slightly more VMT due to the rebound effect. Chapter 8.2.5.3, which describes the changes in the pollutants themselves across alternatives, rather than the changes in costs, includes further explanation of these effects on a CY basis.

When examined on a model year basis, total NOx emissions in the regulatory alternatives are lower than their level in the No-Action Alternative. Emissions for newer vehicles (MYs 2027-2032) are generally lower in the regulatory alternatives owing to a lower share of ICE vehicles, while in older vehicles (MYs 1983-2026) they tend to increase due to increased rebound VMT. While in the aggregate NOx emissions decrease in the regulatory alternatives, we find that downstream emissions are actually higher in the PC3LT5 and PC4LT6 Alternatives than in the No-Action Alternative. This is not the case when we isolate NOx emissions from upstream sources like Fuel Transportation, Storage, and Distribution (TS&D) of gasoline and diesel and from electricity sources. Here we find reductions in each regulatory alternative, again driven by vehicles produced during the standard setting years.

SO_x costs increase in every alternative relative to the baseline in both the model year perspective, and the CY perspective. The increases in SO_x upstream emissions are due to increased electricity shares and are greater than the decreases in downstream emissions which cause overall SO_x emissions to increase incrementally relative to the baseline in all alternatives. In addition, the power sector emissions modeling reflected in this analysis does not incorporate the most up-to-date data on the future evolution of the power sector, and the emission projections are higher than analyses using more recent data indicate is likely to be the case. This modeling will be updated in the final rule.

PM costs decrease across all alternatives due to the decreases in downstream emissions experienced in later CYs. This pattern is seen in both the model year and CY perspective. Incremental magnitudes of the PM decreases do not necessarily increase as alternatives become more stringent, since fleet makeup, vehicle age, and VMT within each model year can vary by alternative.

However, the overall trend for combined criteria pollutant health costs is one that decreases in later CYs. This is due to the impact of the decreasing PM levels, which have more health costs per ton associated with them than NO_x and sulfur dioxide (SO_2).

8.2.4.3. Social Costs of Changes to Congestion and Road Noise

Table 8-8: Social Costs of Congestion and Noise across Alternatives for CYs 2022-2050 (2021$, in billions)

	3% Discount Rate					7% Discount Rate				
	No Action	Relative to No Action				No Action	Relative to No Action			
		PC1LT3	PC2LT4	PC3LT5	PC6LT8		PC1LT3	PC2LT4	PC3LT5	PC6LT8
Congestion	6,914.03	7.34	9.63	12.51	18.70	4,363.77	3.64	4.75	6.13	9.07

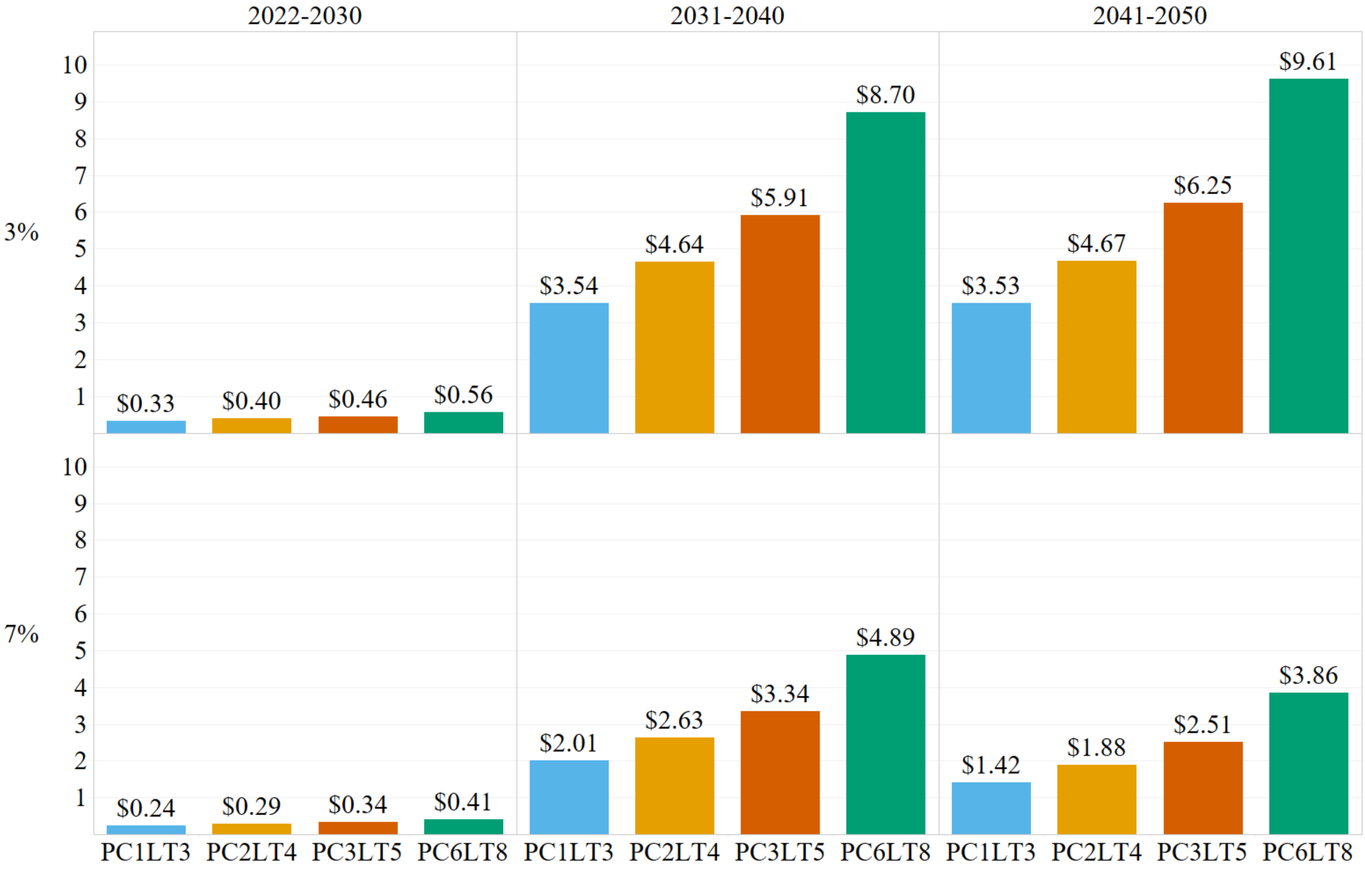
	3% Discount Rate					**7% Discount Rate**				
	No Action	**Relative to No Action**				**No Action**	**Relative to No Action**			
		PC1LT3	**PC2LT4**	**PC3LT5**	**PC6LT8**		**PC1LT3**	**PC2LT4**	**PC3LT5**	**PC6LT8**
Noise	63.04	0.06	0.09	0.11	0.17	39.77	0.04	0.05	0.06	0.09

Table 8-8 reports the incremental SCs of congestion and noise relative to the totals in the baseline across alternatives on a CY basis. Congestion and noise are functions of VMT, and the increases in these costs relate directly to increases in VMT, across MY and alternatives (see Chapter 8.2.5). For information regarding the calculation of congestion and noise costs in the CAFE Model, and how these relate to VMT and other inputs, see Chapter 6.2.3 in the accompanying Draft TSD. Overall, the trend across alternatives consists of small and relatively steady increases in congestion and noise costs as regulatory stringency increases.

Figure 8-29 focuses on these differences in costs between the alternatives relative to the baseline. In this figure, noise and congestion costs are combined (due to the relatively small contribution of noise costs), and the CY perspective is used, showing how the negative benefits are distributed across decades. For example, in the top panel of Figure 8-29 (corresponding to the 3 percent DR), the bar corresponding to Alternative 3 in the period from 2041-2050 represents a $9.6 billion increase in congestion and noise costs relative to the baseline totals. Most of the incremental costs are incurred during the third decade, 2041-2050.

It is important to note that the incremental costs presented in Figure 8-29, even at their highest, are equal in value to a relatively small portion of the total congestion and noise costs incurred in Alternative 0. For instance, under Alternative 3, using a 3 percent DR, the incremental costs arising from noise and congestion between 2041-2050 were equal in magnitude to about 0.2 percent of the total congestion and noise baseline costs. On the smaller end, the additional costs incurred from congestion and noise under Alternative 1 between 2022-2030 (using a 3 percent DR) have a value approximately equal to 0.01 percent of the total baseline congestion and noise costs.

Figure 8-29: Avoided Congestion and Noise Costs Relative to the No-Action Alternative, CYs 2022-2050 (2021$, billions)



8.2.4.4. Benefits of Increased Energy Security

The CAFE Model accounts for benefits of increased energy security by computing changes in SCs of petroleum market externalities. These SCs represent the risk to the U.S. economy incurred by exposure to price shocks in the global petroleum market that are not accounted for by oil prices and are a direct function of gallons of fuel consumed. Chapter 6.2.4 in the accompanying Draft TSD describes the inputs involved in calculating these petroleum market externality costs.

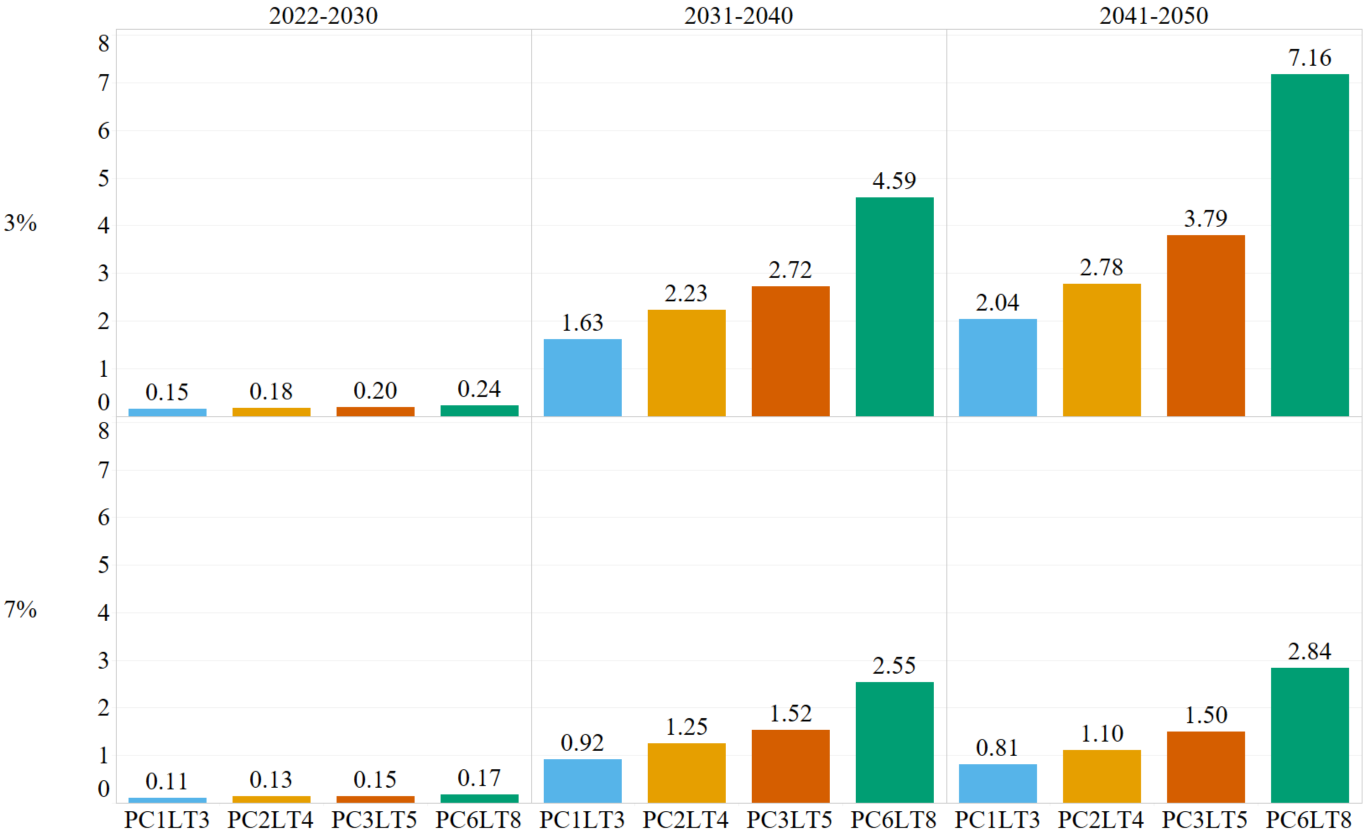
As seen in Table 8-9, SCs of petroleum market externalities decrease (or, the benefits of increased energy security increase) in all alternatives, and the magnitudes of the decreases become greater as the alternatives become more stringent. The scope of these changes is relatively small; using the 3 percent DR, the largest benefits (avoided incremental energy security costs) are approximately equal to 2 percent of the total petroleum market externality costs in the No-Action Alternative.

Table 8-9: Social Costs of Increased Energy Security Relative to the No-Action Alternative, MYs 1983-2032 (2021$, billions)

	PC1LT3	PC2LT4	PC3LT5	PC6LT8
3% discount rate	-1.47	-1.86	-2.10	-2.92
7% discount rate	-0.80	-1.01	-1.14	-1.56

Figure 8-30 shows the distribution of these avoided costs (positive benefits) across CY decades. The majority of benefits accrue after the first decade, and the largest share correspond to the period between 2041-2050, when the reductions in fuel consumption are largest relative to the baseline.

Figure 8-30: Avoided Costs of Petroleum Externalities Relative to the No-Action Alternative, CYs 2022-2050 (2021$, billions)



8.2.4.5. Safety Effects of Changing Standards

Table 8-10 through Table 8-12 summarize the safety impacts of each alternative broken down by safety factor. These impacts are summarized over CYs 2022-2050, for all light passenger vehicles (including PCs and LTs). Economic impacts are shown separately under both 3 and 7 percent DRs. Discounting is applied to CY cost impacts. Fatality, non-fatal injury, and Property Damage-Only (PDO) counts are undiscounted.

As noted previously, safety impacts are expected to be driven by changes in vehicle mass which make vehicles lighter to improve fuel economy, by added exposure from rebound miles driven in response to reduced driving costs that result from improved fuel efficiency, and by changes in fleet composition resulting from the impact of higher prices on new and used vehicle sales, as well as the relative desirability of PCs compared to LTs.

Generally, the stricter efficiency triggers more use of MR and the resulting reductions in driving costs produce more rebound driving. Higher prices resulting from higher CAFE requirement slow the turnover of the vehicle fleet. As standards become more stringent, the additional cost of attaining those standards increases the price of new vehicles. This results in older vehicles without improved safety features and technologies of newer vehicles remaining on the roads longer. Furthermore, consumers purchase fewer new vehicles. This is also coupled with a general shift towards more LTs over time as larger vehicles become less costly to operate.

Across all alternatives, mass changes relative to the baseline result in small reductions in overall fatalities, injuries, and property damage. These results may seem counterintuitive given the agency’s previous analyses. This outcome amounts to noise around zero. Additionally, the change in the model’s fleet share accounting plays a heavy influence on the mass-safety outcome. Because the fleet share now shows more LTs than passenger vehicles, MR is less pronounced or even positive for those vehicles, with a corresponding beneficial safety impact. Rebound and scrappage effects increase fatalities as policy alternatives become more stringent. The total societal crash costs range from $11.4 ($5.9) billion to $34 ($17.6) billion across alternatives with a 3% (7%) DR.

Table 8-12 illustrates the cumulative impact of each alternative on the number of fatalities, nonfatal injuries, and vehicles sustaining property damage during CYs 2022 through 2050. For context, during this same period, baseline fatalities are expected to total somewhat less than 600,000, or an annual average of about 20,000. The PDO costs for sales/scrappage are shown as a benefit. This is caused by how the agency divides PDO crashes between the three effects. The model calculates PDO crashes as a single estimate, and then we account for rebound and mass-safety effects separately. Sales/scrappage PDO crashes are deemed to be the difference between those three estimates.[168]

Table 8-10: Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 for Total Fleet, 3% Percent DR, by Alternative

Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 for Total Fleet, 3% Percent DR, by Alternative				
Alternative	**PC1LT3**	**PC2LT4**	**PC3LT5**	**PC6LT8**
Fatality Costs ($b)				
Fatality Costs From Mass Changes	-0.3	-0.3	-0.1	0.2
Fatality Costs From Rebound Effect	3.5	4.5	5.9	8.7
Fatality Costs from Sales/Scrappage	0.5	0.7	1.2	2.1
Total - Fatality Costs	3.6	4.9	7	11.1
Non-Fatal Crash Costs ($b)				
Non-Fatal Crash Costs From Mass Changes	-0.6	-0.6	-0.1	0.4
Non-Fatal Crash Costs From Rebound Effect	6.9	9.1	11.7	17.5
Non-Fatal Crash Costs from Sales/Scrappage	0.5	0.7	1.3	2.3
Total - Non-Fatal Crash Costs	6.8	9.2	13	20.3
Property Damage Costs ($b)				
Property Damage Costs From Mass Changes	-0.1	-0.1	0	0.1
Property Damage Costs From Rebound Effect	1.2	1.6	2	3
Property Damage Costs From Sales/Scrappage	-0.1	-0.1	-0.2	-0.4
Total - Property Damage Costs	1	1.4	1.8	2.7
Societal Crash Costs ($b)				
Crash Costs from Mass Changes	-1.1	-1	-0.2	0.6
Crash Costs from Rebound Effect	11.6	15.2	19.6	29.3
Crash Costs from Sales/Scrappage	0.9	1.3	2.3	4.1
Total - Societal Crash Costs	11.4	15.5	21.8	34

Table 8-11: Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 for Total Fleet, 7% Percent DR, by Alternative

Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 for Total Fleet, 7% Percent DR, by Alternative

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[168] See Draft TSD Chapter 7.5.

Alternative	PC1LT3	PC2LT4	PC3LT5	PC6LT8
Fatality Costs ($b)				
Fatality Costs From Mass Changes	-0.1	-0.1	0	0.1
Fatality Costs From Rebound Effect	1.7	2.2	2.8	4.1
Fatality Costs from Sales/Scrappage	0.4	0.5	0.9	1.6
Total - Fatality Costs	1.9	2.5	3.6	5.8
Non-Fatal Crash Costs ($b)				
Non-Fatal Crash Costs From Mass Changes	-0.3	-0.3	0	0.2
Non-Fatal Crash Costs From Rebound Effect	3.4	4.4	5.6	8.3
Non-Fatal Crash Costs from Sales/Scrappage	0.4	0.6	1.1	2
Total - Non-Fatal Crash Costs	3.5	4.7	6.6	10.4
Property Damage Costs ($b)				
Property Damage Costs From Mass Changes	0	0	0	0
Property Damage Costs From Rebound Effect	0.6	0.8	1	1.5
Property Damage Costs From Sales/Scrappage	0	-0.1	-0.1	-0.2
Total - Property Damage Costs	0.5	0.7	0.9	1.3
Societal Crash Costs ($b)				
Crash Costs from Mass Changes	-0.4	-0.4	-0.1	0.3
Crash Costs from Rebound Effect	5.6	7.3	9.4	13.9
Crash Costs from Sales/Scrappage	0.7	1	1.8	3.4
Total - Societal Crash Costs	5.9	7.9	11.1	17.6

Table 8-12: Change in Fatalities, Non-Fatal Injuries, and PDO from Alternative 0 (Baseline) for CY 2022-2050 for Total Fleet, by Alternative

Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 by Alternative				
Alternative	**PC1LT3**	**PC2LT4**	**PC3LT5**	**PC6LT8**
Fatalities				
Fatalities From Mass Changes	-53	-46	-8	27
Fatalities from Rebound Effect	516	673	879	1,317
Fatalities from Sales/Scrappage	43	63	118	202
Total Changes in Fatalities	506	690	989	1,546
Non-Fatal Crashes				
Non-Fatal Crash From Mass Changes	-8,223	-7,387	-1,464	4,849
Non-Fatal Crash From Rebound Effect	81,814	107,786	139,933	210,233
Non-Fatal Crash from Sales/Scrappage	3,086	4,658	9,302	14,419
Total - Non-Fatal Crash	76,677	105,057	147,771	229,501
Property Damaged Vehicles				

Property Damage Vehicles From Mass Changes	-28,533	-24,894	-4,321	18,241
Property Damage Vehicles From Rebound Effect	274,761	362,513	471,861	712,423
Property Damage Vehicles From Sales/Scrappage	-16,149	-22,096	-47,046	-82,251
Total - Property Damage Vehicles	230,079	315,523	420,494	648,413

8.2.4.6. Summary of Social Benefits and Costs

Table 8-13 describes the costs and benefits of increasing CAFE standards in each alternative, as well as the party to which they accrue. Manufacturers are directly regulated under the program and incur additional production costs when they apply technology to their vehicle offerings in order to improve their fuel economy. We assume that those costs are fully passed through to new car and truck buyers, in the form of higher prices. We also assume that any civil penalties – paid by manufacturers for failing to comply with their CAFE standards – are passed through to new car and truck buyers and are included in the sales price. However, those civil penalties are paid to the U.S. Treasury, where they currently fund the general business of government. As such, they are a transfer from new vehicle buyers to all U.S. citizens, who then benefit from the additional Federal revenue. While they are calculated in the analysis, and do influence consumer decisions in the marketplace, they do not contribute to the calculation of net benefits (and are omitted from the tables below).

While incremental maintenance and repair costs would accrue to buyers of new cars and trucks affected by more stringent CAFE standards, we do not carry these costs in the central analysis. They are difficult to estimate for emerging technologies but represent real costs (and real benefits in the case of AFVs that may require less frequent maintenance events). They may be included in future analyses as data become available to evaluate lifetime maintenance costs. This analysis assumes that drivers of new vehicles internalize 90 percent of the risk associated with increased exposure to crashes when they engage in additional travel (as a consequence of the rebound effect).

Private benefits are dominated by the value of fuel savings, which accrue to new car and truck buyers at retail FPs (inclusive of Federal and state taxes). In addition to saving money on fuel purchases, new vehicle buyers also benefit from the increased mobility that results from a lower cost of driving their vehicle (higher fuel economy reduces the per-mile cost of travel) and fewer refueling events. The additional travel occurs as drivers take advantage of lower operating costs to increase mobility, and this generates benefits to those drivers – equivalent to the cost of operating their vehicles to travel those miles, the consumer surplus, and the offsetting benefit that represents 90 percent of the additional safety risk from travel.

In addition to private benefits and costs—those borne by manufacturers, buyers, and owners of cars and LTs—there are other benefits and costs from increasing CAFE standards that are borne more broadly throughout the economy or society, which the agency refers to as SCs.[169] Of these SCs, the largest is the loss in fuel tax revenue that occurs as a result of falling fuel consumption.[170] Buyers of new cars and LTs produced in MY subject to increasing CAFE standards save on fuel purchases that include Federal, state, and sometimes local or Tribal taxes, so revenues from these taxes decline; because that revenue funds maintenance of roads and bridges as well as other government activities, the loss in fuel tax revenue represents a SC.[171] The additional driving that occurs as new vehicle buyers take advantage of lower per-mile fuel costs is a benefit to those drivers, but the congestion (and road noise) created by the additional travel also imposes a small additional SC to all road users.

Among the purely external benefits created when CAFE standards are increased, the largest is the reduction in damages resulting from GHG emissions. Table 8-13 shows the different SC results that correspond to each GHG DR. The associated benefits related to reduced health damages from criteria pollutants and the benefit of improved energy security are both significantly smaller than the associated change in GHG damages across alternatives. As the tables also illustrate, the majority of both costs and benefits are private

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[169] Some of these external benefits and costs result from changes in economic and environmental externalities from supplying or consuming fuel, while others do not involve changes in such externalities but are similar in that they are borne by parties other than those whose actions impose them.

[170] Changes in tax revenues are a transfer and not an economic externality as traditionally defined, but we group these with SCs instead of private costs since that loss in revenue affects society as a whole as opposed to impacting only consumers or manufacturers.

[171] It may subsequently be replaced by another source of revenue, but that is beyond the scope of this rulemaking to examine.

costs and benefits that accrue to buyers of new cars and trucks, rather than external welfare changes that affect society more generally (with the exception of the 95th percentile SC-GHG case). This has been consistently true in CAFE rulemakings.

The choice of GHG DR or social DR also affects the resulting benefits and costs. As the tables show, net social benefits are positive for all alternatives when SC-GHG DRs of 2.5 or 3 percent are used, but are negative under Alternatives PC3LT5 and PC6LT8 when the 5 percent SC-GHG DR is applied, using the 3% social DR. When using the 7% social DR, all of the alternatives yield negative net benefits under the 5% SC-GHG DR. Totals in the following table may not sum perfectly due to rounding.

Table 8-13: Incremental Benefits and Costs Over the Lifetimes of Total Fleet Produced Through 2032 (2021$ Billions), by Alternative

	3% Discount Rate				7% Discount Rate			
	PC1 LT3	**PC2 LT4**	**PC3 LT5**	**PC6 LT8**	**PC1 LT3**	**PC2 LT4**	**PC3 LT5**	**PC6 LT8**
Private Costs								
Technology Costs to Increase Fuel Economy	29.9	37.8	50.7	68.8	21.5	27.1	36.1	48.5
Increased Maintenance and Repair Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sacrifice in Other Vehicle Attributes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consumer Surplus Loss from Reduced New Vehicle Sales	0.0	0.1	0.2	1.1	0.0	0.1	0.2	0.8
Safety Costs Internalized by Drivers	4.3	5.3	6.6	8.7	2.3	2.9	3.6	4.7
Subtotal - Private Costs	34.2	43.3	57.5	78.6	23.8	30.0	39.8	54.0
Social Costs								
Congestion and Noise Costs from Rebound-Effect Driving	3.0	3.6	5.3	5.3	1.7	2.1	3.1	3.4
Safety Costs Not Internalized by Drivers	1.7	1.7	4.6	5.0	1.2	1.4	3.1	4.3
Loss in Fuel Tax Revenue	7.9	10.0	11.3	15.6	4.4	5.6	6.2	8.5
Subtotal - Social Costs	12.6	15.4	21.2	26.0	7.4	9.1	12.4	16.3
Total Societal Costs (incl. Private)	46.8	58.6	78.7	104.5	31.2	39.1	52.2	70.3
Private Benefits								
Reduced Fuel Costs	37.6	47.7	55.1	75.9	20.6	26.0	30.0	40.7
Benefits from Additional Driving	7.3	9.0	11.0	14.1	4.0	4.9	6.0	7.6
Less Frequent Refueling	2.0	2.7	3.1	4.6	1.1	1.5	1.7	2.5
Subtotal - Private Benefits	46.9	59.4	69.1	94.6	25.6	32.4	37.6	50.9
External Benefits								
Reduction in Petroleum Market Externality	1.5	1.9	2.1	2.9	0.8	1.0	1.1	1.6
Reduced Health Damages	0.2	0.3	0.2	0.4	0.1	0.1	0.1	0.1
Reduced Climate Damages								
SC-GHG @ 5% DR[172]	2.7	3.5	4.0	5.5	2.7	3.5	4.0	5.5

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[172] DR = Discount rate.

	3% Discount Rate				7% Discount Rate			
	PC1 LT3	PC2 LT4	PC3 LT5	PC6 LT8	PC1 LT3	PC2 LT4	PC3 LT5	PC6 LT8
SC-GHG @ 3% DR	11.0	14.0	16.0	22.2	11.0	14.0	16.0	22.2
SC-GHG @ 2.5% DR	16.8	21.4	24.6	34.1	16.8	21.4	24.6	34.1
SC-GHG @ 95th pctile at 3% DR	33.3	42.4	48.7	67.5	33.3	42.4	48.7	67.5
Total Societal Benefits (incl. Private)								
SC-GHG @ 5% DR	51.2	65.0	75.5	103.4	29.2	37.0	42.8	58.1
SC-GHG @ 3% DR	59.5	75.5	87.5	120.1	37.5	47.5	54.9	74.8
SC-GHG @ 2.5% DR	65.3	82.9	96.1	132.0	43.3	54.9	63.5	86.7
SC-GHG @95th pctile at 3% DR	81.8	103.9	120.2	165.4	59.8	75.9	87.6	120.1
Net Societal Benefits								
SC-GHG @ 5% DR	4.4	6.3	-3.2	-1.2	-2.0	-2.1	-9.4	-12.2
SC-GHG @ 3% DR	12.7	16.8	8.8	15.6	6.3	8.4	2.7	4.5
SC-GHG @ 2.5% DR	18.5	24.3	17.4	27.5	12.1	15.8	11.3	16.4
SC-GHG @ 95th pctile at 3% DR	35.0	45.2	41.5	60.9	28.7	36.8	35.4	49.8

Table 8-14: Incremental Benefits and Costs for the On-Road Fleet CY 2022-2050 (2021$ Billions), by Alternative

	3% Discount Rate				7% Discount Rate			
	PC1 LT3	PC2 LT4	PC3 LT5	PC6 LT8	PC1 LT3	PC2 LT4	PC3 LT5	PC6 LT8
Private Costs								
Technology Costs to Increase Fuel Economy	77.7	104.7	170.5	270.0	45.6	60.8	96.1	149.3
Increased Maintenance and Repair Costs	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sacrifice in Other Vehicle Attributes	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Consumer Surplus Loss from Reduced New Vehicle Sales	0.1	0.1	0.5	1.9	0.0	0.1	0.3	1.2
Safety Costs Internalized by Drivers	10.4	13.7	17.7	26.4	5.0	6.6	8.5	12.5
Subtotal - Private Costs	88.2	118.5	188.7	298.2	50.7	67.5	104.8	163.1
Social Costs								
Congestion and Noise Costs from Rebound-Effect Driving	7.4	9.7	12.6	18.9	3.7	4.8	6.2	9.2
Safety Costs Not Internalized by Drivers	1.0	1.8	4.1	7.7	0.8	1.3	2.7	5.0
Loss in Fuel Tax Revenue	19.7	26.8	34.5	61.1	9.7	13.1	16.5	28.7
Subtotal - Social Costs	28.1	38.3	51.2	87.7	14.2	19.2	25.4	42.9
Total Societal Costs (incl. private)	116.3	156.8	239.9	385.9	64.9	86.7	130.2	206.0
Private Benefits								
Reduced Fuel Costs	97.6	131.7	170.6	291.0	47.2	63.5	81.2	135.9

	3% Discount Rate				**7% Discount Rate**			
	PC1 LT3	**PC2 LT4**	**PC3 LT5**	**PC6 LT8**	**PC1 LT3**	**PC2 LT4**	**PC3 LT5**	**PC6 LT8**
Benefits from Additional Driving	17.6	22.8	29.2	41.7	8.6	11.1	14.1	20.0
Less Frequent Refueling	0.6	1.9	0.0	-2.7	0.7	1.3	0.6	-0.3
Subtotal - Private Benefits	115.8	156.4	199.8	330.1	56.5	75.8	95.9	155.5
External Benefits								
Reduction in Petroleum Market Externality	3.8	5.2	6.7	12.0	1.8	2.5	3.2	5.6
Reduced Health Damages	1.5	2.0	2.7	5.5	0.6	0.7	1.0	2.0
Reduced Climate Damages								
SC-GHG @ 5% DR	7.1	9.6	12.4	21.3	7.1	9.6	12.4	21.3
SC-GHG @ 3% DR	29.3	39.7	51.6	89.3	29.3	39.7	51.6	89.3
SC-GHG @ 2.5% DR	45.3	61.2	79.6	137.9	45.3	61.2	79.6	137.9
SC-GHG @ 3% at 95th pctile DR	89.3	120.8	156.9	271.7	89.3	120.8	156.9	271.7
Total Societal Benefits (incl. private)								
SC-GHG @ 5% DR	128.2	173.2	221.6	369.0	66.0	88.6	112.5	184.4
SC-GHG @ 3% DR	150.5	203.3	260.8	436.9	88.3	118.8	151.6	252.3
SC-GHG @ 2.5% DR	166.4	224.8	288.8	485.5	104.2	140.3	179.6	301.0
SC-GHG @ 3% at 95th pctile DR	210.4	284.3	366.1	619.3	148.2	199.8	257.0	434.8
Net Social Benefits								
SC-GHG @ 5% DR	11.9	16.3	-18.2	-16.9	1.2	1.9	-17.8	-21.6
SC-GHG @ 3% DR	34.2	46.5	21.0	51.0	23.4	32.1	21.4	46.4
SC-GHG @ 2.5% DR	50.1	68.0	49.0	99.7	39.3	53.6	49.4	95.0
SC-GHG @ 3% at 95th pctile DR	94.1	127.5	126.3	233.5	83.3	113.1	126.7	228.8

8.2.5. Physical and Environmental Effects

Since improvements in vehicle fuel economy typically add costs to those vehicles, and since added cost often results in higher prices, the sale of new vehicle models may be impacted as consumers prefer to hold on to their existing vehicles for longer if they perceive that the value of fuel savings is less than the increase in purchase price. Over time, the cumulative change in new vehicle sales and retirement of older vehicles would impact the annual growth of the overall on-road fleet. Because we assume that consumers value fuel savings over the life of a vehicle as equal to the first 30 months of undiscounted fuel savings, we analyze higher CAFE standards exemplified by the action alternatives as leading to a reduction to the on-road vehicle fleet when compared to the baseline scenario (the No-Action Alternative) in the out years. Concurrently, increasing fuel economy is assumed to decrease the overall consumption of various fuel sources (and also reduce emissions of CO_2, the primary GHG released during vehicle operation), while also reducing the fuel cost-per-mile of driving, thereby increasing the total demand for travel. As a consequence of reduced overall fuel consumption, the on-road fleet also generates fewer emissions resulting from criteria air pollutants. This, in turn, leads to a reduction in adverse health incidents caused by exposure to these pollutants.

The following table and figure demonstrate the cumulative impacts over the next three decades for all alternatives. Since the first model year evaluated for today's analysis begins in MY 2022, the first decade in the table and figure cover the range of CYs between CYs 2022 and 2030, while the latter two encompass effects over the full ten-year periods. As such, the values shown for the first decade are marginally lower (by comparison) than what they would have been if the entire ten-year horizon was available. Nevertheless, the cumulative impacts are presented in such a way to provide a reader with a snapshot of the overall results of the analysis, while also demonstrating the relative differences between the decades. Meanwhile, the later chapters present this information in a disaggregated manner, by focusing on the effects during the individual CYs.

Table 8-15: Cumulative Impacts for All Alternatives

	No-Action	PC1LT3	PC2LT4	PC3LT5	PC6LT8
On-Road Fleet (Million Units)					
2022 - 2030	2,393	2,394	2,394	2,394	2,394
2031 - 2040	2,606	2,603	2,602	2,600	2,594
2041 - 2050	2,645	2,640	2,638	2,631	2,619
Vehicle Miles Traveled (Billion Miles)					
2022 - 2030	28,057	28,061	28,061	28,062	28,063
2031 - 2040	33,745	33,795	33,811	33,829	33,869
2041 - 2050	34,490	34,556	34,578	34,607	34,670
Fuel Consumption (Billion Gallons/GGE)					
2022 - 2030	1,115	1,114	1,113	1,113	1,113
2031 - 2040	997	974	966	959	935
2041 - 2050	709	675	663	646	596
CO_2 Emissions (mmT)					
2022 - 2030	12,362	12,342	12,338	12,335	12,330
2031 - 2040	10,988	10,735	10,644	10,562	10,290
2041 - 2050	7,633	7,252	7,116	6,931	6,352

Figure 8-31: Cumulative Impacts for All Alternatives

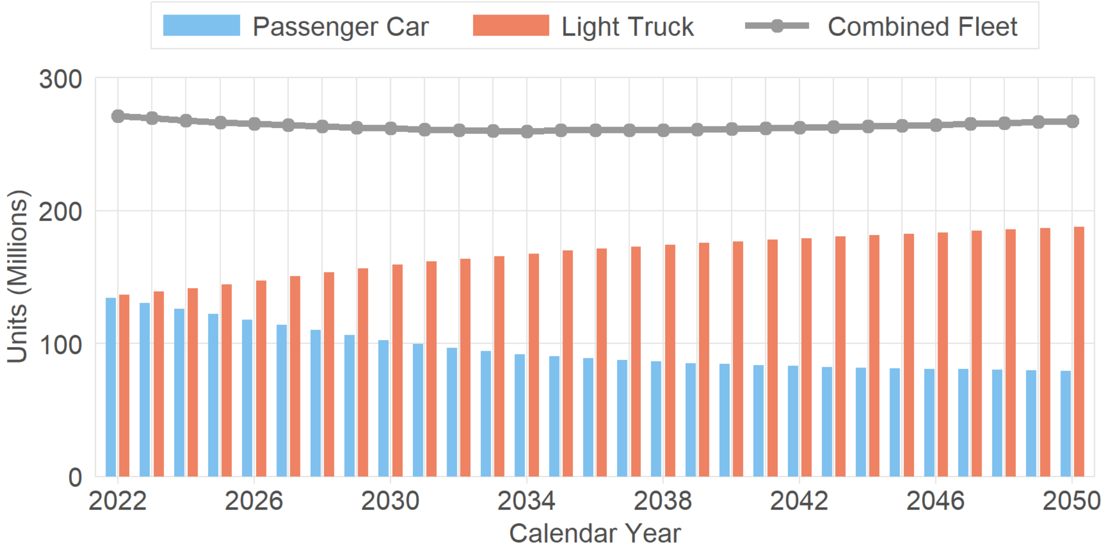
As Table 8-15 and Figure 8-31 show, the differences in the on-road fleet and VMT between alternatives are marginal; however, the differences in the amount of aggregate fuel consumed and CO_2 emitted are more pronounced in the latter two decades. At the same time, while the cumulative on-road fleet and VMT grow moderately between the decades, fuel consumption and CO_2 emissions see a drastic decline during the last decade (covering CY 2041 to 2050). The chapters that follow provide additional detail of the aforementioned effects, while comparing the outcomes of the action and No-Action Alternatives.

8.2.5.1. Changes to On-Road Fleet and Vehicle Miles Traveled

The CAFE Model simulates the consumer response to increases in vehicle prices and fuel economy imposed by action alternatives, including the effect on new vehicle sales as well as the ancillary impacts these changes pose to the existing vehicle fleet. As CAFE standards become more stringent, the cost of new vehicles would rise, which would cause a decline in new vehicle sales—if consumers perceived that the present value of fuel savings did not justify the increase in price. In such a case, over time, this would extend to an overall slowing in the growth of the on-road fleet if vehicle retirement rates remain relatively constant. Conversely, introducing more fuel-efficient options into the vehicle population is assumed to have an opposite effect on the amount of miles traveled, marginally increasing the total VMT as the cost of travel becomes cheaper. While these characteristics are present within the action alternatives (that is, a sales response when measured in proportion to the baseline), under the No-Action Alternative, these effects are intentionally omitted (by using external models) with the intent of producing the same *baseline* that is representative of the future outlook of the light-duty fleet. However, the impacts of more fuel-efficient vehicles occurring under the No-Action Alternative are still captured in the analysis via the changes to the scrappage rates of historic and new vehicle models, which also lead to the marginal annual increases in total VMT (as a consequence of the fuel economy rebound effect as well as fleet turnover).

Figure 8-32 presents the size of the on-road fleet through 2050 under the No Action Alternative. The vertical bars in the figure denote the annual progression of the PC and LT fleets independently, while the evolution of the combined fleet is depicted by the gray line. As demonstrated by Figure 8-32, the overall fleet undergoes a moderate decline during the first half of the analysis, while regaining most of the lost vehicle population during the second half. This decline is attributed entirely to the declining sales of PCs. The subsequent resurgence in the later years, however, is ascribed to continual annual growth of the LT fleet pared with a slowing in the decline of PCs.

Figure 8-32: Total On-Road Fleet in the Baseline Scenario



At the onset of analysis for this rulemaking (in MY 2022), the production of LTs (8.91m units) exceeds that of PCs (5.48m units) by over 60 percent. To project future years, NHTSA utilizes a macroeconomic model to estimate the production volumes of the overall light-duty fleet, and the 2022 AEO projections were adapted to estimate the individual shares of new car and truck sales.[173] The AEO projections show a shift from PCs toward LTs, and as a result, by the end of the analysis (MY 2050), the volume of new LTs sold (11.09m units) is estimated to be more than double the volume of PCs (4.78m units). The surplus of truck sales, coupled with the accompanying decline in car shares, leads to a sharp shift of the on-road fleet from cars to trucks throughout the future CYs, as aging vehicles are retired in favor of newer models. The outcome of this behavior is visualized by Figure 8-32.

While the on-road fleet declines somewhat in the No-Action Alternative, the total amount of VMT increases steadily year over year, as illustrated in Figure 8-33. Around CY 2040, the total fleet-wide VMT peaks, and remains steady thereafter (with only imperceivable fluctuations).[174] The VMT projections for both PC and LT fleets follow similar patterns that were observed for the on-road fleet, showing a decrease in the total VMT for the car fleet, and an increase for the truck fleet. By the end of the analysis (in MY 2050), the share of total miles traveled by the LT fleet is nearly two and half times higher than that of the car fleet.

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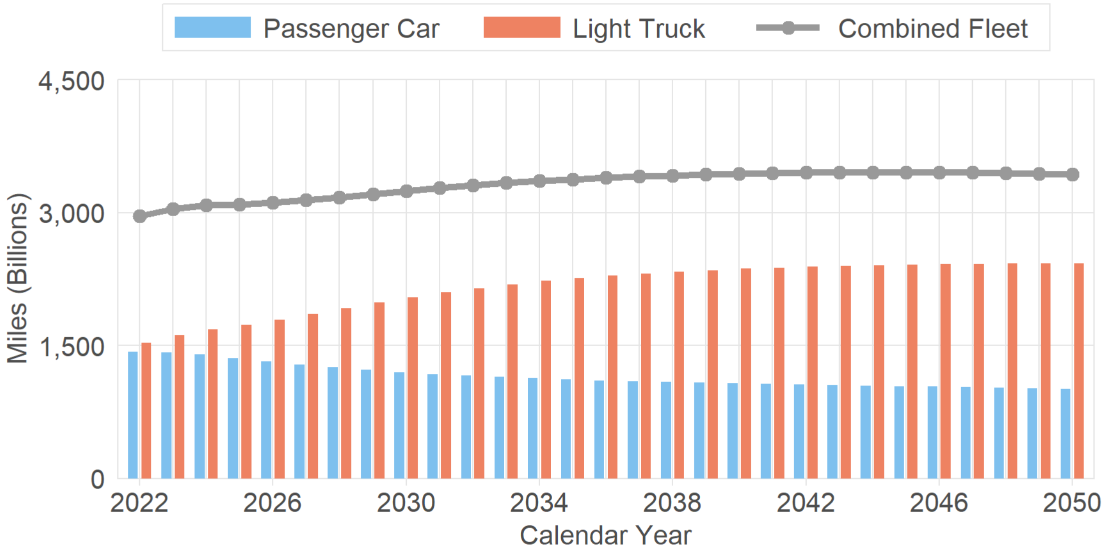
[173] Refer to Draft TSD Chapters 4.2.1.2 and 4.2.1.3 for more detail on the way NHTSA has modeled projections to sales and fleet-mix changes during the future years under the baseline (No Action) and the action alternatives.

[174] The agency breaks VMT into two components: “non-rebound VMT” and “rebound VMT”. Non-rebound VMT is assumed to be unaffected by the proposed standards as much of the demand of travel is presumed to be inelastic, and therefore is the same across all regualtory scenarios. Rebound VMT is the direct measurement of how demand for VMT will respond to decreases in vehicle operating costs. See Draft TSD Chapter 4.3. Since non-rebound VMT is affixed across alternatives, rebound VMT is responsible for the changes in VMT across altenratives.

Figure 8-33: Total VMT in the Baseline Scenario



With the increases in stringency that the action alternatives represent, the number of new vehicles produced and sold during future MY declines slightly to moderately as compared to the No-Action Alternative.[175] As with the No-Action Alternative, this reduction generally translates to the cumulative decrease of the on-road population of the combined fleet in most CYs, as can be seen in Figure 8-34. Likewise, as shown in the figure, the individual car and truck fleets follow a similar pattern as the overall fleet. This figure presents the incremental differences, as compared to the baseline scenario (the No Action Alternative), for each action alternative evaluated as part of this rulemaking. From this figure, higher CAFE standards, such as Alternative PC6LT8, lead to a greater reduction of the volume of the on-road fleet in later MY (whether combined or for individual fleets) as compared to the alternatives with smaller increases of the standards. During the standard setting years, the on-road fleet grows; since new vehicle sales are decreasing, this increase is attributable to a slowing of existing vehicle retirements. Since the existing fleet in the early CY consists of more PCs, the slowing rate of retirement leaves more PCs in the on-road fleet.

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[175] New vehicle sales in the action alternatives decline by up 2.8% depending on the fleet, model year, and alternative. For the LT fleet, however, some of the action alterantives show a slight increase in sales by up to 0.2% in a few of the later model years.

Figure 8-34: Changes in On-Road Fleet Compared to Baseline

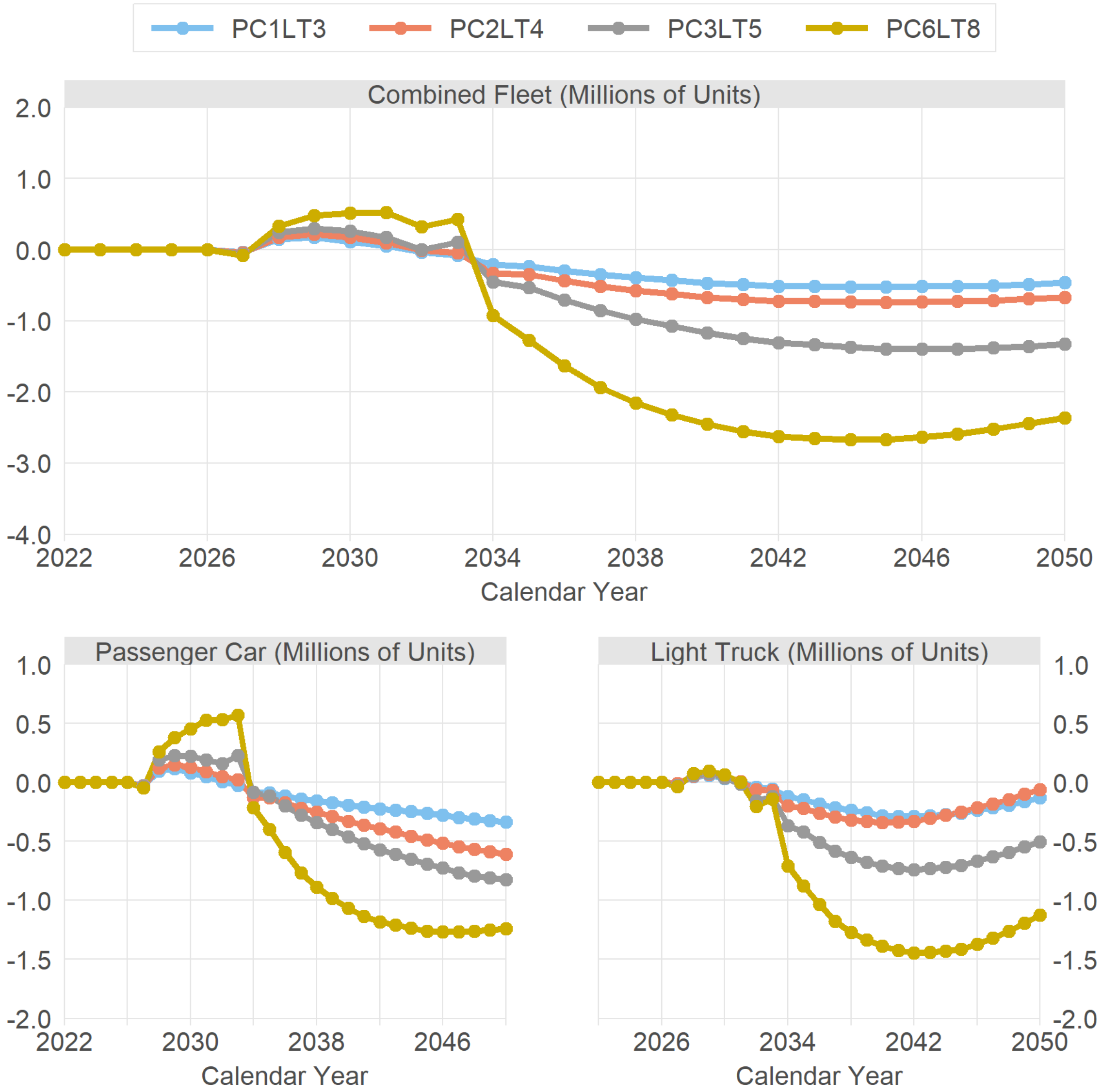
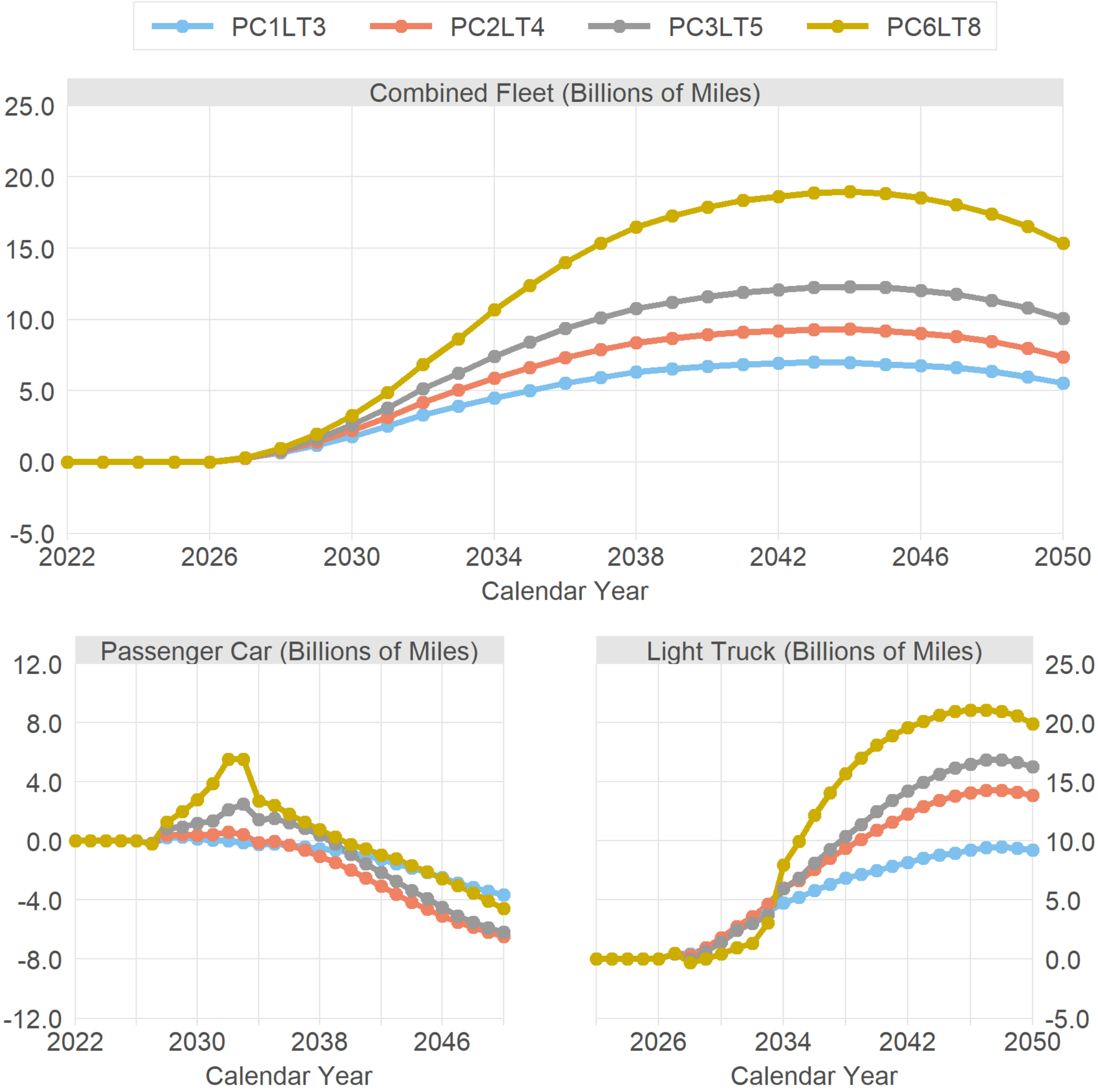


Figure 8-34 shows the incremental differences in the on-road fleet by CY. During the standard setting years the fleet grows, as a reduction in the scrappage of used vehicles dominates the reduction in sales of new vehicles. Sales and scrappage are expected to be lower than in the No-Action Alternative due to the effect of greater technology adoption costs on the prices for new vehicles. In later years the effect on sales dominates the scrappage effect and the on-road fleet becomes smaller in the action alternatives. While the volume of the on-road fleet decreases slightly as a consequence of the new CAFE standards defined by the action alternatives, the amount of total miles traveled by the entire fleet grows slightly when compared to the No-Action Alternative. The VMT increases, which are attributable to the fuel economy rebound effect, result in an overall greater demand for travel, as the average cost-per-mile reduces. Figure 8-35 illustrates the incremental differences for each CY between the action alternatives and the baseline scenario.

Figure 8-35: Changes in VMT Compared to Baseline

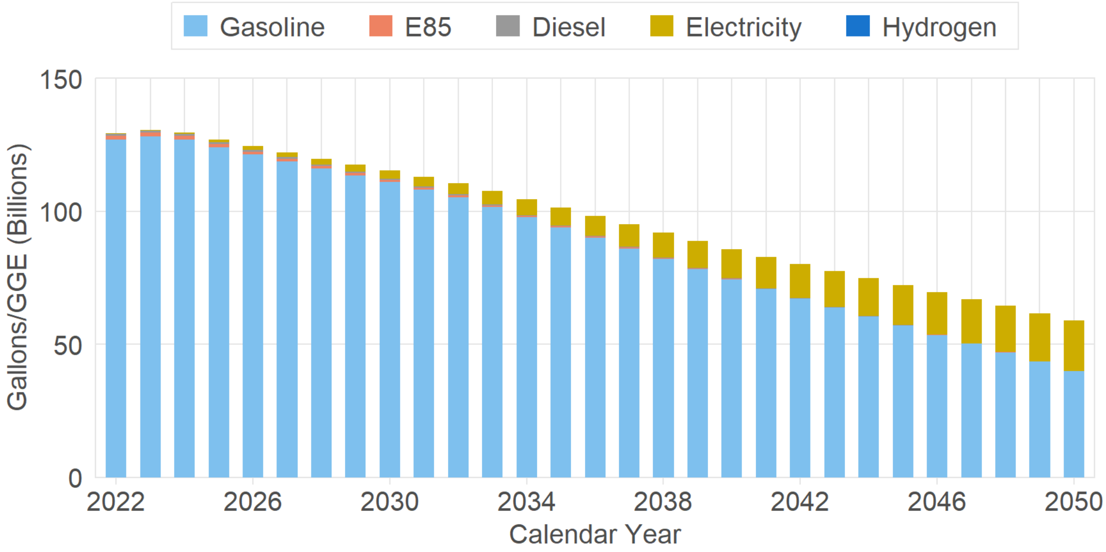


Although the rebound effect increases VMT for the entire fleet, the decline of the PC population during the later years results in the accompanying downward trend to the annual miles traveled by PCs. During those later years, even though the per-vehicle VMT may increase due to the rebound effect, these increases are not enough to offset the impacts of the declining on-road car fleet. Hence, the overall PC VMT goes down during the later years. However, the initial increases to VMT during the mid-years (around CYs 2028 to 2038 for the two more stringent alternatives) occur due to the car population experiencing a brief period of growth between CYs 2028 and 2033 with respect to the No-Action Alternative, coupled with the impacts of the rebound effect on car travel. In contrast, even though the population of LTs as compared to the baseline generally decreases throughout the years, the accompanying increases in trucks' fuel economy ratings result in the greater portion of the total on-road miles. This occurs because incremental improvements from fuel saving technologies typically have a greater impact on vehicles that begin with lower fuel economy ratings, as they are able to achieve a greater reduction in the consumption of fuel, than what would have been possible by their higher rated counterparts. Thus, the amount of miles traveled by LTs is more likely to be impacted by pushing the CAFE standards (and, hence, vehicle fuel economies) beyond the baseline level, since the decreases in the cost of travel for the truck fleet are marginally better than for the car fleet.

8.2.5.2. Changes to Fuel Consumption and Emissions of GHGs

Increases in CAFE standards reduce the total amount of fuel consumed, as more fuel-efficient vehicles enter the market, displacing older and less efficient models. With the existing fleet gradually turning over with each subsequent CY, the benefits of higher standards enforced during earlier MY become even more apparent, as the annual fuel consumption of the U.S. passenger vehicle fleet declines further. Moreover, with the rise of AFVs, specifically BEVs being added in the No-Action Alternative, the use of gasoline within the light-duty fleet is gradually supplanted by electricity. At the same time, increased production of SHEVs during earlier to middle MY leads to further decline of gasoline use. Figure 8-36 presents the consumption of various fuel types in each CY for the No-Action Alternative. In Figure 8-36, the consumption of gasoline, E85, and diesel are denominated in gallons of the native fuel (e.g., gallons of E85), while electricity and hydrogen are specified as gasoline gallon equivalent (GGE).

Figure 8-36: Fuel Consumption in the Baseline Scenario



As illustrated by Figure 8-36, gasoline remains the main source of fuel well into the future under the No-Action Alternative. However, with increasing fuel economy ratings and large-scale conversion to SHEVs and BEVs, the use of gasoline greatly diminishes during the later years. Conversely, electricity consumption rapidly increases year over year, culminating in about one third of the total amount of fuel consumed (on GGE basis) being attributed to electricity by CY 2050. Meanwhile, the collective sum of all the other fuel types used by the on-road fleet is only a fraction of the total energy consumed during each CY.[176] Figure 8-37 provides a closer look at the consumption of non-gasoline fuels. This figure shows electricity with the strongest annual growth, while over the same timeframe, the use of E85 and diesel steadily declines.

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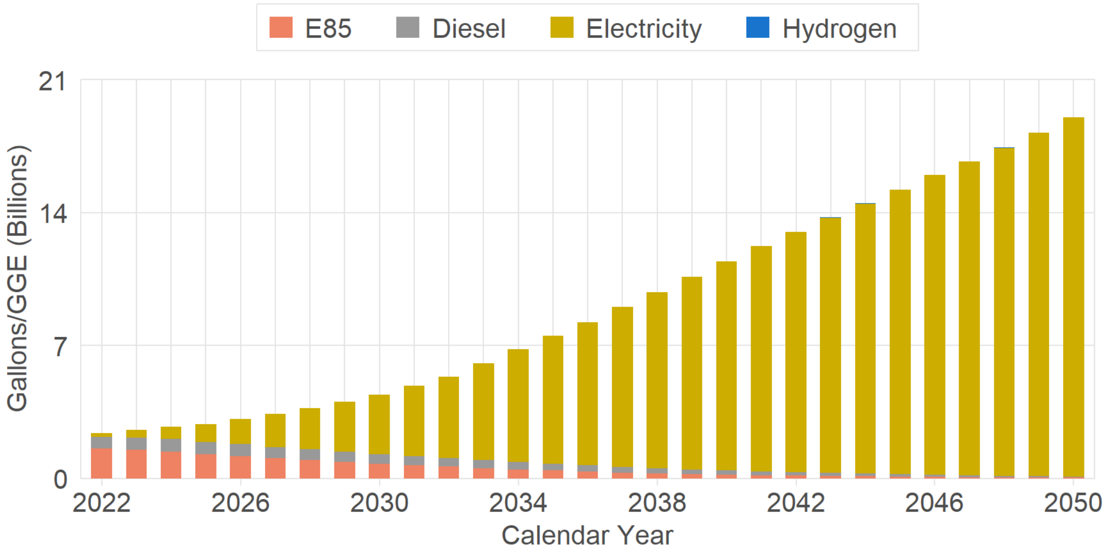
[176] In CY 2022, the total amount of E85, diesel, and hydrogen fuels consumed by the on-road fleet is 1.7 percent in the No Action Alternative. By CY 2050, that number declines to 0.2 percent.

Figure 8-37: Consumption of Non-Gasoline Fuels in the Baseline Scenario



Since consumption of fuel by the fleet directly releases CO_2, reducing overall energy consumption also reduces emissions of CO_2. Equally, emissions attributed to the other GHGs – CH_4 and N_2O – see an annual decline as well. Figure 8-38 displays the amount of annual GHG emissions generated by the light-duty fleet under the No-Action Alternative. In the figure, the emissions of CO_2, CH_4, and N_2O are combined and presented using a cumulative total. The amount of CO_2 is measured using million metric tons (mmT), while emissions coming from CH_4 and N_2O are scaled by the GWP multipliers of 25 and 298 respectively,[177] and are denominated using mmT of CO_2 equivalent emissions. However, CO_2 remains the predominant contributor of GHGs, making up approximately 86 percent of total GHG upstream emissions and 99.5 percent of GHG vehicle-based emissions.[178] This analysis does not include HFC emissions from vehicles. As shown in Figure 8-38, the upstream emissions, which are attributed to the production and distribution of various types of fuel, stay at a mostly constant level throughout the years, with only a mild amount of fluctuation, as the effects of increased electricity generation offset the reduction in emissions from the production, storage, and distribution of motor fuels.[179] The downstream emissions, which occur during vehicle operation, see a large declining trend similar to what was observed for the overall annual consumption of fuel.

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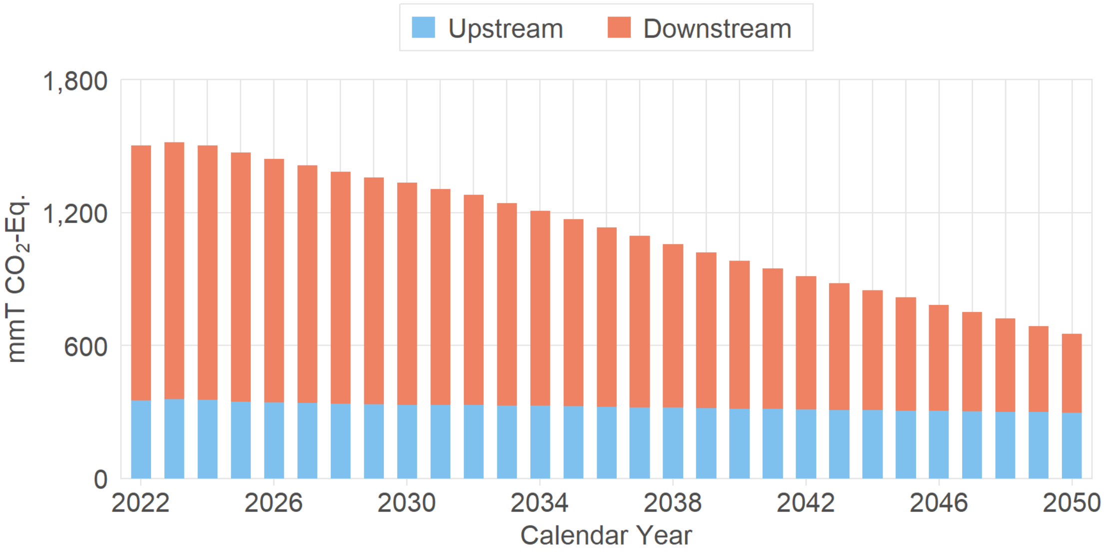
[177] GWP multipliers here are derived from the 4th IPCC Report; NHTSA is aware that the 5th IPCC report changes these values slightly, but tentatively concludes that the difference is not meaningful for purposes of Figure 8-38. NHTSA calculates emissions of CH_4 and N_2O directly in terms of tons emitted for benefits purposes.

[178] Depending on CY being considered, the CO_2 share of GHG upstream emissions varies by up to 4 percent, while the share of downstream emissions varies by about 0.1 percent.

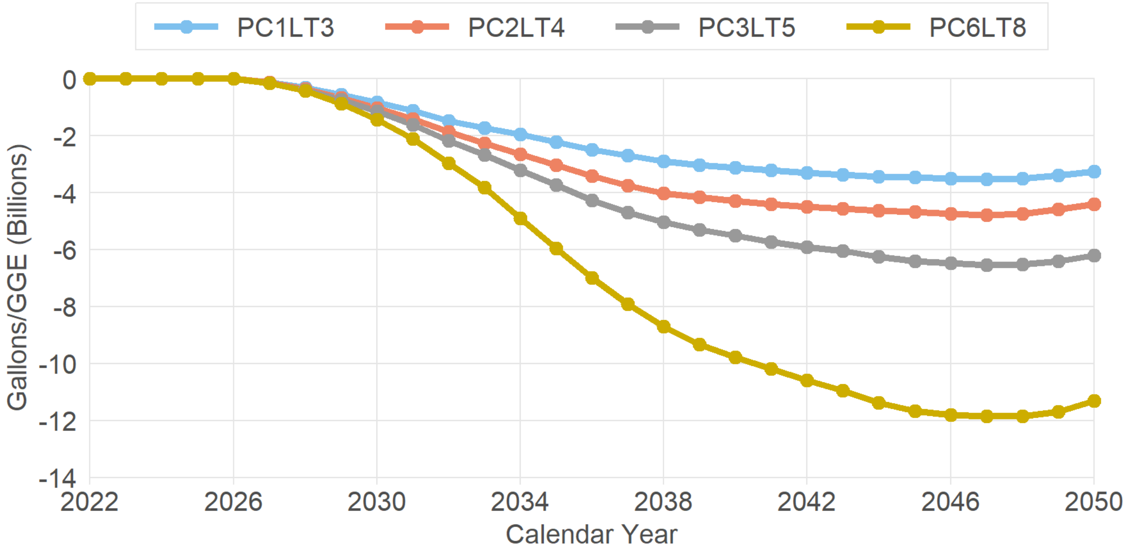
[179] At the time of NHTSA's analysis, the latest upstream emission factors (EFs) available were from GREET 2022, which are based on AEO 2022 forecasts of the electricity generation mix. We understand AEO 2023 forecasts assume faster rates of grid decarbonization than previous releases and include some recent IRA and BIL provisions that are expected to impact emissions results associated with future CAFE standards, in particular including provisions that would reduce SO_2 emissions from upstream sources. For these reasons, we anticipate updating our upstream analyses with projections from GREET 2023 and AEO 2023 or other relevant forecasts as the final rule schedule permits.

Figure 8-38: Emissions of GHG in the Baseline Scenario



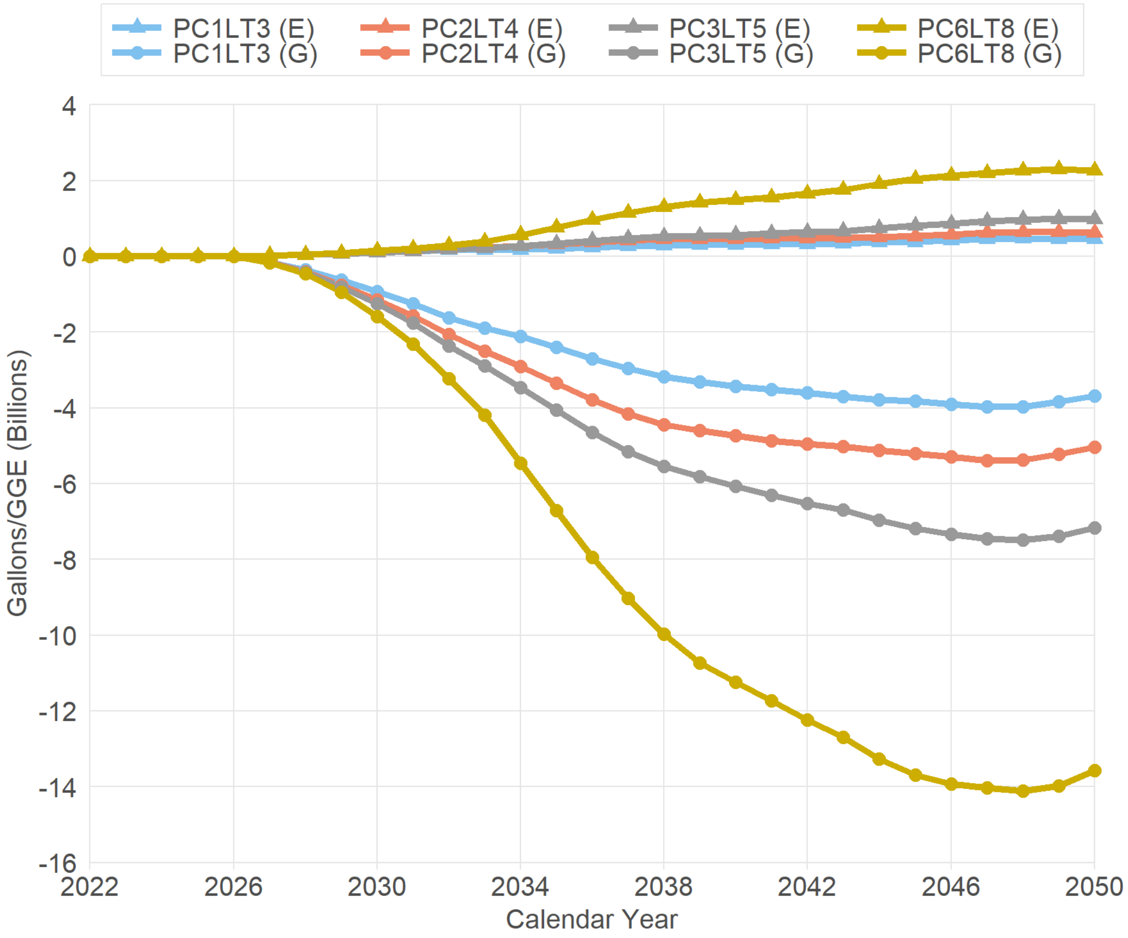
Fleet-wide fuel consumption and GHG emissions continue to decline further under the action alternatives in response to higher CAFE standards. Figure 8-41 presents the incremental differences to overall energy consumption, as compared to the baseline scenario, for each action alternative. As shown in the figure, the outcome of the progressively increasing stringency defined by each action alternative is a greater reduction to the amount of fuel consumed by the on-road light-duty fleet.

Figure 8-39: Changes in Fuel Consumption Compared to Baseline



As was the case under the No Action Alternative, gasoline remains the dominant source of fuel for the light-duty fleet in all CYs, and for all action alternatives. However, as was noted above for the No Action Alternative, gasoline consumption rapidly decreases with each passing year, while electricity use undergoes a rapid growth. This trend continues under the action alternatives as well, and with more stringent standards, gasoline consumption falls by even larger margins, while the annual use of electricity increases further. Figure 8-40 separates and presents the incremental changes of gasoline and electricity use, as those had the largest observable difference over the baseline. The differences observed between the action and the No Action Alternatives for all other fuels were inconsequential, and are omitted from the figure.

Figure 8-40: Changes in Gasoline and Electricity Consumption Compared to Baseline by Fuel Type



Along with the reduction of fuel use, the GHG emissions generated by the on-road fleet also decline in each action alternative. Figure 8-41 presents the incremental changes to emissions of GHG as compared to the No Action Alternative. The larger chart at the top presents the overall emissions of GHG, while the left and right portions at the bottom provide deconstructed views of upstream and downstream components, respectively. In each case, the incremental emissions of GHGs decrease at a greater rate as the standards defined by the action alternatives increase in stringency. Hence, the highest CAFE standards, defined by Alternative PC6LT8, lead to the greatest reduction of upstream, downstream, and overall emissions of GHG.

Figure 8-41: Changes in GHG Emissions Compared to Baseline

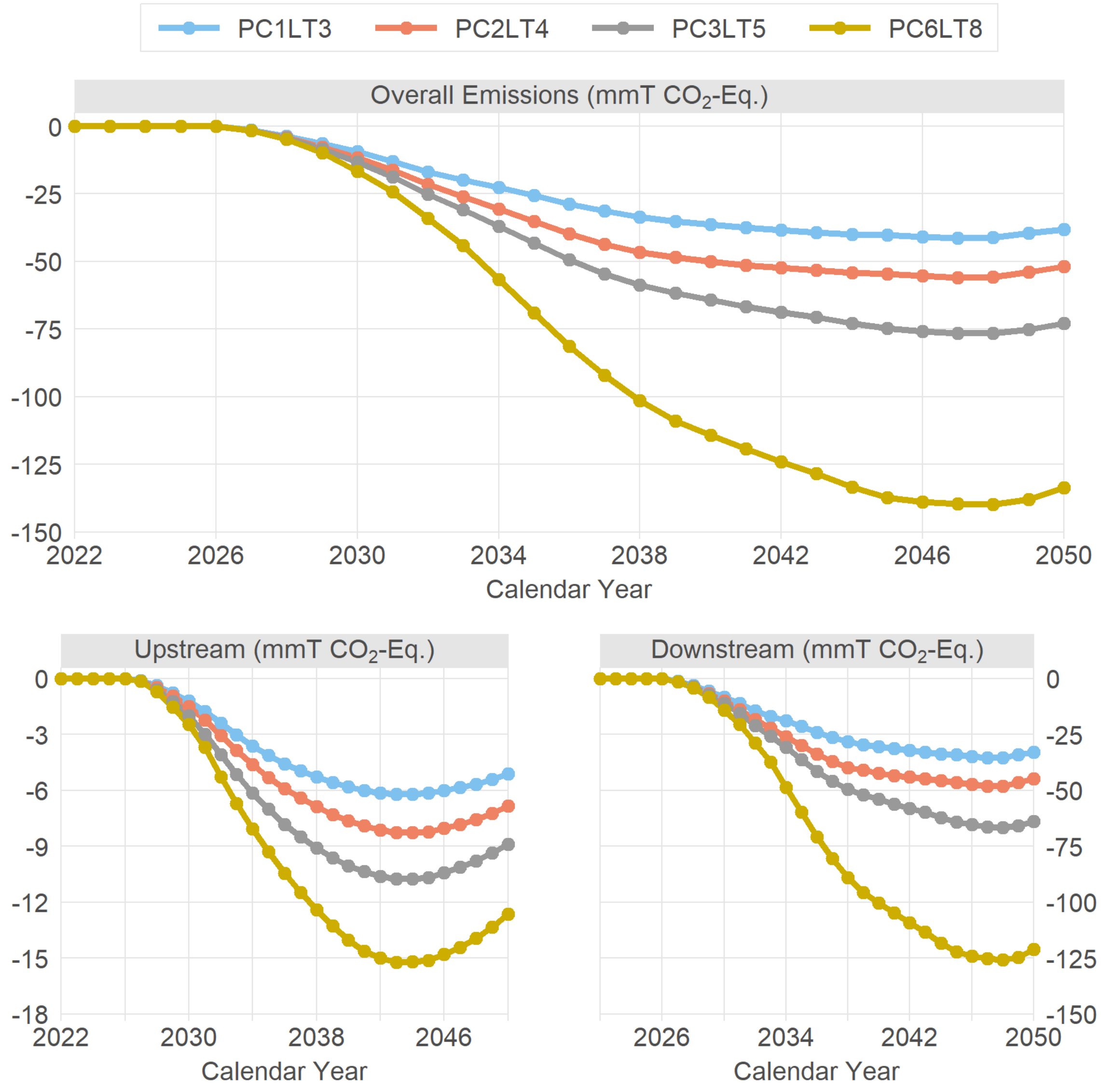
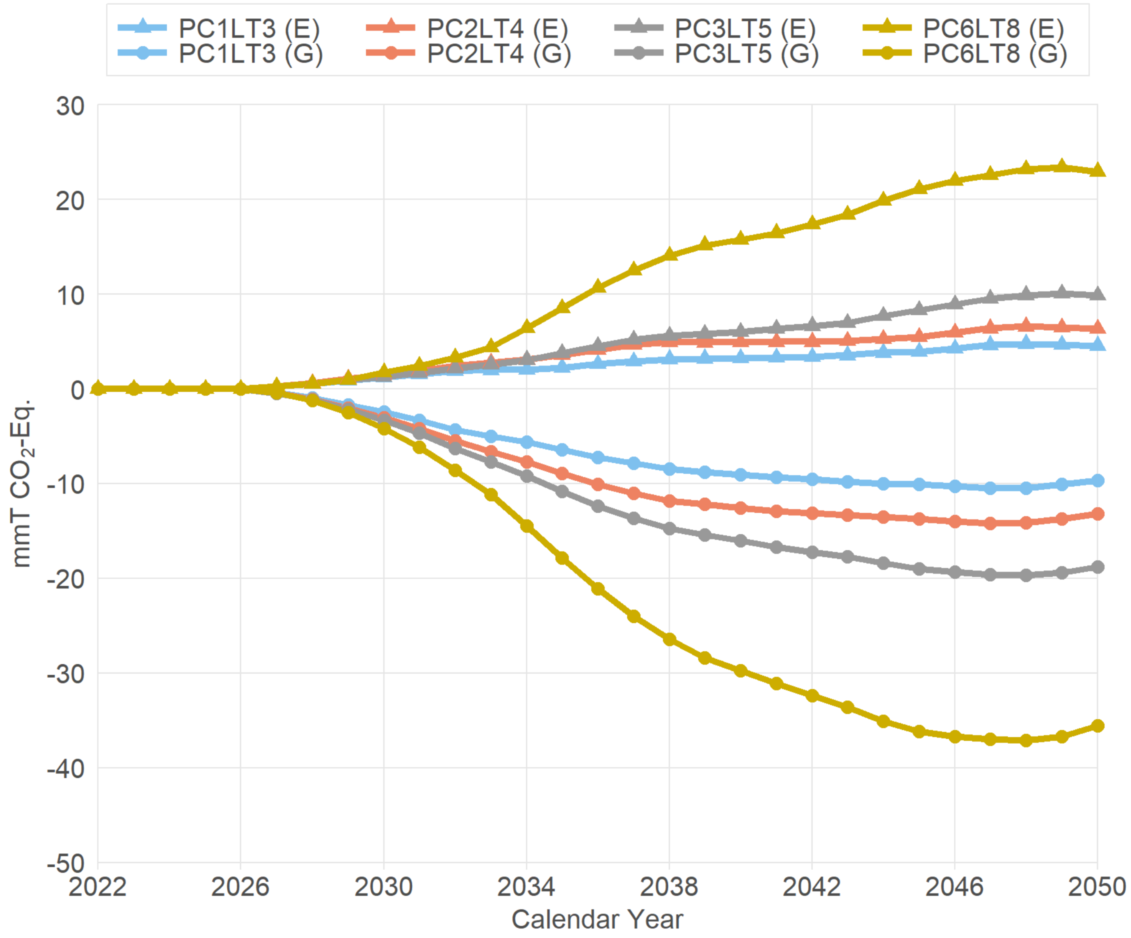


Figure 8-42 displays the incremental GHG upstream emissions for gasoline and electricity for each action alternative. As with fuel consumption, the other fuel types do not differ meaningfully here, and are therefore omitted. As shown in the figure, the increases in electricity emissions become more significant during the mid-to-end years. This occurs since higher standards result in manufacturers adopting additional BEVs in the action alternatives during later model years.

Figure 8-42: Changes in Upstream Gasoline and Electricity GHG Emissions Compared to Baseline



8.2.5.2.1. Impacts of Select Sensitivity Cases on Fuel Consumption and GHG Emissions

Varying certain input assumptions, such as FPs, may change the mix of technologies that the CAFE Model selects in order to achieve compliance. Additionally, the degree of voluntary over-compliance may be affected if, for example, the cost of technology application becomes cheaper or the value of fuel savings increase with respect to the reference input assumptions. As a result, fuel consumption and emissions of GHGs may change as well. In this chapter, the impacts of several sensitivity cases are examined and compared to the central analysis (or the RC). The selected sensitivity cases were chosen in an effort to examine some of the important factors related to fuel consumption and emissions. Specifically, two cases with different FP forecasts are considered, two cases where the learning rate of battery costs is either decreased or increased by 20 percent, and one additional case where upstream emissions factors use lower input assumptions compared to the central case. These and other sensitivity analysis cases are described in greater detail in Chapter 9. The following listing provides brief summaries of the cases presented here, along with the abbreviations used by the various figures throughout this chapter.

- Central: Central analysis case.
- Low FP: FPs from AEO 2022 low oil price forecast.
- High FP: FPs from AEO 2022 high oil price forecast.
- Battery -20%: Battery costs learn down at a 20 percent slower rate.
- Battery +20%: Battery costs learn down at a 20 percent faster rate.
- Clean Grid (low): Upstream emissions factors from AEO 2022 low renewables costs projections.

Among the sensitivity cases selected, the first four cases (with varying FPs and battery costs) will produce different compliance decisions and therefore affect the fleet's overall fuel consumption and GHG emissions. Conversely, the last case with lower upstream emissions factors will only differ in the amount of GHG (and other pollutants) that are emitted into the atmosphere. This is because the inputs that influence the model's technology selection under this *clean grid* case (along with the resulting on-road fleet, VMT, and fuel consumption) remain unaffected when compared to the central case.

Figure 8-43 shows a comparison of fuel consumption between sensitivity cases for the No Action Alternative. The overall consumption from all fuel types is presented in the larger chart at the top, while the left and right portions at the bottom provide separate views of gasoline and electricity consumption, respectively. For all sensitivity cases, gasoline begins as the dominant source of fuel, but rapidly declines as vehicle fuel efficiency improves and gasoline use is supplanted by electricity. In this figure, the outcomes of the central analysis are displayed using a thicker gray line, with bullet point markers, while the sensitivity cases are shown with thinner lines and asterisk markers (and with varying colors). Since fuel consumption does not change between the *clean grid* case and the central analysis, the trends from the *clean grid* results are presented as overlapping the central analysis.

The *high FP* case shows the fastest annual reduction to the overall fuel consumption, while the *low FP* case is the slowest. These differences can be attributed to the degree of voluntary over-compliance that the CAFE Model employees during analysis. Under the *high FP* case, the fuel savings resulting from technology application increase, leading to a greater selection of cost-effective technologies[180] and to additional over-compliance. For the *low FP* case, however, the potential for fuel savings diminishes, which, in turn, reduces the amount of voluntary over-compliance. Readers may also note that under the *high FP* case, electricity use rises significantly when compared to the central analysis, with consumption of gasoline and electricity becoming nearly equivalent by CY 2050. For the *high FP* case, this can be attributed to much higher fuel savings, resulting in SHEVs, PHEVs, and BEVs becoming more attractive options.

As shown in Figure 8-43, the *faster battery cost learning* case results in the greater reduction to overall annual fuel consumption, as compared to the central case, while also having greater adoption of electric-powered vehicles. Meanwhile, the *slower battery cost learning* case performs somewhat worse than the central analysis, with higher consumption of gasoline and lower electricity use. These results can be explained by the cumulative impacts of battery cost learning beginning to amplify and influence SHEV and BEV technology utilization starting around CY 2035, as the two cases are shown diverging from the central analysis during that timeframe.

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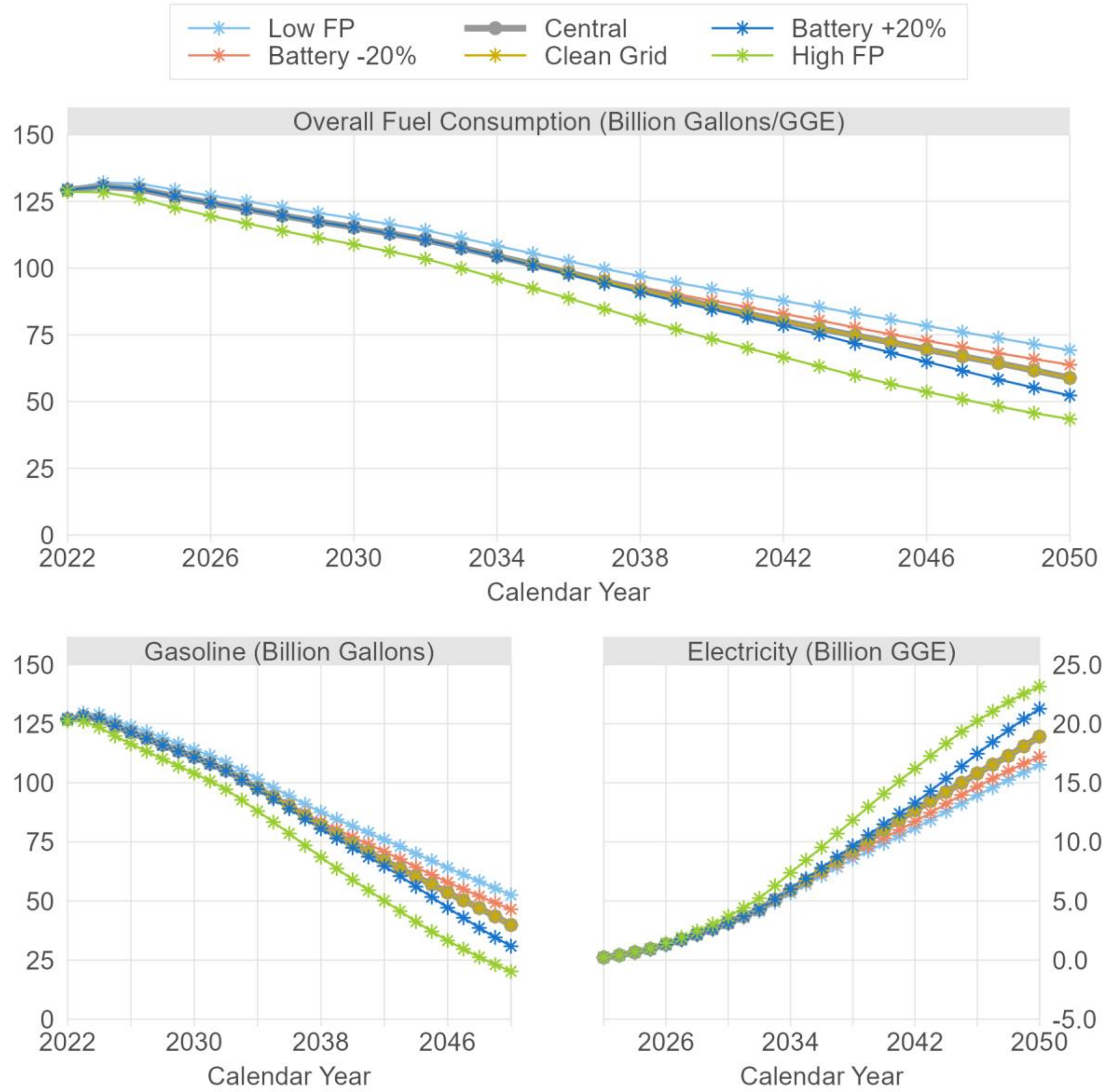
[180] Cost-effective technologies are defined as those where fuel savings resulting from application of a specific technology are greater than the cost of that technology. For more information on how the CAFE Model calculates cost-effectiveness refer to Chapter 2, Section S5.3.2 of the CAFE Model Documentation.

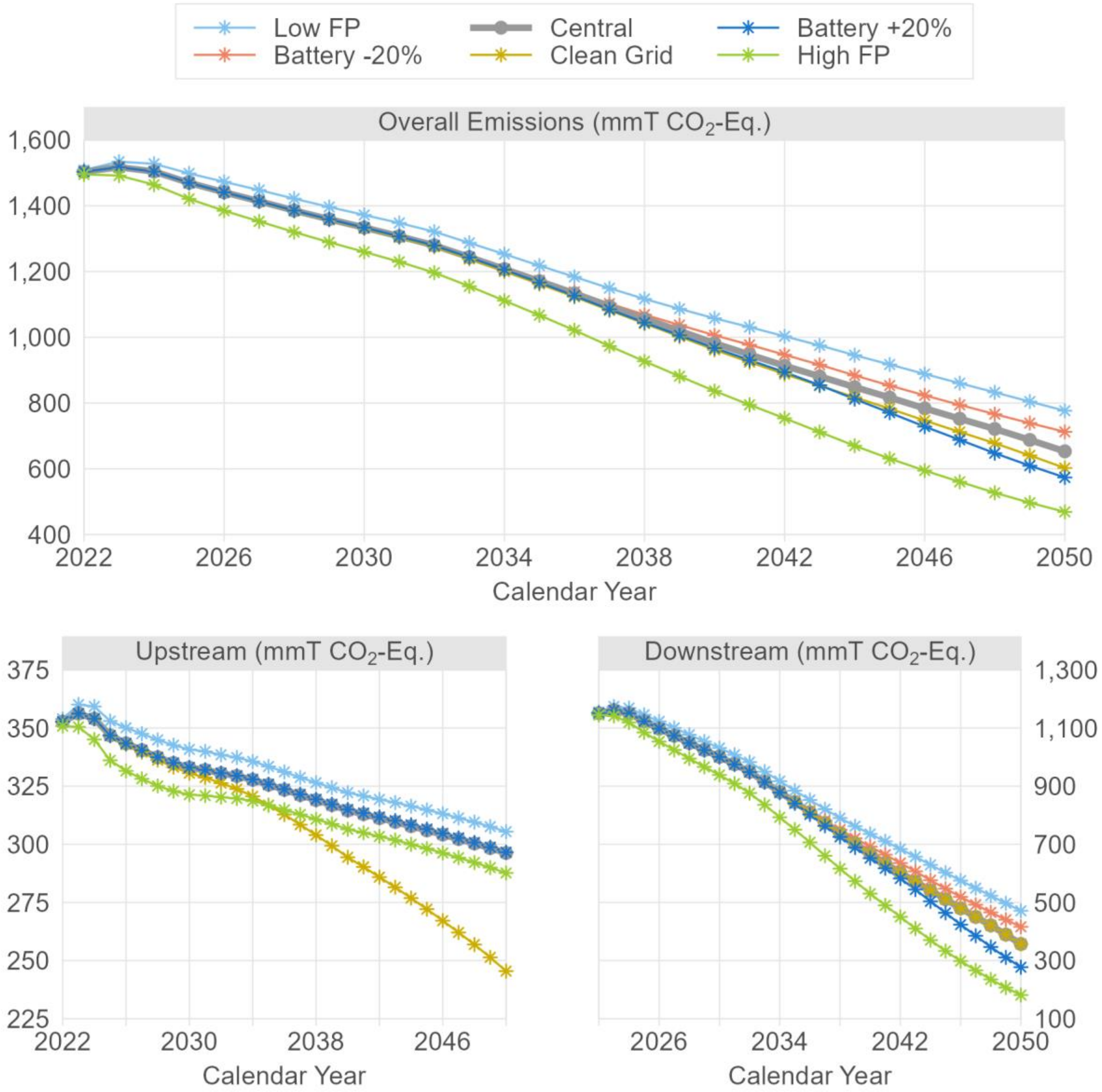
Figure 8-43: Comparison of Fuel Consumption Across Sensitivity Cases in the Baseline Scenario



As noted earlier, fuel consumed by the on-road fleet during vehicle operation emits GHGs. Hence, as demonstrated in Figure 8-44, the downstream GHG emissions for all sensitivity cases under the No Action Alternative show the same patterns and annual trends that were observed for the total fuel consumption. With the exception of the *clean grid* case, the overall GHG emissions in all other sensitivities follow the same patterns as well. Under the *clean grid* case, however, the additional reductions in overall GHG emissions are the result of using lower input assumptions for the upstream emissions factors.

When looking at the upstream GHG emissions (bottom-left chart in Figure 8-44), the *clean grid* case outpaces all other sensitivities (and the central analysis) in terms of the annual reduction of emissions beginning with CY 2036. This behavior occurs because, under the *clean grid* case and starting at around the same timeframe, upstream emissions factors of CO_2 and other GHGs (from all stages of production and distribution) are decreased by much greater margins for electricity generation than for gasoline production. At the same time, the reduced demand for fuel under the *high FP* case, and, conversely, the increased demand under the *low FP* case, leads to these two sensitivities generating less upstream GHG emissions for the “*high*” case and more for the “*low*" case. The two “*battery*” sensitivity cases, however, do not differ meaningfully between each other (or the central analysis). According to GREET modeling used in today’s analysis for generating upstream emissions factors, upstream emissions of GHG from electricity generation are higher than from production and distribution of gasoline. Hence, the greater electricity consumption under the *faster battery* *cost learning* case results in an increase to upstream emissions of electricity, when compared to the central analysis, offsetting any aggregate emissions benefit from reduced gasoline use. For the *slower battery cost learning* case, however, the reverse is observed, where reduction in electricity decreases the GHG upstream emissions attributed to that fuel, while concurrently increased gasoline consumption leads to additional emissions due to added demand for gasoline.

Figure 8-44: Comparison of GHG Emissions Across Sensitivity Cases in the Baseline Scenario



For the action alternatives, when considering the values on an absolute basis, the patterns of behavior and relative ordering of sensitivity cases were identical to the No Action Alternative, although with lower overall fuel consumption and GHG emissions. Figure 8-45 and Figure 8-46 present the comparison of cumulative impacts to fuel consumption and GHG emissions over the next three decades for all sensitivity cases and action alternatives.[181]

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[181] As discussed at the introduction to Chapter 8.2.5, the first decade in all figures presented by this chapter cover the range of years between CYs 2022 and 2030, while the latter two encompass effects over the full ten-year period. While this marginally reduces the magnitude of cumulative fuel consumption and GHG emissions occurring during the first decade (as compared to the following ones), the figures still demonstrate the relative differences and a declining trend between the decades.

Figure 8-45: Comparison of Fuel Consumption Across Sensitivity Cases in the Action Alternatives

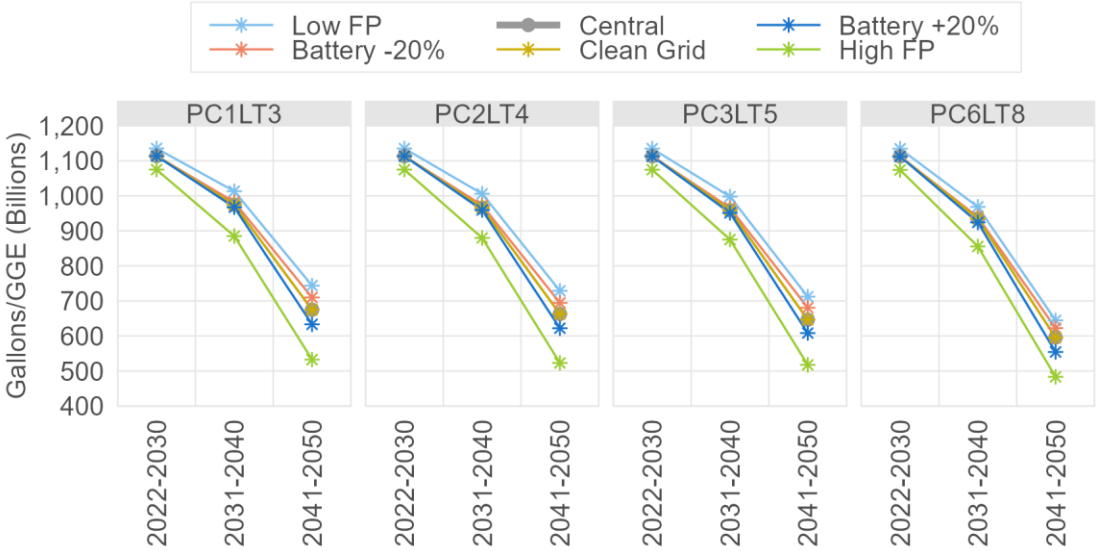
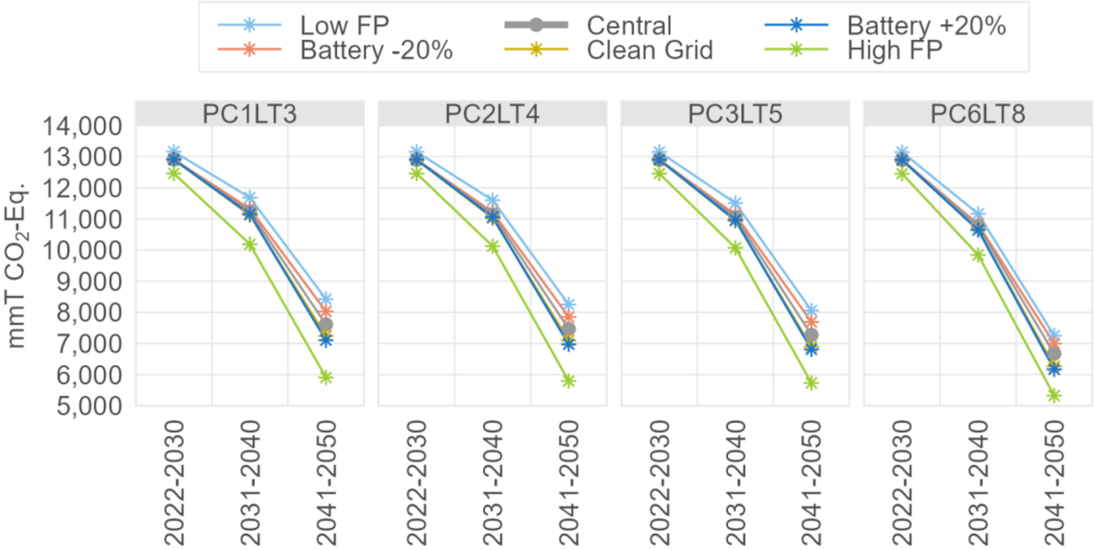


Figure 8-46: Comparison of GHG Emissions Across Sensitivity Cases in the Action Alternatives



However, when considering the incremental changes in fuel consumption and GHG emissions compared to the No-Action Alternative, the relative ordering of sensitivity cases generally reverses as illustrated by Figure 8-47 and Figure 8-48. Here, the *high FP* case is shown as having the lowest incremental reduction of fuel consumption and GHG emissions when compared to the baseline scenario, while the *low FP* case shows the greatest reduction of these values. Under the *high FP* case, as the No Action Alternative absorbs additional cost-effective technologies due to voluntary over-compliance, the potential for improvements in the action alternatives (with respect to the baseline scenario) reduces. Hence, the incremental changes to fuel consumption and GHG emissions reduce as well. Conversely, for the *low FP* case, as the degree of voluntary over-compliance in the No Action Alternative declines, the potential for improvements in the action alternatives increases. Thus, the incremental changes go up in each alternative in the *low FP* case. For the rest of the sensitivities, the incremental differences for fuel consumption and GHG emissions are largely insignificant between the varying cases and the central analysis.

Figure 8-47: Comparison of Changes in Fuel Consumption Across Sensitivity Cases

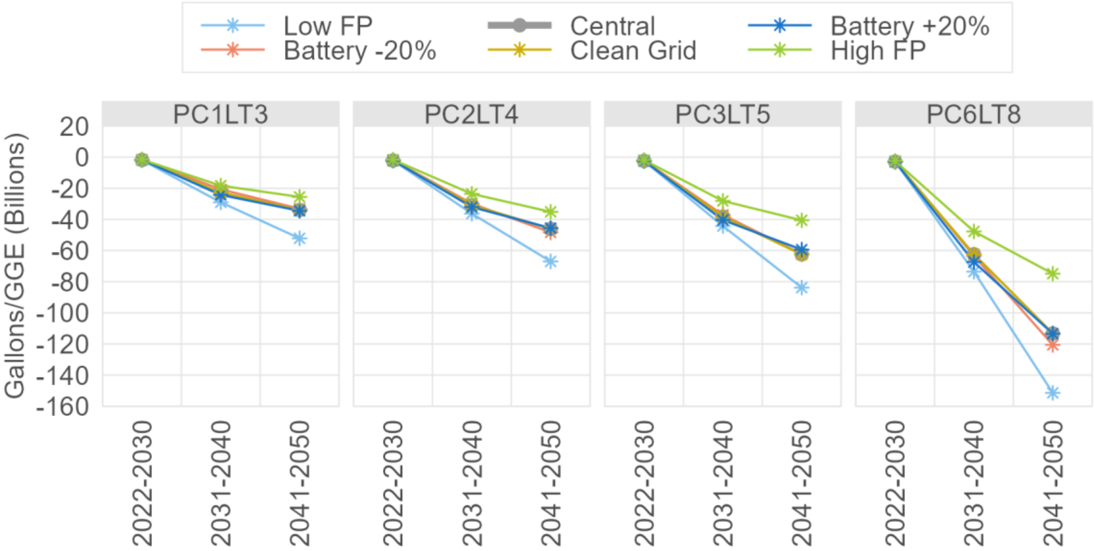
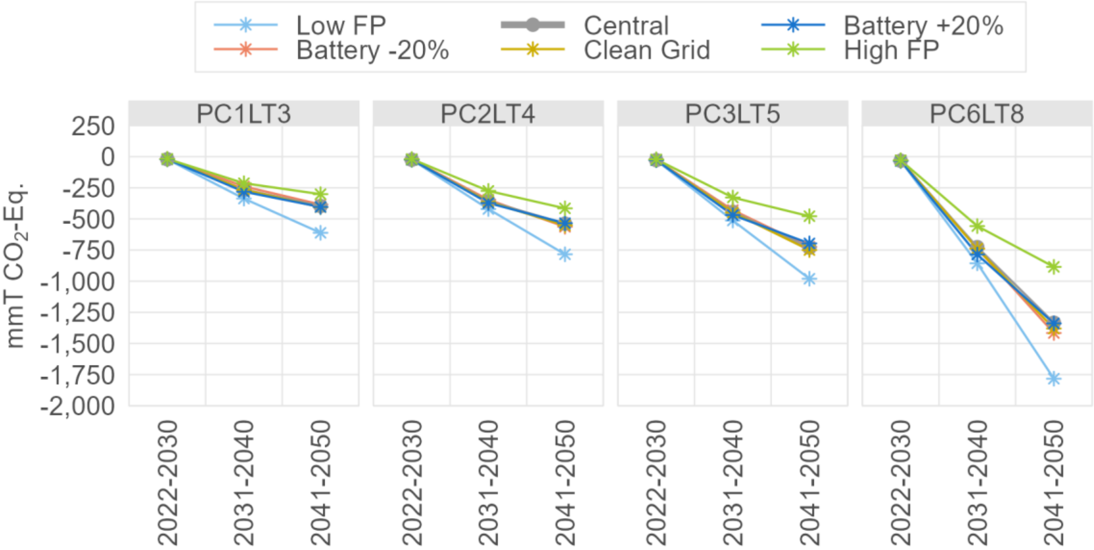


Figure 8-48: Comparison of Changes in GHG Emissions Across Sensitivity Cases



8.2.5.3. Changes to Emission of Criteria Air Pollutants

Reduction in the total amount of fuel consumed by the on-road vehicle fleet may result in either increases or decreases to upstream emissions from criteria air pollutants. These upstream changes depend mainly on the magnitude by which the alternative fuel sources (specifically electricity) supplant more traditional options (of which gasoline is the dominant one). Since the production and distribution of gasoline in the United States is significantly cleaner than generation of electricity for most pollutants according to GREET, introducing even small volumes of PHEVs and BEVs into the on-road population tends to have a disproportionally negative impact on the *upstream* emissions resulting from criteria air pollutants.[182] Conversely, stricter vehicle emission standards, which are defined on a per-mile basis and are adopted by the new fleet, greatly reduce

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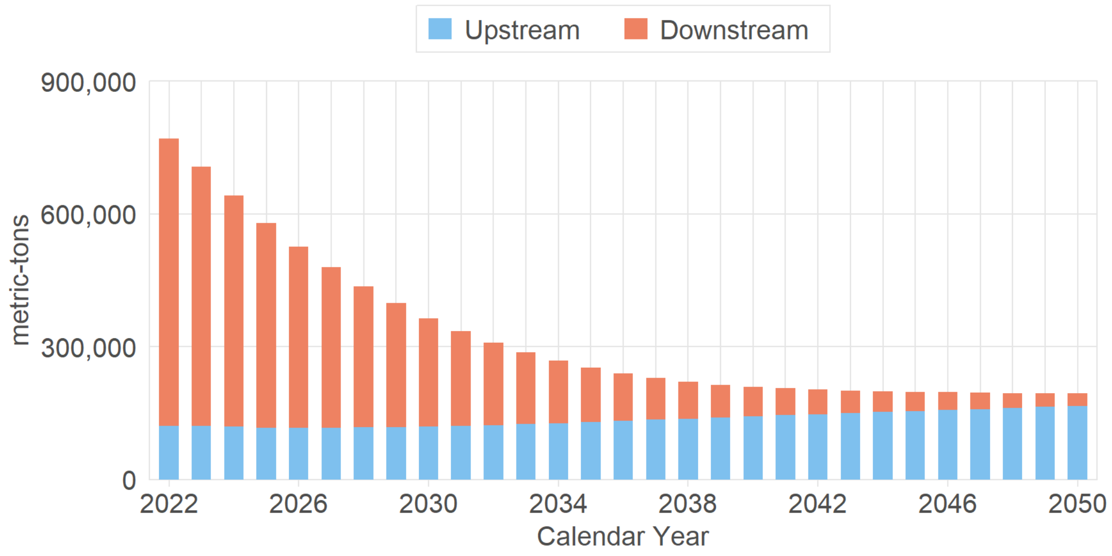
[182] At the time of NHTSA's analysis, the latest upstream emission factors (EFs) available were from GREET 2022, which are based on AEO 2022 forecasts of the electricity generation mix. We understand AEO 2023 forecasts assume faster rates of grid decarbonization than previous releases and include some recent IRA and BIL provisions that are expected to impact emissions results associated with future CAFE standards, in particular including provisions that would reduce SO_2 emissions from upstream sources. For these reasons, we anticipate updating our upstream analyses with projections from GREET 2023 and AEO 2023 or other relevant forecasts as the final rule schedule permits.

the amount of *downstream* pollutants that are emitted into the atmosphere from vehicle operation. This chapter presents changes in emissions for a subset of criteria air pollutants that are supported by the CAFE Model. Specifically, upstream and downstream emissions related to NO_X, SO_X, and $PM_{2.5}$ are examined. As a consequence of changes to emissions, the magnitude of adverse health incidents caused by exposure to these pollutants typically reduces, as discussed in Chapter 8.2.5.4.

Figure 8-49 and Figure 8-50 present annual upstream and downstream emissions of NO_X and $PM_{2.5}$ respectively, which are attributed to the light-duty fleet under the standards defined by the No Action Alternative. In the case of $PM_{2.5}$, downstream emissions are split and presented separately for emissions related to brake & tire wear (BTW) and vehicular emissions originating at a vehicle's exhaust.[183] As the older vehicles are retired and replaced by models compliant with stricter emissions standards, a rapid decline of NO_X and $PM_{2.5}$ downstream emissions can be seen from both figures. Given that vehicles operating on electricity do not emit criteria pollutants at the exhaust, the increased presence of BEVs within the No Action Alternative further contribute to the accelerated reduction of downstream emissions shown in the figures. However, since the BTW emissions are defined at a constant rate, rather than varying by vehicle production year and age, downstream BTW emission of $PM_{2.5}$ are shown to increase proportionally as the demand for travel goes up.

The relative impacts on upstream emissions for both pollutants are comparatively less pronounced, however, showing marginal to moderate annual increases. The annual upsurge in upstream emissions correlates with the higher demand for electricity, as more vehicles are gradually converted to BEVs during each subsequent year (as was presented by Figure 8-36 and Figure 8-37). Although there is a sharp decline in gasoline consumption under the No Action Alternative, the significant shift to electric-powered vehicles throughout the analysis, coupled with the increased upstream emissions attributed to the generation of electricity, outweigh the larger cumulative savings resulting from reduction in gasoline consumption. As such, Figure 8-49 and Figure 8-50 show an annual increase to the upstream emissions of NO_X and $PM_{2.5}$.

Figure 8-49: Emissions of NO_X in the Baseline Scenario



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[183] NHTSA has introduced separate accounting of $PM_{2.5}$ brake & tire wear (BTW) emissions into the analysis for the current rulemaking.

Figure 8-50: Emissions of $PM_{2.5}$ in the Baseline Scenario

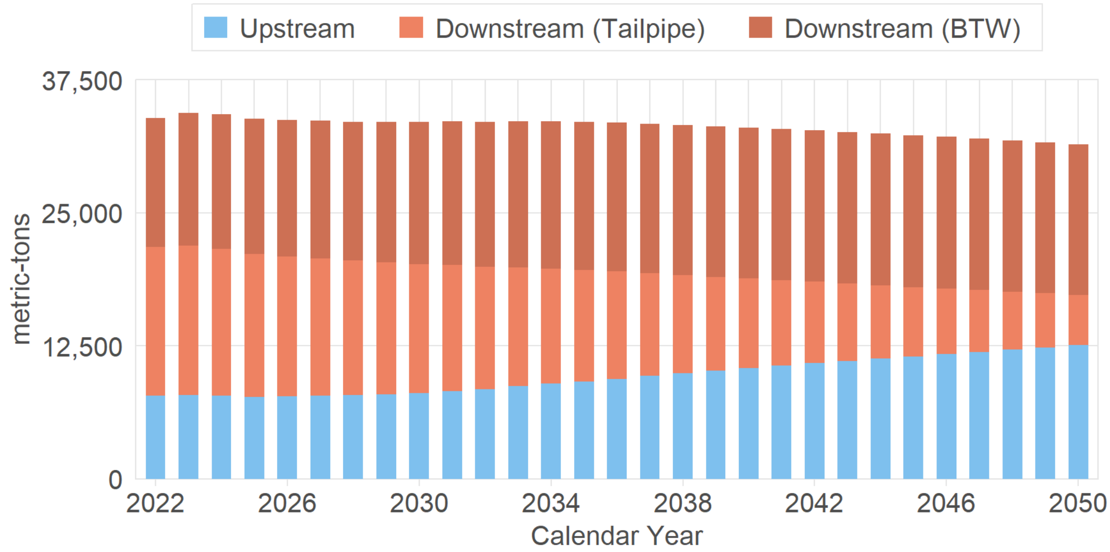
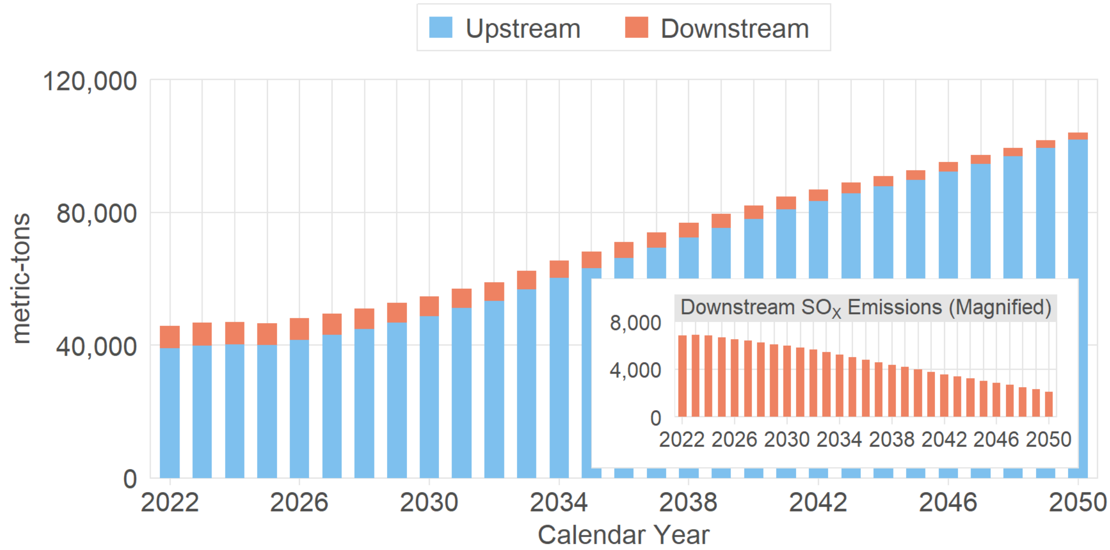


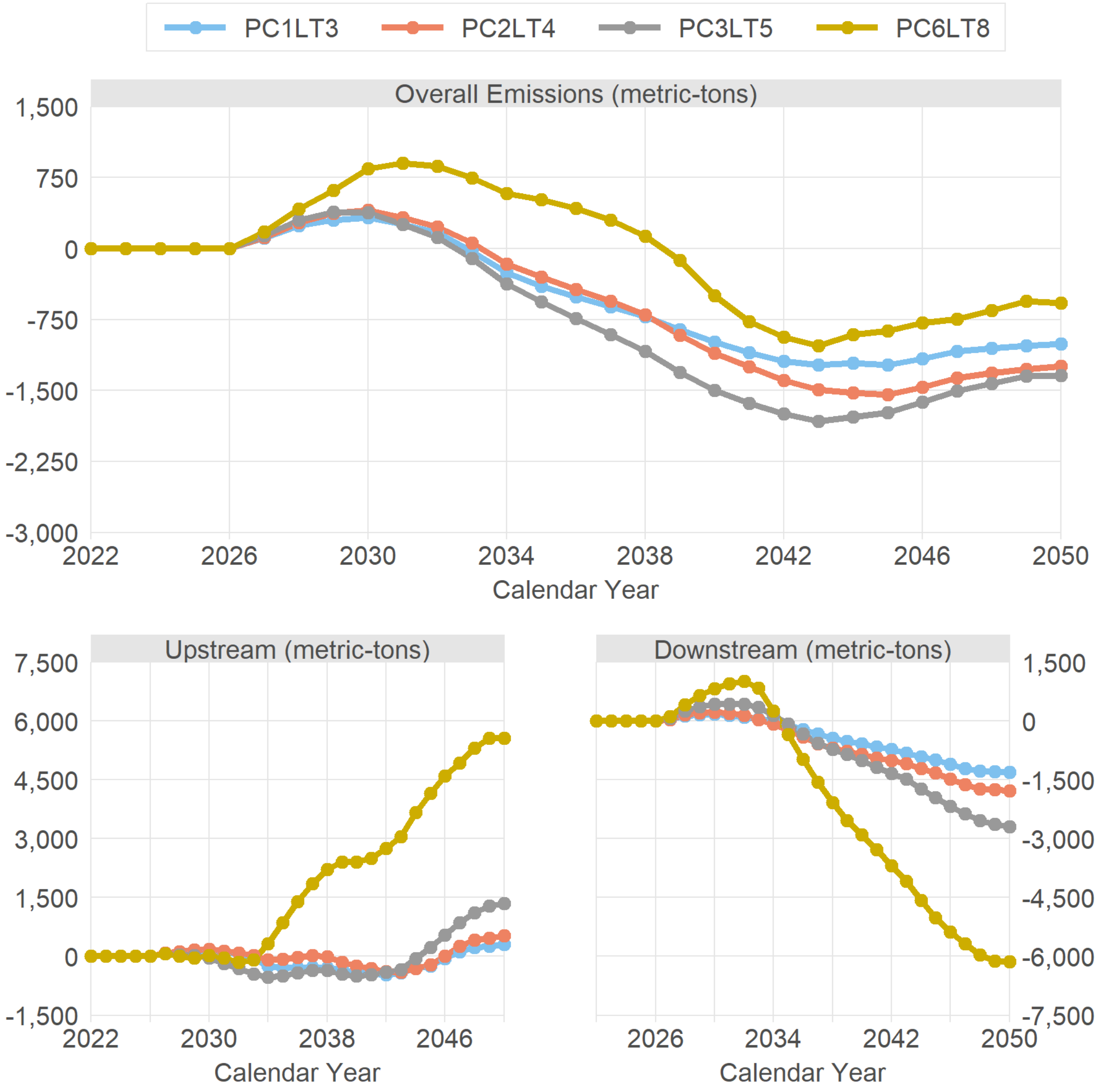
Figure 8-51 shows the annual SO_X emissions for the on-road fleet under the No Action Alternative. Contrary to the previous two pollutants, downstream emissions of SO_X are measured based on the consumption of fuel, rather than on a per-mile basis dictated by the vehicle emissions standards. Hence, SO_X emissions are influenced directly by changes to the amount of fuel consumed, rather than the total miles traveled by the light-duty fleet. Figure 8-51 shows the downstream component provides a marginal contribution to the overall SO_X emissions, and generally undergoes a downward trend as fuel consumption decreases. The inner plot in the bottom-right corner of the figure presents a magnified view of downstream SO_X emissions for clarity. The upstream SO_X emissions see a similar pattern as was observed for NO_X and $PM_{2.5}$ pollutants. Here, emissions continue to increase annually due to a greater presence of electric-powered vehicles in the fleet.

Figure 8-51: Emissions of SO_X in the Baseline Scenario



As demonstrated in the next several figures, increases in CAFE standards generally lead to increases in upstream emissions, while also decreasing the downstream emissions of NO_X, $PM_{2.5}$, and SO_X for all alternatives evaluated. The net changes to emissions, though, depend on the alternative, CY, and pollutant being presented, where overall values may show an increase or a decrease in total emissions generated. Figure 8-52 shows the incremental changes to NO_X emissions in the action alternatives versus the baseline scenario. The larger chart at the top presents the overall emissions of NO_X, while the left and right portions at the bottom provide deconstructed views of upstream and downstream components, respectively. The upstream emissions for the most stringent alternative (PC6LT8) show a rapid increase over the baseline starting in CY 2034. This largely occurs due to BEVs being adopted into the fleet sooner under Alternative PC6LT8 than in the other alternatives, coupled with the added use of PHEVs during the early-to-mid model years. For the less stringent alternatives, as BEVs are phased into the on-road fleet at a slightly faster rate than in the baseline, upstream emissions increase in the latter years as well. Additionally, while NO_X upstream emissions in Alternatives PC1LT3, PC2LT4, and PC3LT5 are close to one another, the minor fluctuations in their relative ordering can be attributed to the variances of utilization of electricity-consuming vehicles (PHEVs and BEVs), which increase upstream emissions, as well as variances to the use of SHEVs, which decrease upstream emissions.

Figure 8-52: Changes in NO_X Emissions Compared to Baseline



The downstream emissions in Figure 8-52 show an increase in the earlier years under all action alternatives as compared to the baseline, before leading to a net decrease in the later years. In response to the higher standards under the action alternatives, the CAFE Model simulates a slight reduction of new vehicle sales, causing a slight shift in the VMT from newer vehicles to older models. With the downstream emission standards enforced for future vehicle models being significantly more stringent than that for older vehicles,[184] the net downstream NO_X emissions rise while the on-road fleet gradually turns over. As the older models are replaced in the later years, NO_X emissions quickly begin to fall, declining to below baseline levels.

Figure 8-53 presents the incremental changes to $PM_{2.5}$ emissions in the action alternatives as compared to the baseline scenario. The upstream and downstream emissions trends for $PM_{2.5}$ criteria air pollutant are similar to that of NO_X, while also having the same underlying root causes for the observed behavior. In the case of $PM_{2.5}$, however, the downstream portion represents a combination of vehicle exhaust and brake and tire wear emissions.

Figure 8-53: Changes in $PM_{2.5}$ Emissions Compared to Baseline

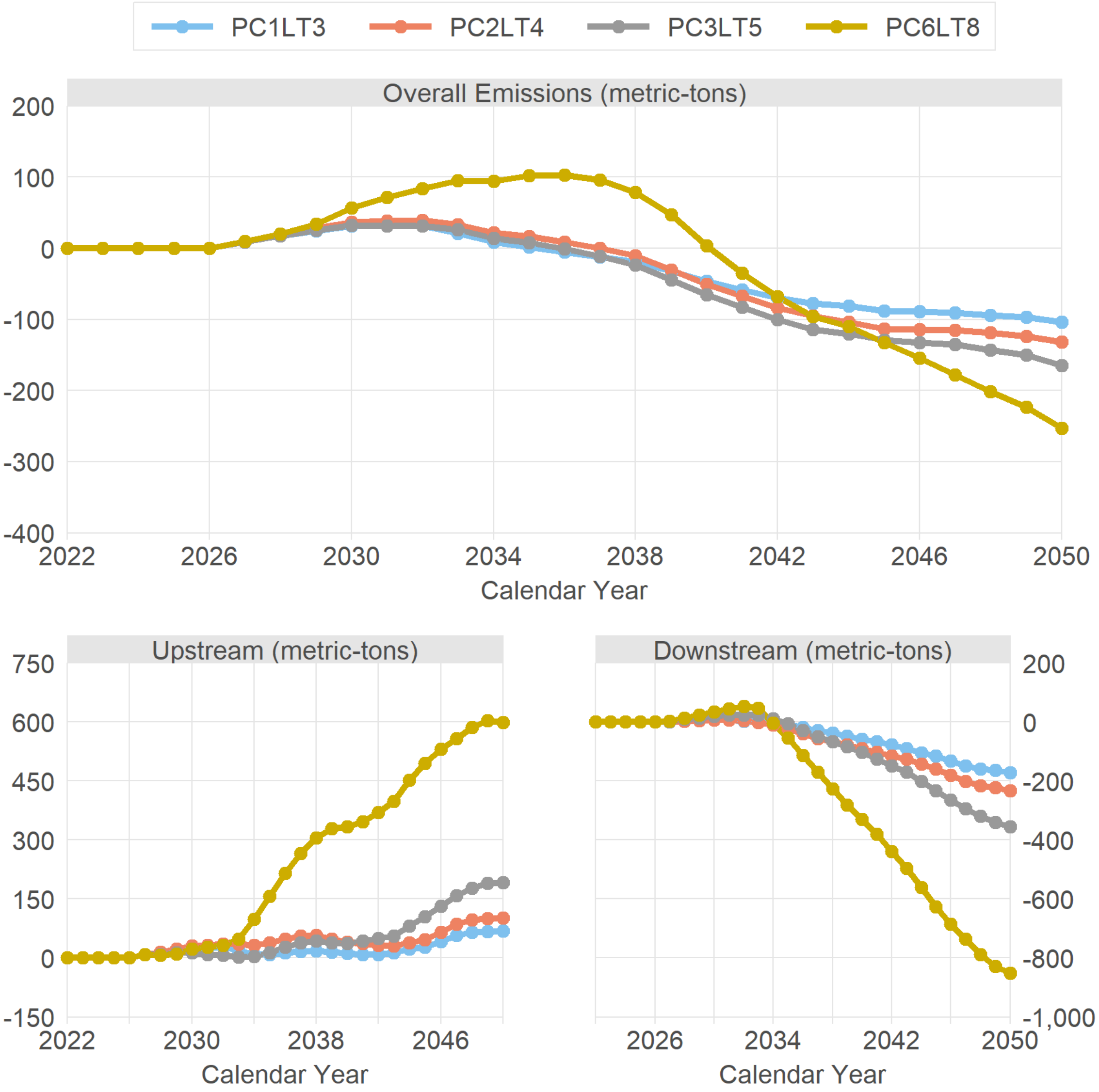


Figure 8-54 illustrates the incremental emission changes for SO_X for the action alternatives versus the baseline. As was noted earlier, the SO_X downstream emissions are measured based on the total consumption of fuel, rather than on per-mile basis. Thus, the reduction in fuel use in the action alternatives reduces the downstream emissions as compared to the No Action Alternative. Conversely, the upstream

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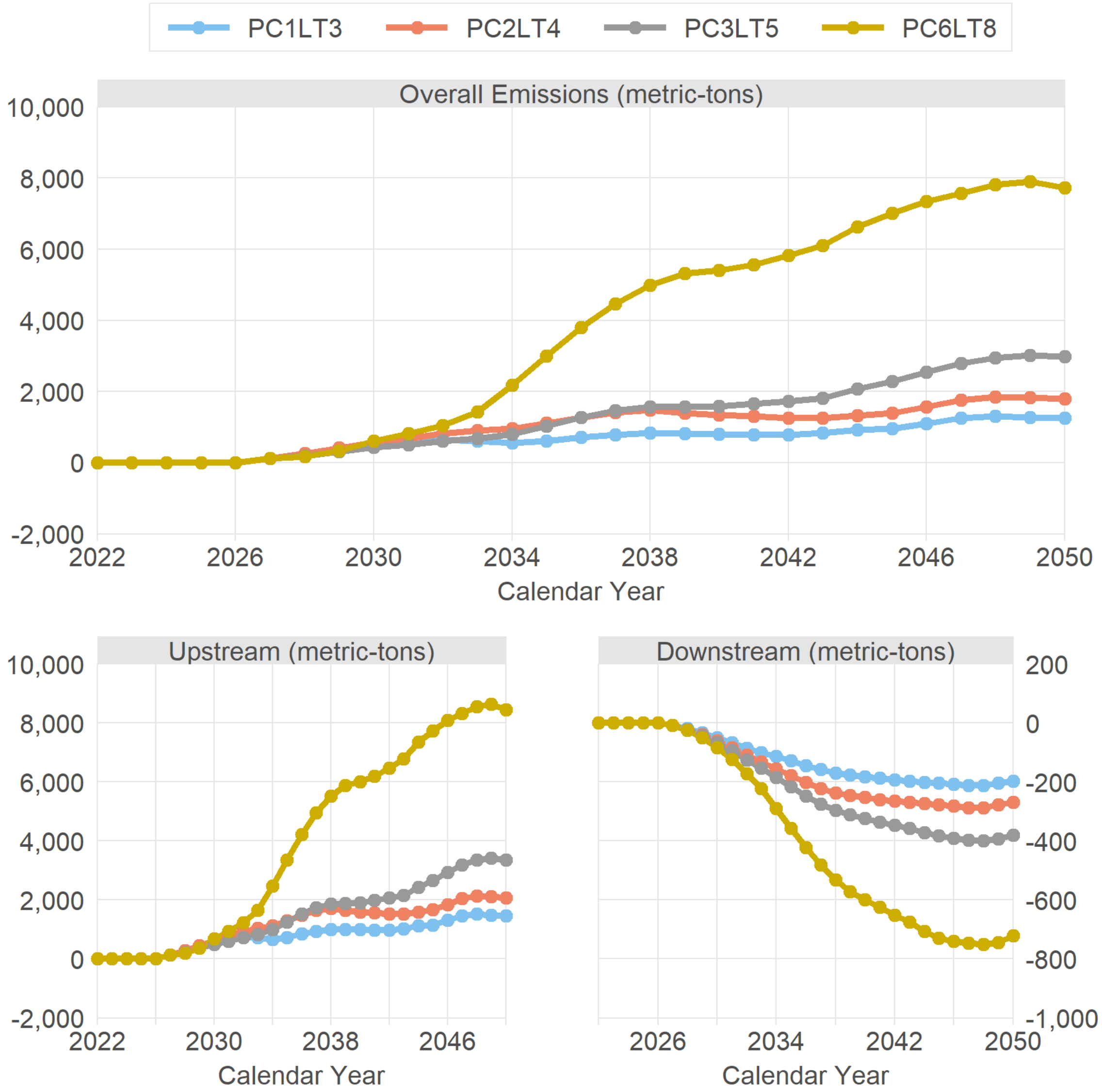
[184] Readers should refer to the Parameters Input File for the current assumptions of the annual downstream emission inputs for various pollutants.

emissions of SO_X are higher than the baseline in all action alternatives. This also leads to a net increase in the overall SO_X emissions over the baseline.

Figure 8-54: Changes in SO_X Emissions Compared to Baseline



As demonstrated in this chapter, while the emissions of NO_X and $PM_{2.5}$ show an eventual decrease, SO_X emissions increase in all action alternatives as compared to the baseline scenario. Though these results may appear counterintuitive, they are a direct consequence of the input assumptions used for this analysis, as well as the uncertainty surrounding these assumptions. When estimating the upstream emissions, the CAFE Model relies on the upstream emission rates provided by the GREET 2022 Model for the various supported fuel types. These input emission rates may change over time (and between rulemaking analyses) depending on the version of the GREET Model used and the internal assumptions a particular GREET version uses regarding the production and distribution of various petroleum-based feedstocks.

When estimating the downstream emissions, the CAFE Model relies on the emission rates provided by the MOVES3 Model, which are defined on a per-mile basis (except for the SO_X pollutant), independently for the light-duty passenger vehicle (LDV) and light-duty trucks (LDT) class of vehicles. Hence, the differences in the downstream emissions between various alternatives largely depend on the total VMT attributed to the on-road population from each vehicle class. However, some uncertainty also exists regarding the impacts of increasing standards on new vehicle sales, the mix shifting between cars and trucks, and the longevity of the historic population. Hence, the number of miles traveled by the resulting on-road fleet may change in such a way that it may increase the amount of downstream criteria air pollutants emitted during some CYs under the more stringent alternatives.

8.2.5.4. Changes to Adverse Health Outcomes Caused by Exposure to Criteria Pollutants

The magnitude of adverse health incidents caused by exposure to criteria air pollutants reduces as the consumption of gasoline by the light-duty fleet drops between CYs and more stringent alternatives. Table 8-16 presents the number of incidents and proportions for each of the various emission health impacts, which are considered in this rulemaking. Since CY 2022 corresponds to the initial year evaluated for today's analysis (MY 2022), and since the CAFE Model does not apply any fuel saving technologies during that initial year, the health impacts shown in the table are the same across all alternatives at the beginning of the analysis.

Table 8-16: Emission Health Impacts in CY 2022

	Incidents (Units)	Share of Total
High Incident Counts		
Asthma Exacerbation	93,478	3.1%
Work Loss Days	403,341	13.4%
Minor Restricted Activity Days	2,368,040	78.6%
Upper Respiratory Symptoms	79,410	2.6%
Lower Respiratory Symptoms	55,934	1.9%
Low Incident Counts		
Non Fatal Heart Attacks (All Others)	339	0.01%
Non Fatal Heart Attacks (Peters)	3,146	0.10%
Respiratory Hospital Admissions	759	0.03%
Cardiovascular Hospital Admissions	801	0.03%
Acute Bronchitis	4,399	0.15%
Respiratory Emergency Room Visits	1,692	0.06%
Premature Deaths	3,037	0.10%

As demonstrated by Table 8-16, the "Minor Restricted Activity Days" category significantly outweighs the cumulative total of all the other health-related incidents. Conversely, the respiratory and cardiovascular hospital admissions categories are the least significantly affected by exposure to emissions from criteria air pollutants. Throughout the analysis of all alternatives, the proportion of each category remains mostly the same during each CY, although these proportions moderately decline with each subsequent year.

The emission health impacts attributed to the No Action Alternative for the remainder of the CYs are presented as cumulative impacts over the next three decades in Figure 8-55 and Figure 8-56.[185] The figures are split into subsets of major incident counts (above ten thousand per year) and minor incident counts (below ten thousand) to aid with interpretation. The figures show that the health-related outcomes in every category follow a significant downward trend between the decades in response to significantly declining overall emission of the NO_X pollutant and marginal decreases to the $PM_{2.5}$ pollutant (discussed in Chapter 8.2.5.3).

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[185] As discussed at the introduction to Chapter 8.2.5, the first decade in all figures presented by this chapter cover the range of CYs between CYs 2022 and 2030, while the latter two encompass effects over the full ten-year period. While this marginally reduces the magnitude of cumulative incidents occurring during the first decade (as compared to the following ones), the figures still demonstrate the relative differences and a declining trend between the decades.

Figure 8-55: Cumulative Emission Health Impacts in the Baseline Scenario (Part 1)

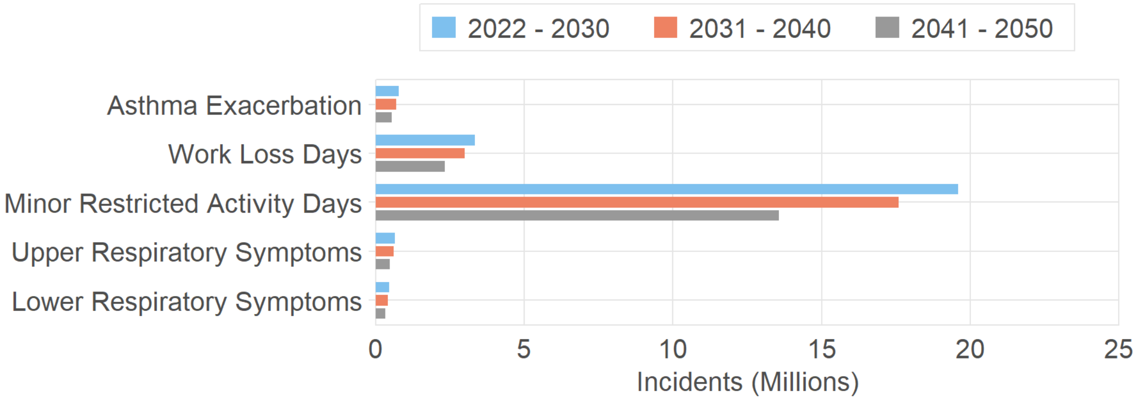
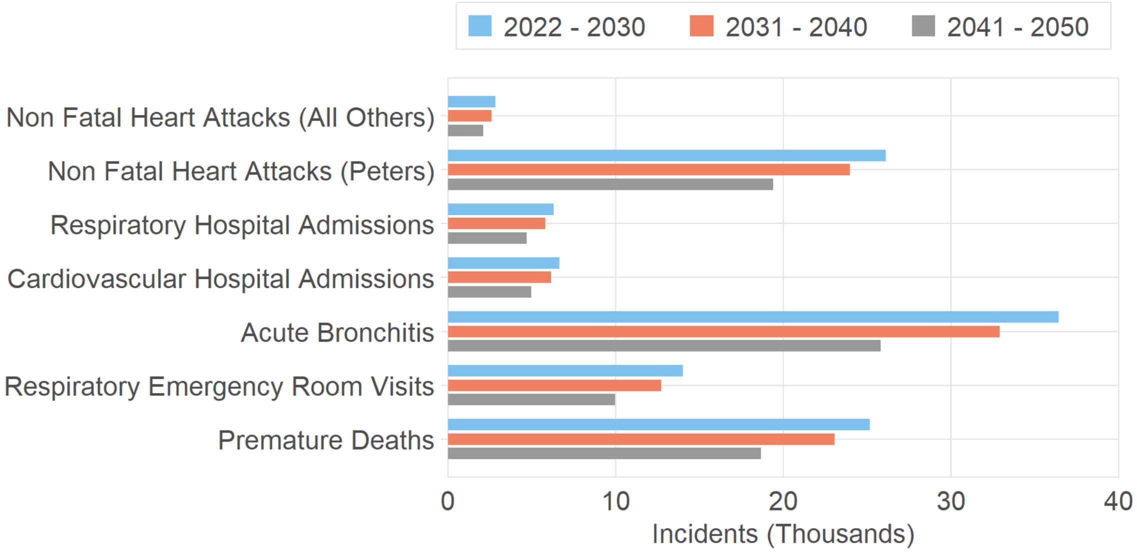


Figure 8-56: Cumulative Emission Health Impacts in the Baseline Scenario (Part 2)



Health-related incidents decrease as CAFE stringencies increase because of reductions in fuel consumed. Although the net emissions of SO_X increase in some action alternatives, the decreases in net NO_X and fine $PM_{2.5}$ emissions lead to an eventual decline in adverse health outcomes. Figure 8-57 and Figure 8-58 illustrate the incremental changes in emission health impacts for each alternative over the baseline scenario for the next three decades. With the most stringent CAFE standards, Alternative PC6LT8 sees the greatest reduction in the number of incidents among the alternatives evaluated. However, the differences between all alternatives during the first decade (CY 2022-2030) are marginal.

Figure 8-57: Changes in Cumulative Emission Health Impacts Compared to Baseline (Part 1)

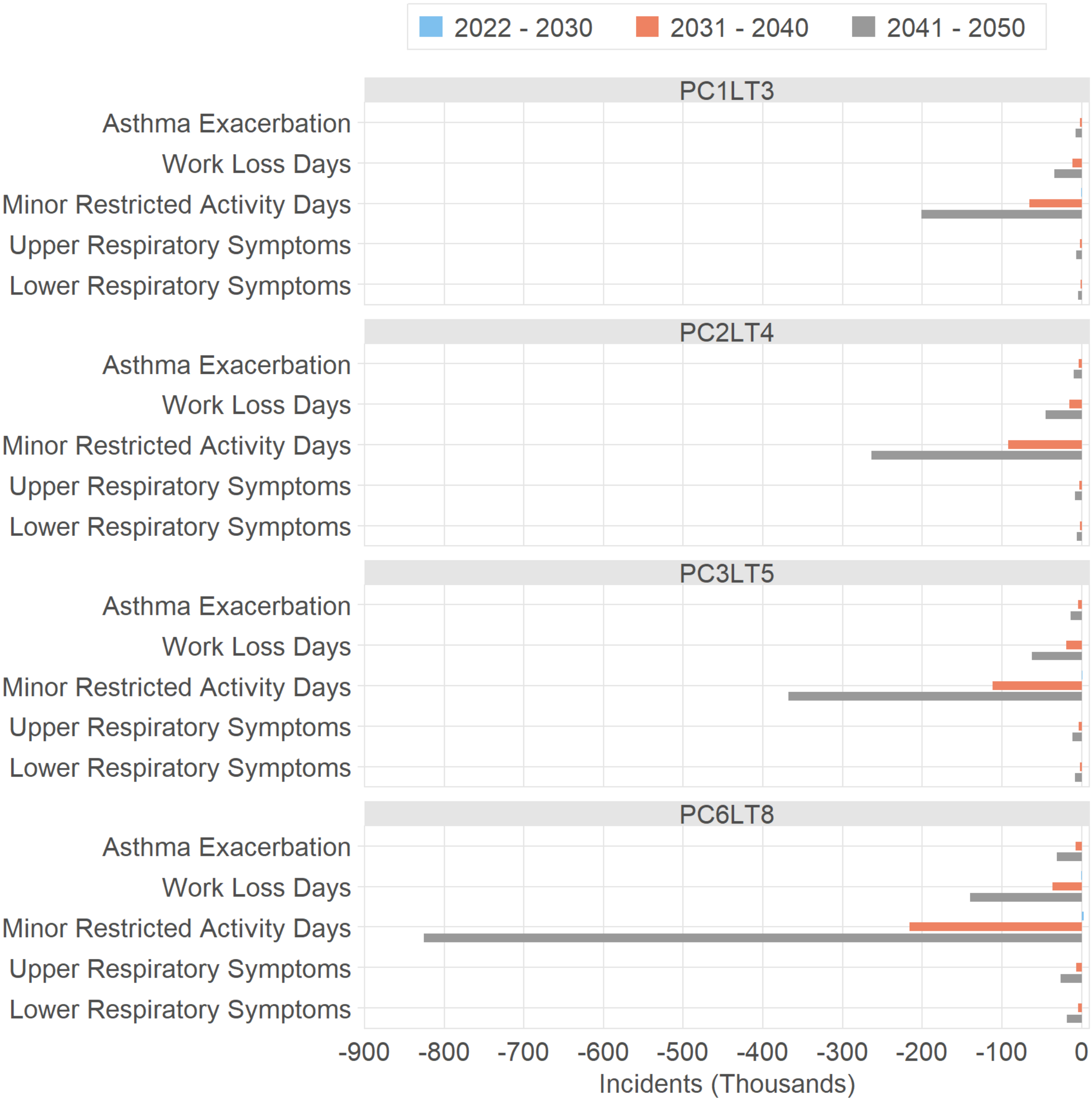
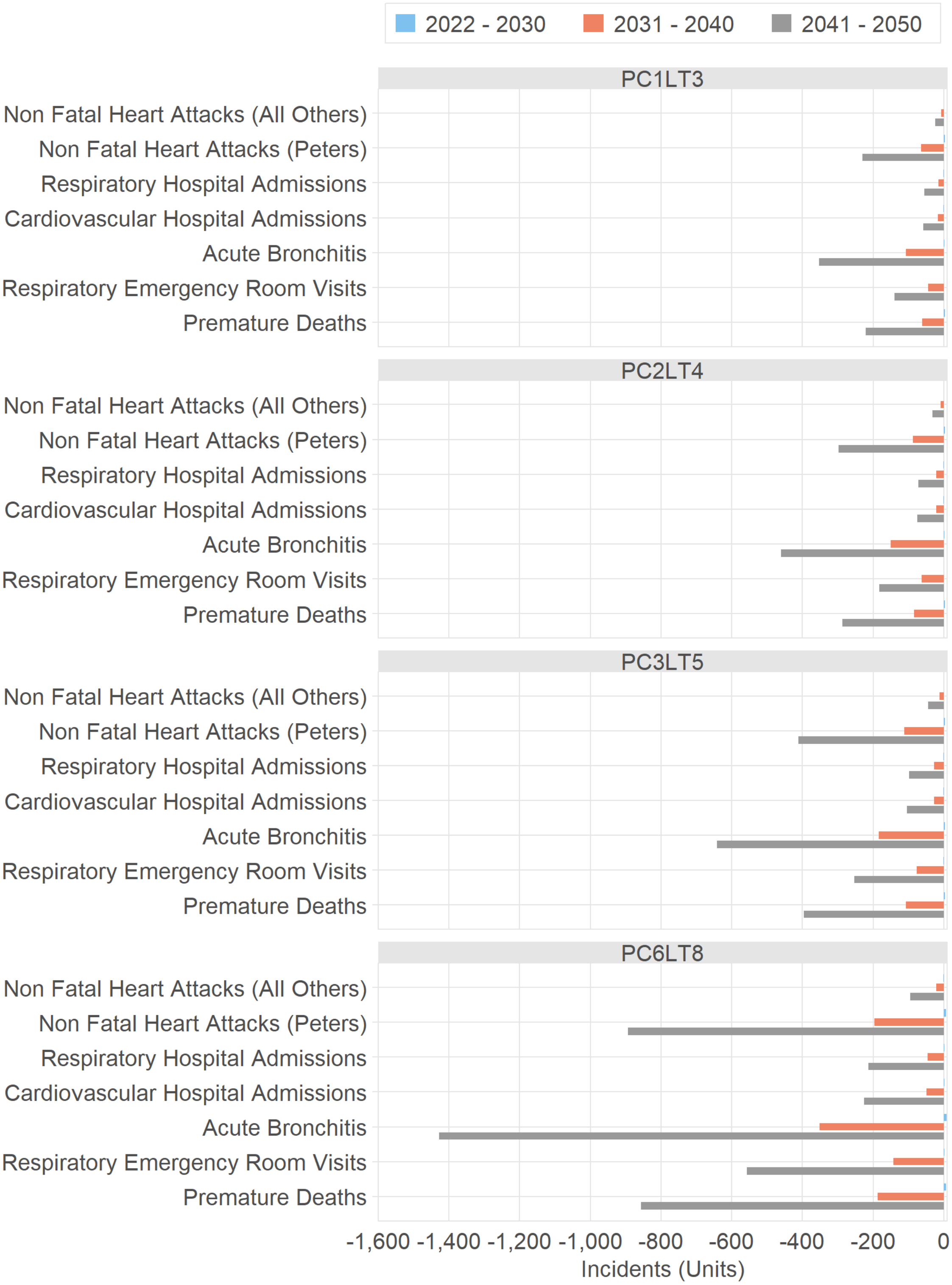


Figure 8-58: Changes in Cumulative Emission Health Impacts Compared to Baseline (Part 2)



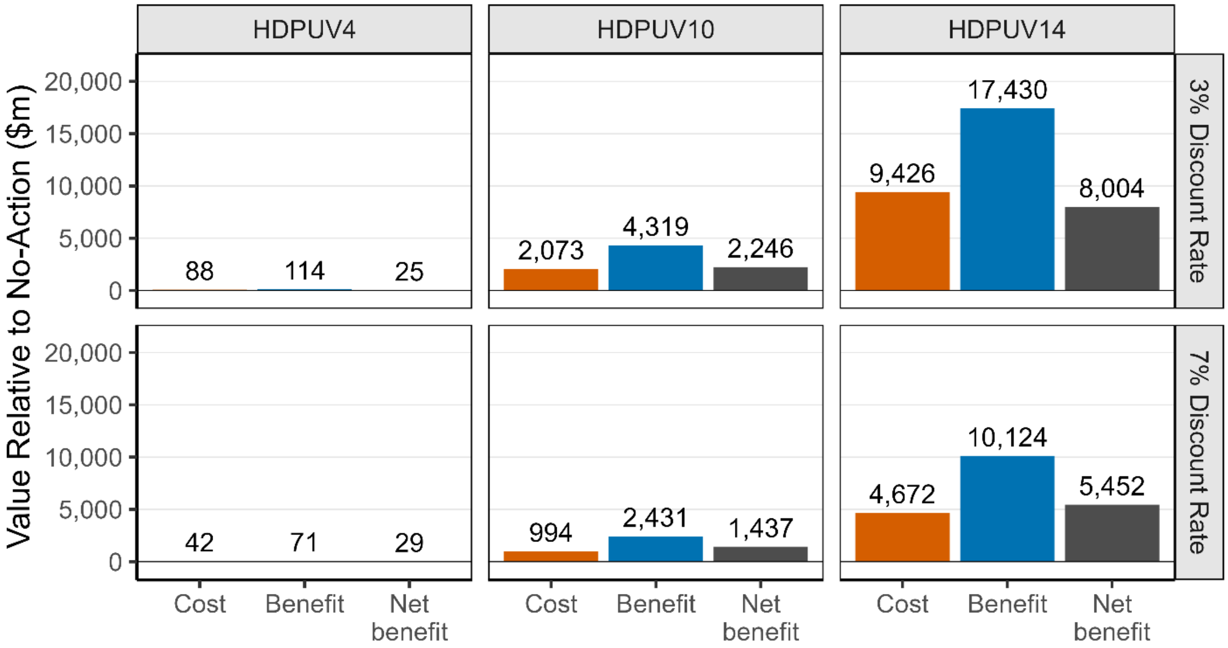
8.3. HDPUV Fleet

8.3.1. Summary of Benefits and Costs

To assess the effects of the considered regulatory alternatives, NHTSA aggregates outputs of the CAFE Model and compares the resulting cost and benefit values for each simulated alternative to those of the No-Action Alternative. Figure 8-59 reports the outcome of this calculation for CYs 2022-2050 at both a three and seven percent social discount rate.[186] Costs and benefits in the HDPUV segment are significantly smaller than in the LD segment. These segments represent very different fleets with regard to baseline technology levels, available technology improvements, and overall fleet size. The MY 2022 HDPUV fleet is approximately 6 percent of the size of the LD fleet of the same vintage. Examining costs and benefits across alternatives, both metrics increase with increases in stringency. Relative to the No-Action Alternative, program net benefits are positive across all alternatives.

The HDPUV fleet is considerably smaller than the LDV fleet. As a consequence, the costs and benefits of the proposed fuel efficiency standards are significantly less than the proposed CAFE standards. The limited number of vehicle models within the HDPUV also means that changes to one or two vehicle lines within the fleet may create a sizeable difference in costs and benefits between alternatives.

Figure 8-59: Costs and Benefits for the HDPUV Fleet, CYs 2022-2050



Chapter 8.3.4 outlines the main categories of costs and benefits aggregated to produce Figure 8-59. The largest component of these estimated costs is the technology cost that manufacturers pay to improve fleet fuel efficiency and meet the proposed targets under each alternative. Reductions in fuel costs for consumers who purchase more fuel-efficient vehicles is the largest benefit component.

8.3.2. Effects on Vehicle Manufacturers

The CAFE Model produces the industry-level, achieved fuel efficiency values for the heavy-duty fleet as shown in Figure 8-60. Note that these graphs are plotted as gallons required to drive 100 miles, which is a more common metric in the heavy-duty fleet compared to the light-duty fleet. This means that a graph that slopes down and to the right represents higher fuel efficiency. Under all scenarios, over the period from 2022

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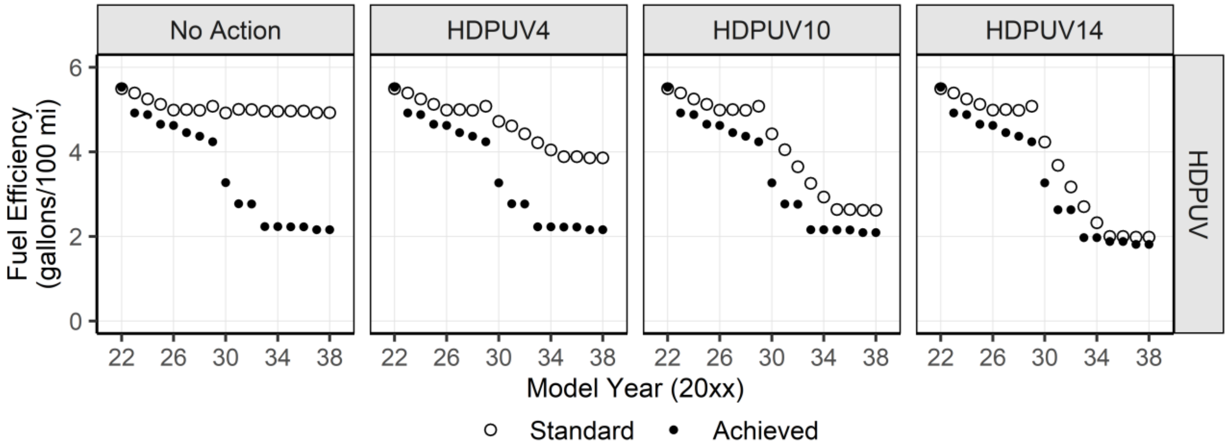
[186] Results are presented for SC-GHG discount rates of 3 percent. Benefit summaries for alternate SC-GHG discount rates are included in Chapter 8.2.4.1 Table 8-13.

until 2038, the achieved fleet fuel efficiency exceeds the regulatory standard. This is especially true under the No Action and HDPUV4 scenarios. The one exception is in the starting year, 2022. In this year the achieved fuel efficiency and the regulatory standard exactly align.

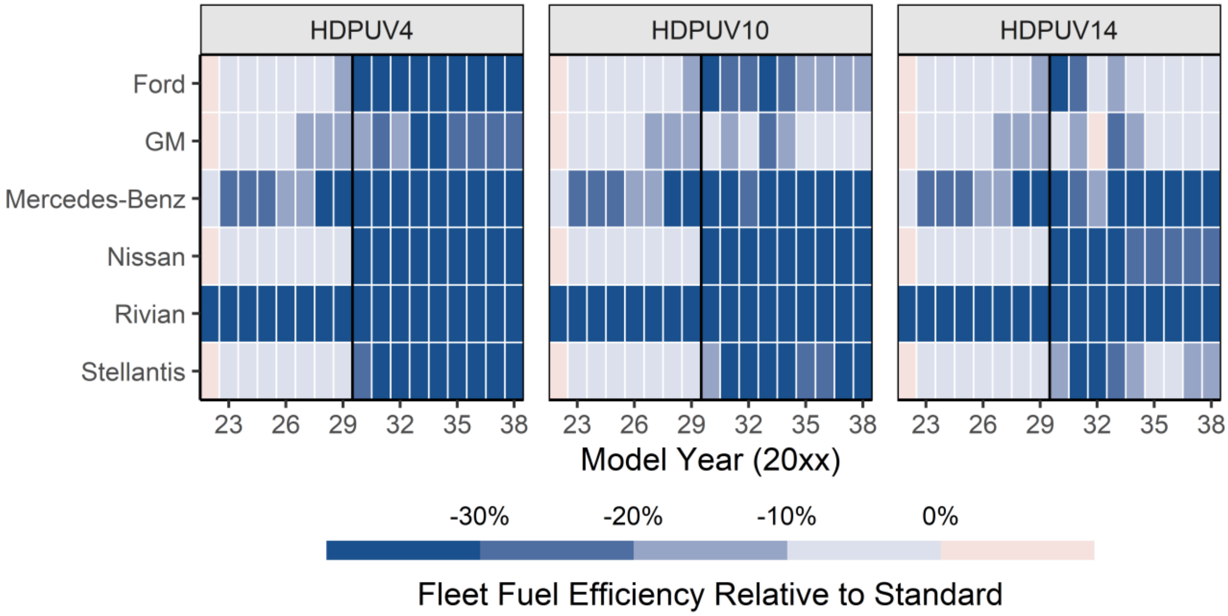
Figure 8-60: Fleet Modeled Fuel Efficiency



These are industry-wide fleet-level results, and we note that results vary considerably among specific manufacturers. Figure 8-61 presents manufacturer-level differences between achieved and required fuel efficiency levels on a fleet-wide basis. Lighter colored shading represents manufacturer-years with small, estimated deviations between standards and achieved efficiency levels. Regions shaded blue indicate manufacturer fleets that are more efficient than required and those shaded pink fall short of their compliance thresholds. By statute, manufacturers need not precisely fulfill their compliance obligations through technology application in each given model year, though the difference must be made up through the use of over-compliance credits from another fleet or model year, or civil penalty payments, as discussed in Section VI of the preamble. The vertical line in the figure indicates the start of MY 2030, which would be the beginning of the new revised standards for the HDPUV fleet.

Unsurprisingly, Rivian, which produces only BEVs, easily meets the regulatory requirements for all three stringency scenarios as shown by the solid dark blue boxes in Figure 8-61. Mercedes-Benz, with its line of work vans, is also able to meet compliance requirements over the time period of the analysis from 2022 to 2038 for all three scenarios. The other four manufacturers of heavy-duty vehicles—Ford, GM, Nissan and Stellantis—comply in every year except for the first year of the analysis, 2022 for all three scenarios. There is one exception. GM is not only unable to comply in MY 2022, but it also misses compliance in MY 2032 of the most stringent scenario, HDPUV14.

Figure 8-61: Modeled Fleet-wide Achieved Fuel Efficiency by HDPUV Manufacturer



8.3.2.1. Technology Application

To meet the required HDPUV FE levels under each regulatory alternative, the CAFE Model simulates compliance in part by applying various technologies to vehicle models in a given manufacturer's regulated fleet. As shown in Figure 8-62, the majority of this technology application occurs for model years 2023 and 2025 and is clustered in some later years as defined by vehicle redesign schedules. The quantity and timing of technology application across the three scenarios is quite similar to the No-Action alternative.

Figure 8-62: Timing of Technology Application in Response to Regulatory Alternatives

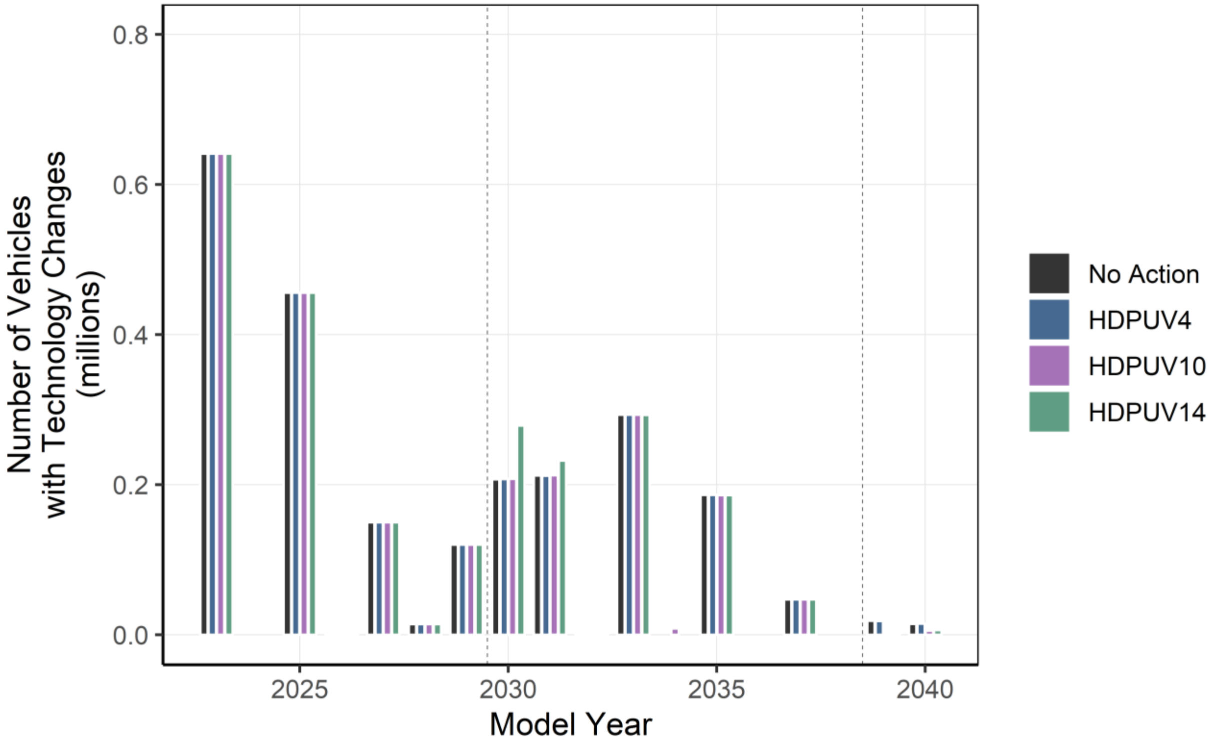
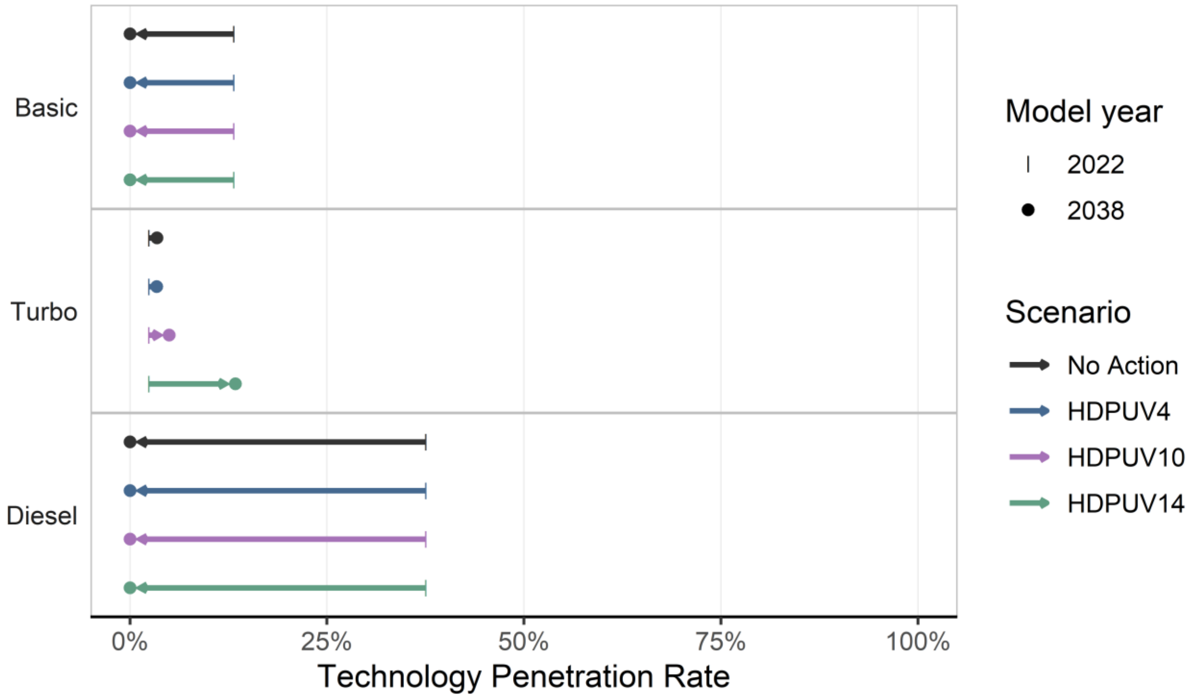


Figure 8-63 and Figure 8-64 present the resulting industry-wide technology penetration rates. Note that the spectrum of technologies applied in the light-duty fleet is broader than that of the HDPUV fleet. Consequently, there are technologies not included in the two graphs below that are included in similar graphs for the light-duty fleet, such as CVT technology. Such transmissions are common in the light-duty fleet, but absent from the heavy-duty fleet because CVTs do not have the torque handling capability necessary to function properly on heavy duty (HD) trucks and work vans. In the two figures below, each horizontal line segment in the figures represents the change in technology penetration between 2022 (represented by a short vertical line segment) and 2038 (represented by a circle). Arrows indicate the direction of the change (increase of decrease in % penetration) and line colors represent the regulatory alternative. Between 2022 and 2038, CAFE Model estimates reveal several trends, including:

Engine technology (Figure 8-63):

- Basic engine technology (including SOHC, DOHC, VVL, DEAC, and stoichiometric gasoline direct injection [SDGI]) penetration rates decrease close to zero percent by MY 2038 across all scenarios.
- ICE application of Turbo between MY 2022 and MY 2038 increases slightly for the No Action, HDPUV4, and HDPUV10 alternatives and then increases by roughly 5-10% for the most stringent alternative, HDPUV14.
- HCR engine technology increases under all scenarios except for the most stringent (PC6 LT8)
- Diesel engine penetration approaches zero for all scenarios by MY 2038.

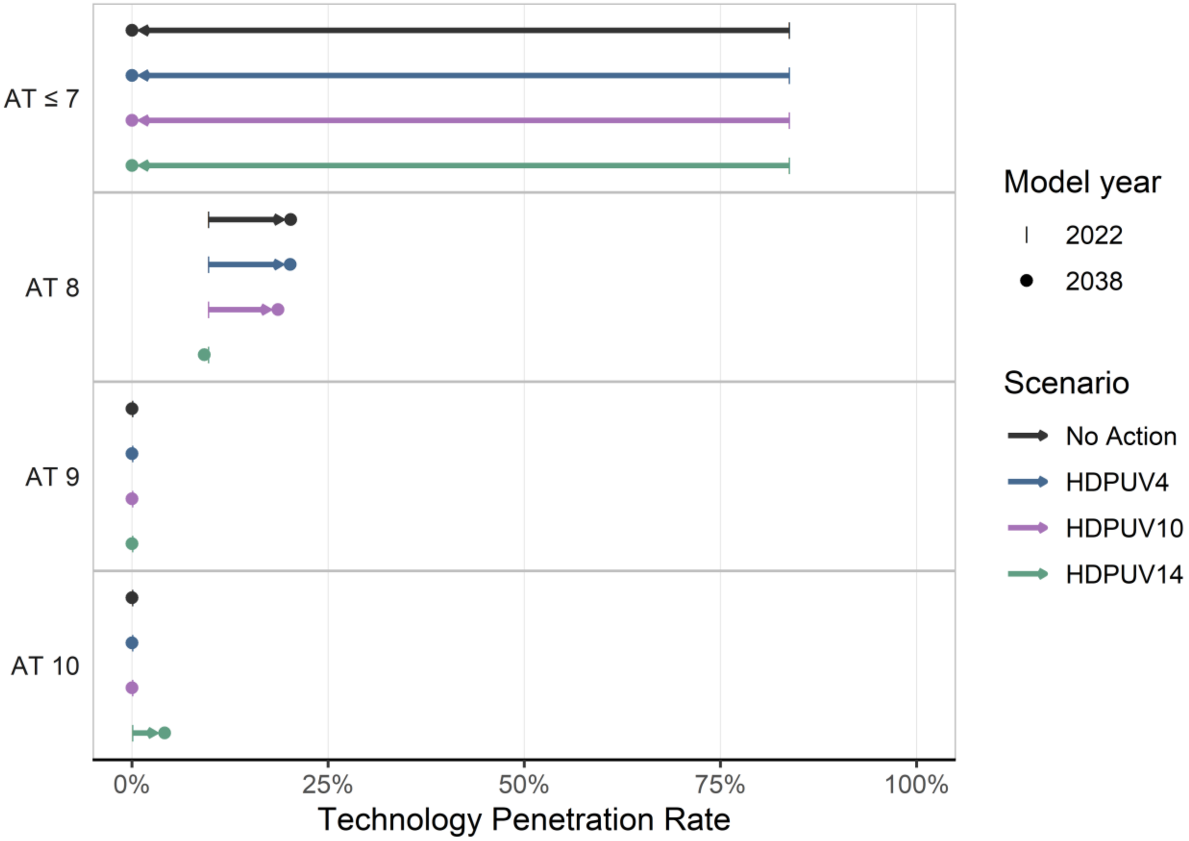
Figure 8-63: Prevalence of Engine Technology in the HDPUV Fleet Under Different Regulatory Alternatives



Transmission technology (Figure 8-64):

- Penetration of AT7 approaches zero by MY 2038. The AT7 transmissions are partially replaced with AT8 except in the most stringent scenario HDPUV14 which requires replacing some of the AT7s with AT10s. By 3038, most of the ICE powertrains are replaced with electric versions and in the process, the multi ratio transmissions noted above are replaced with single speed transmissions.

Figure 8-64: Prevalence of Transmission Technology in the Fleet Under Different Regulatory Alternatives



Electrified powertrain technology (Figure 8-65):

- Trends in technology penetration rates for various electrified powertrain technologies are similar across model years.
- Penetration of SHEV and PHEV technology increases from MY 2022 until MY 2032. Penetration of both technologies peak in MY 2032. After this point, their penetration rates remain roughly steady through MY 2050, with some minor variation.
- The penetration of BEV technology never goes above roughly 50% for all scenarios.
- The penetration of SHEVs reaches 25% by MY 2050.
- The penetration of PHEVs reaches about 15% by MY 2050.

Figure 8-65: Hybrid and Electrified Technology Penetration Rates by Model Year

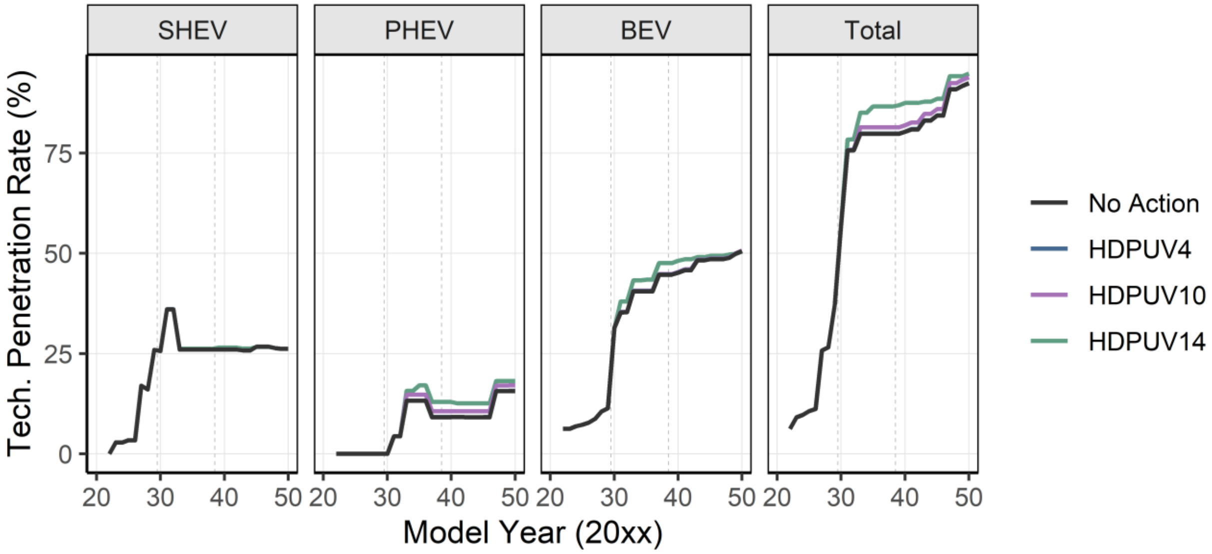


Figure 8-66 Provides more detail regarding the penetration of hybrid and electric powertrain technologies to the heavy-duty fleet from MY 2022 through MY 2038.

- The use of ICE technology decreases to only a few percentage points. For the most stringent scenario, HDPUV14 the penetration of ICE technology goes down to about a single percentage point.
- Stop-start penetration increases by low double-digit percentages.
- Most of the penetration in the heavy-duty fleet is BEV1 and penetration of BEV2 reaches only a few single percentage points.
- Penetration of SHEV technology is greater than PHEV technology.

Figure 8-66: Prevalence of Powertrain Technology in the Fleet Under Different Regulatory Alternatives

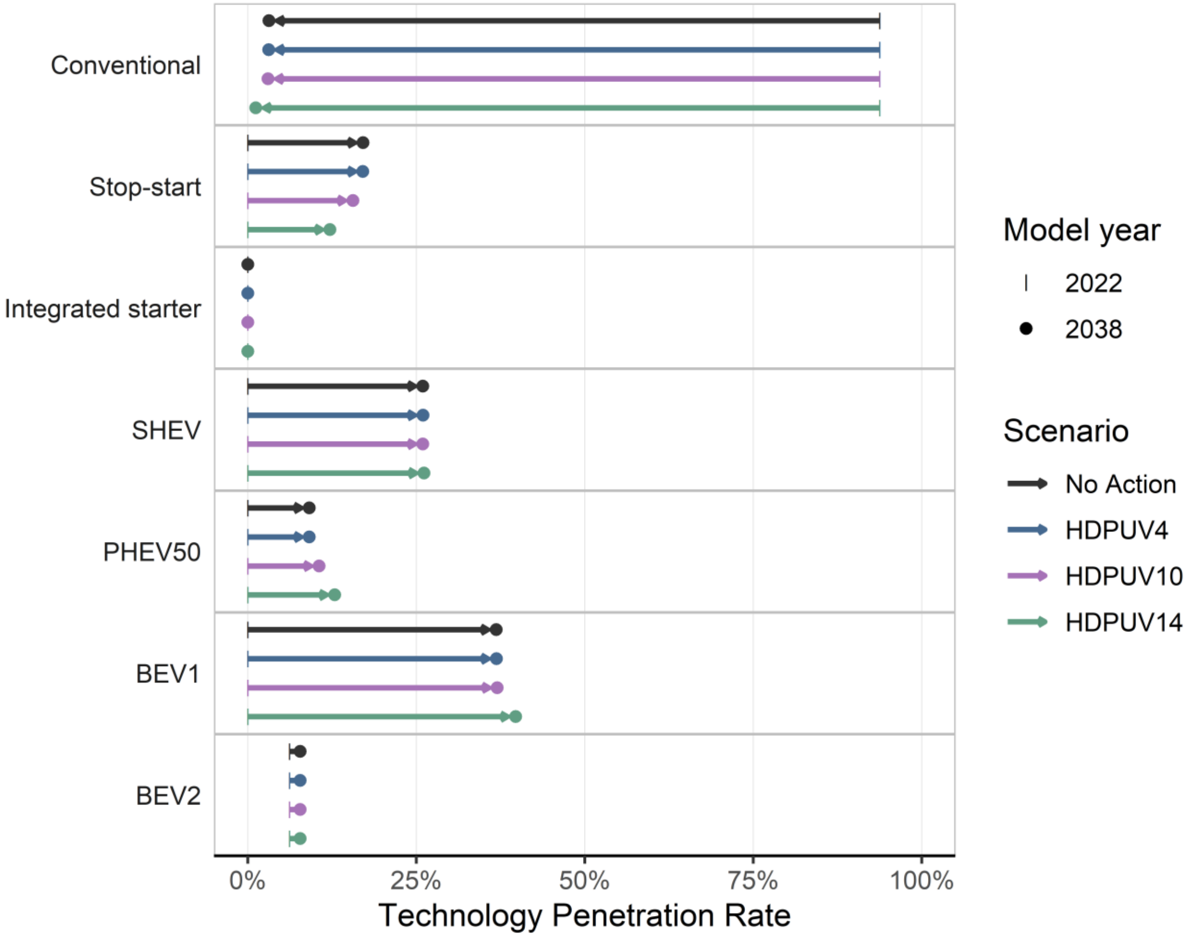
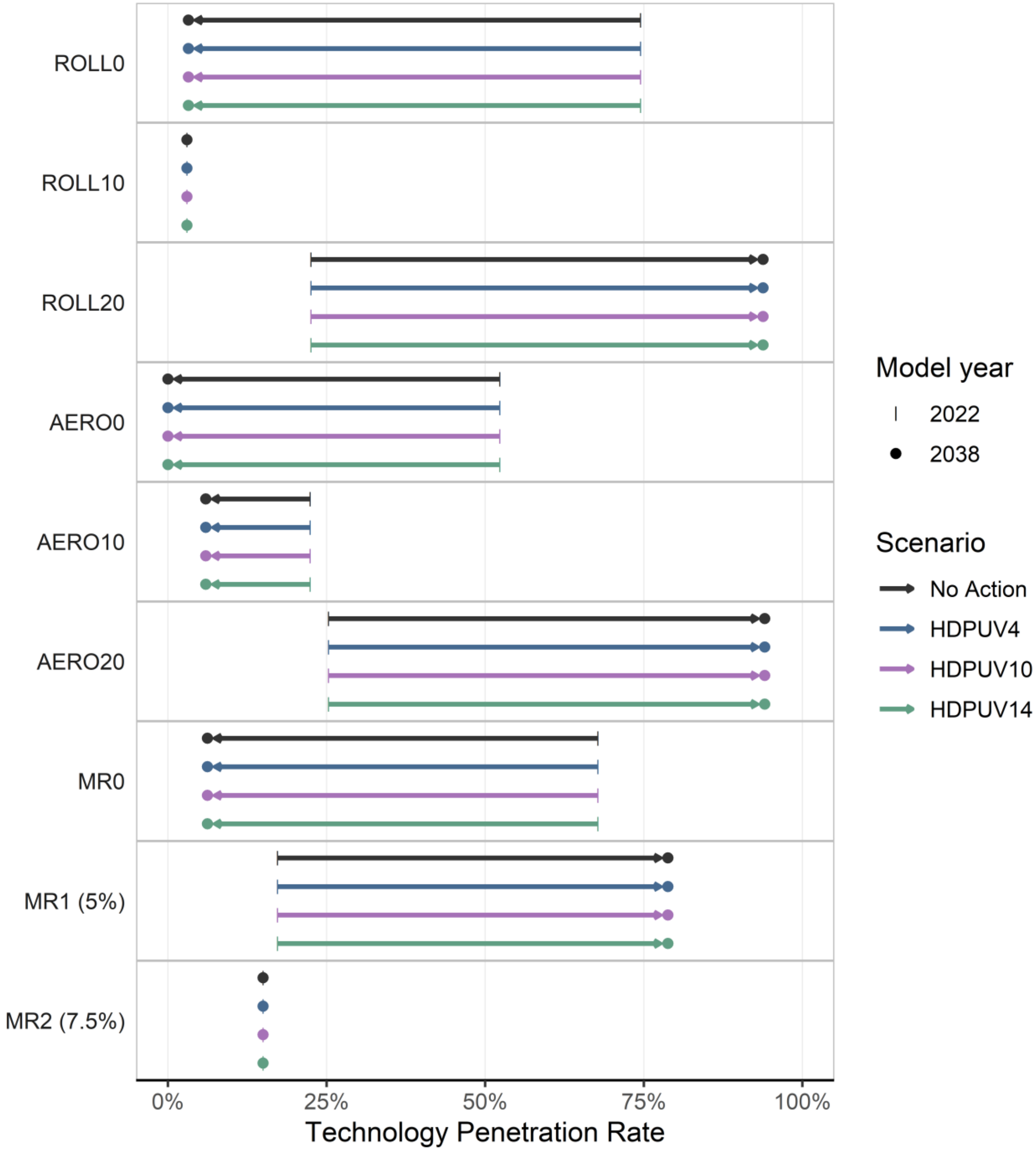


Figure 8-67 shows the penetration of road load reduction technologies for the heavy-duty fleet between MYs 2022 and 2038. The notable trends are as follows:

- Penetration of road load reduction technologies is the same for all scenarios.
- Low rolling resistance tires transition from ROLL0 to ROLL20 by MY 2038.
- Decrease in aerodynamic drag is broadly applied across the fleet for all scenarios. The penetration of AERO30 reaches nearly 100% for all scenarios over the period of the simulation.
- The model broadly applies moderate mass reduction technologies. MR1 is applied to nearly 80% of the fleet in all scenarios and MR2 penetration reaches about 20%.

Figure 8-67: Prevalence of Tire Rolling Resistance, Aerodynamics, and Mass Reduction Technologies in the Fleet Under Different Regulatory Alternatives



8.3.2.2. Compliance Costs

Manufacturers comply with HDPUV FE by applying fuel-economy-improving technologies or use over-compliance credits (whether earned or purchased). The CAFE Model computes both aggregate and per-vehicle values of these costs. Civil penalties for HDPUVs are significantly higher than light-duty penalties, and manufacturers have not found them to be a cost-effective method for meeting the HDPUV standards. As such, the regulatory costs for HDPUVs consist solely of the technology costs. Figure 8-68 reports industry-wide, model year trends in per-vehicle technology costs. In line with technology application trends, costs across alternatives remain within a relatively narrow band. Costs for alternative HDPUV4 are nearly identical to those in the baseline and HDPUV10 presents differences only beyond MY 2032. A portion of this clustering of modeled costs is the increase in technology cost in the baseline in MY 2030. This cost increase and the associated decrease in fleet-wide fuel efficiency is the result of assumed redesign scheduling (e.g., a tranche of Ford vans in MY 2030) and the relative cost-effectiveness levels of technology available at that time (e.g., BEVs relative to alternative technology options).

Figure 8-68: Average Per-vehicle Technology Cost

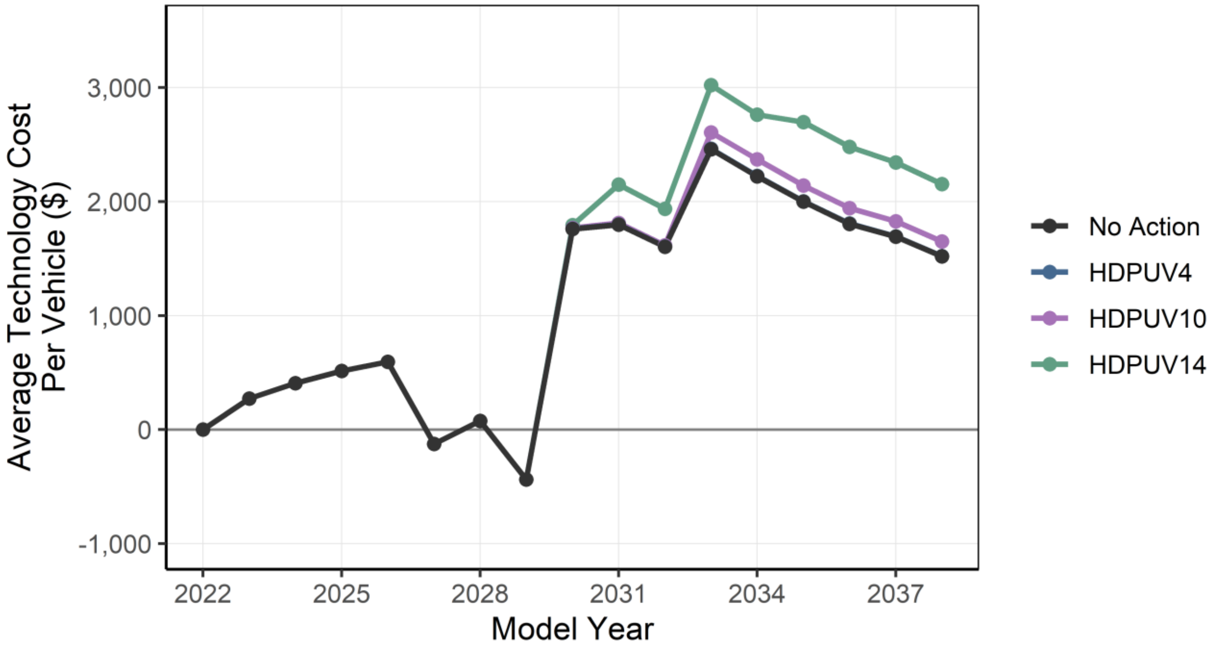


Figure 8-68Figure 8-13 presents per-vehicle technology costs for MY 2038 vehicles by manufacturers in each alternative. Gray bars in the figure are costs in the No-Action Alternative. Total No-Action Alternative costs are listed in the data labels in the “No-Action” panel. The portions of the bar in color represent the changes in manufacturer technology costs for each action alternative. For example, average per-vehicle technology costs for GM are $650 for the No-Action scenario. The cost increases by $410 for the second most stringent scenario, HDPUV10, for a total cost of $1,060 (an increase of 63%). Moreover, the cost would increase by $1,520 to a total of $2,170 (an increase of 334%) for GM to achieve the most stringent scenario, HDPUV14. Some manufacturers like Nissan and Mercedes-Benz meet the standards of the action alternatives without any additional costs.

Figure 8-69: Per-vehicle Technology Cost, MY 2038 Vehicle

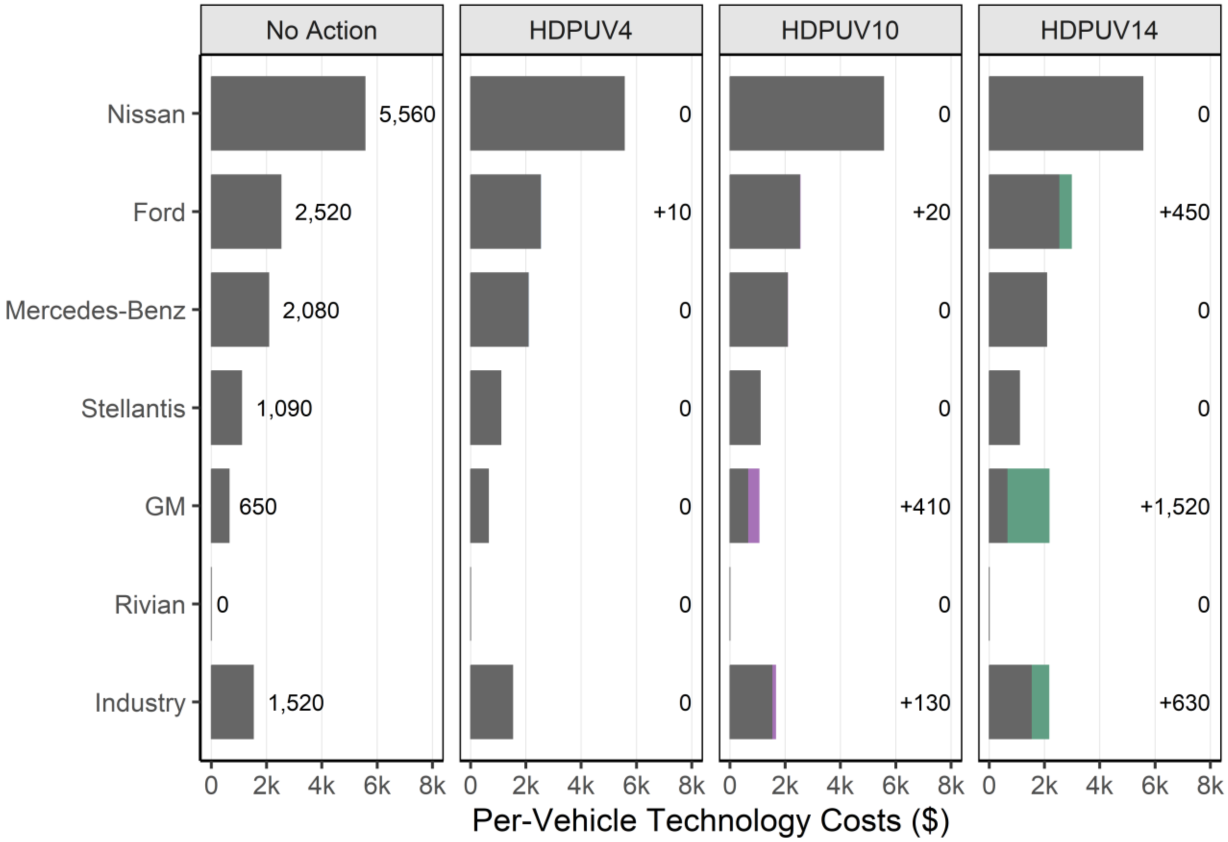
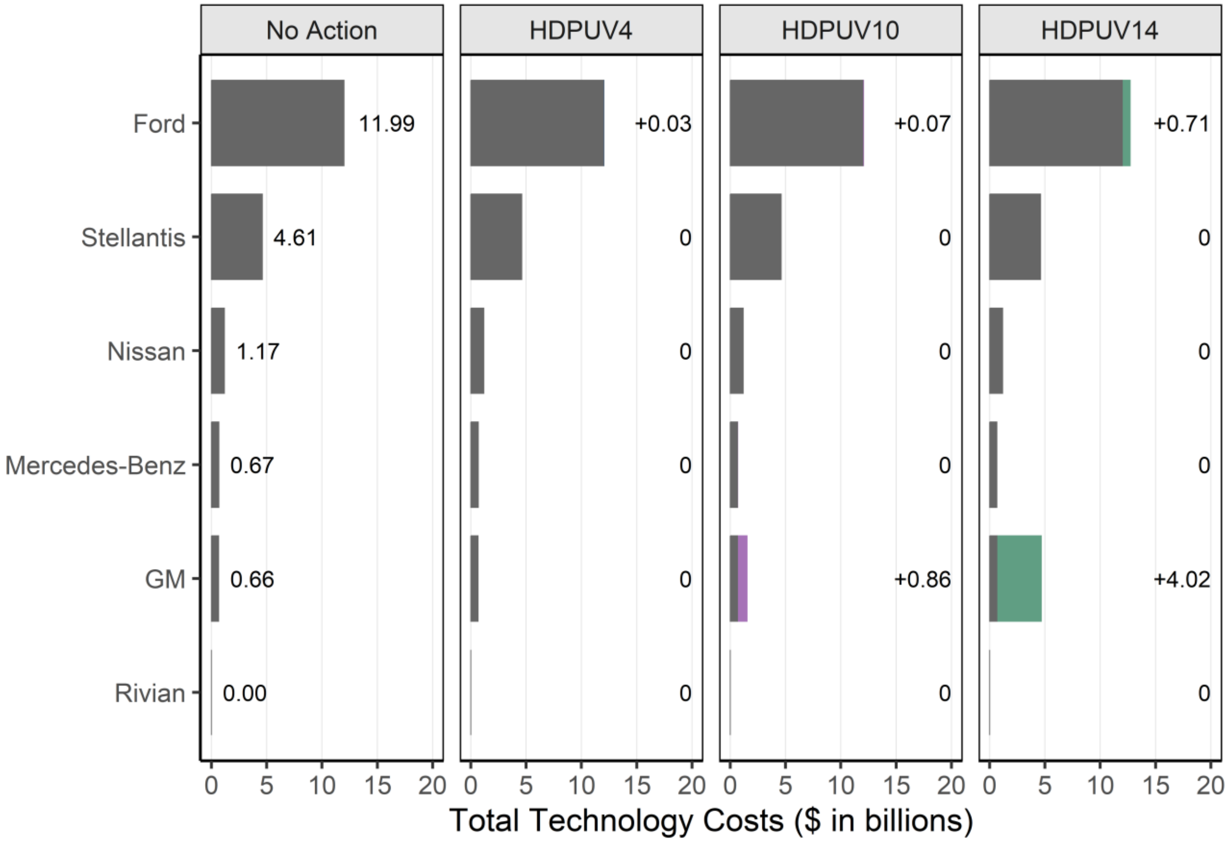


Figure 8-70 reports total technology costs for MYs 2022 through 2038 in the No-Action scenario alongside labeled aggregate technology cost increases for each action alternative. In most cases, differences in manufacturer rankings between Figure 8-69 and Figure 8-70 are the result of production-scale variation (e.g., and importantly, Ford's large production volumes means it has the largest total technology cost even though Ford's average per-vehicle costs place it in the second position of the manufacturer ranking in Figure 8-69). As with the per-vehicle technology costs, Stellantis, Nissan, Mercedes-Benz, and Rivian do not incur any technology costs beyond the No-Action alternative; these manufacturers are in compliance in the No-Action alternative and therefore do not require any fuel efficiency technology to meet the proposed standards.

Figure 8-70: Technology Costs by Manufacturer, MYs 2022-2038



8.3.2.3. Sales and Employment Impacts

As manufacturers modify their vehicle offerings and utilize fuel-efficient technologies in response to HDPUV FE standards, vehicle costs may increase. The analysis assumes any cost increases are passed on to consumers and higher retail prices decrease vehicle sales. Because each of the two most stringent action alternatives leads to technology costs above those of the No-Action baseline, sales decline in these two alternatives relative to the No-Action Alternative.[187] Figure 8-71 illustrates the rather minute magnitude (less than a single percentage point) of this effect in the context of total sales from MY 2022 through MY 2050.

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[187] Sales differences among alternatives are dictated by the assumed price elasticity of demand and the change in vehicle price net of future fuel savings. For this analysis, the assumed price elasticity is -0.4 and the model assumes new vehicle buyers value the first 2.5 years of future fuel savings. For a detailed discussion of these assumptions, see Draft TSD Chapter 4.2.

Figure 8-71: Industry-wide Sales

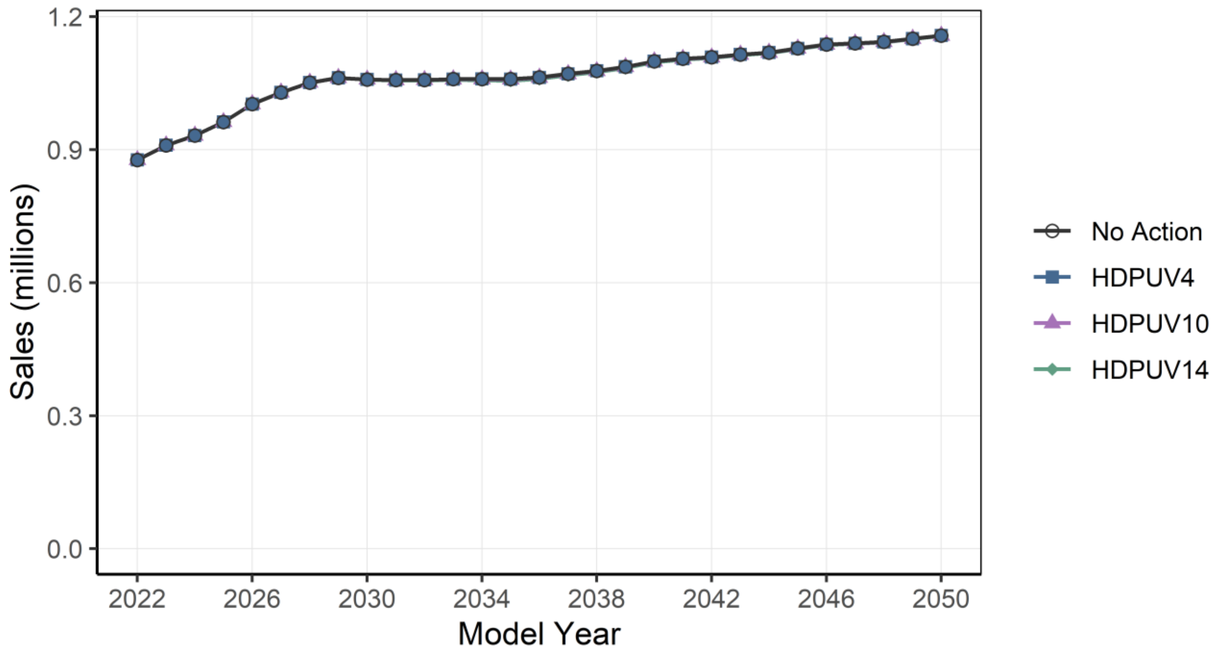
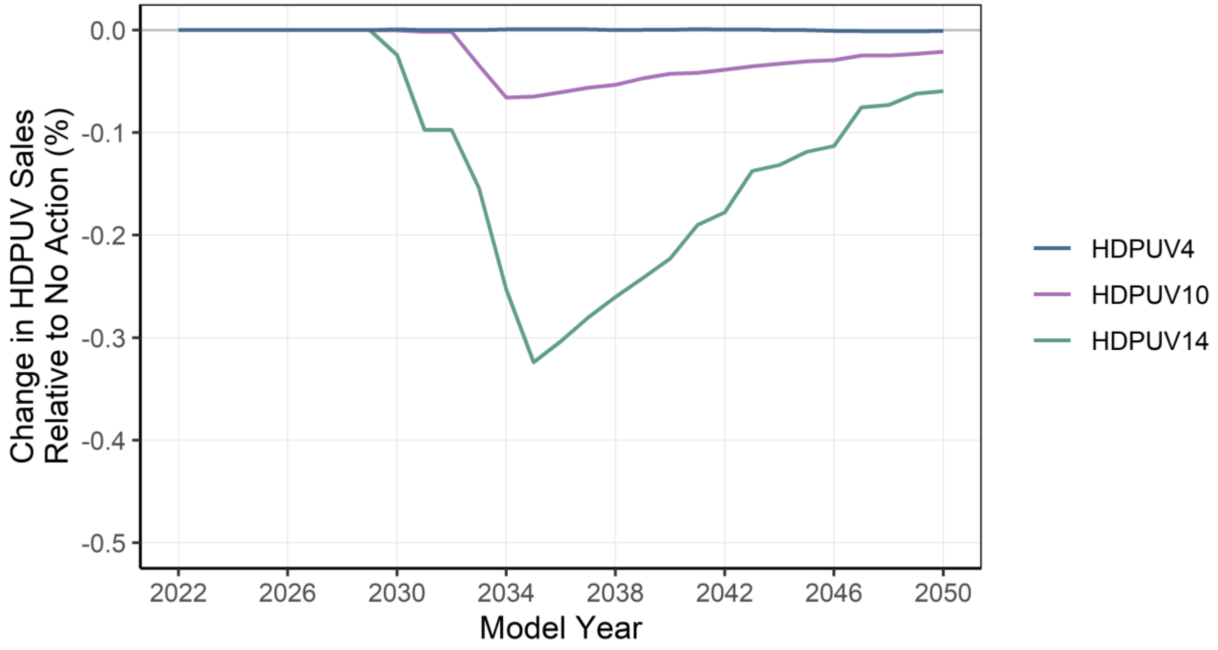


Figure 8-72 shows the simulated sales differences for the current analysis at the industry level across alternatives relative to the No-Action alternative between MY 2022 and MY 2050. For the two most stringent alternatives, HDPUV10 and HDPUV14, sales stay constant relative to the No-Action Alternative until MY 2033 and MY 2029 respectively. After this, sales begin to decline in these two scenarios which reflects the cost increases associated with FE technology. As the stringency level increases within each scenario, the sales decrease accelerates. Sales begin to rebound in the action alternatives in MY 2034 for HDPUV10 and in MY 2035 for HDPUV14. The least stringent alternative, HDPUV4, shows no deviation from the No-Action Alternative because the cost of meeting its requirements does not differ from that of the baseline.

Figure 8-72: Percentage Change in Sales, by Alternative



When fewer vehicles are sold, manufacturers require fewer labor hours to satisfy demand. Hence, the decline in sales shown in Figure 8-72 reduces industry-wide labor hours. However, development and deployment of new fuel-efficient technologies increases demand for labor. Overall estimated impacts on employment utilization depend on the relative magnitude of these two factors. Table 8-17 reports total employment utilization in full-time equivalent job units (i.e., the number of individuals working a full-time position that are required to meet new vehicle demand). Chapter 6.2.5 of the Draft TSD offers further detail on this measure and how it is calculated. In the No-Action alternative, net employment utilization increases until it peaks in 2038. The first scenario, HDPU4 does not add or subtract from the No Action alternative. However, the two highest stringency alternatives, HDPUV10 and HDPUV14 both subtract moderately from the baseline employment utilization. HDPUV14 subtracts more employment utilization from the baseline No Action alternative than does HDPUV10.

Table 8-17: Industry-wide Labor Utilization Effects (in Full-time Equivalent Jobs)

Model Year	No Action	HDPUV4	HDPUV10	HDPUV14
2030	64,451	0	0	-16
2031	64,363	0	-1	-63
2032	64,381	0	-1	-63
2033	64,493	0	-23	-100
2034	64,518	1	-43	-163
2035	64,494	1	-42	-209
2036	64,729	1	-39	-196
2037	65,221	1	-36	-182
2038	65,643	0	-34	-171

8.3.3. Effects on New HDPUV Buyers

8.3.3.1. Vehicle Purchasing Price

The approach that CAFE Model uses to model vehicle purchase prices is equivalent to its treatment of light-duty vehicles. Individual vehicle MSRP values for the 2022 fleet are modified for each successive model year to incorporate the costs of compliance, and do not include the effects of tax credits for electric vehicles (EVs) and batteries.[188] While increasing the stringency of standards over time affects the compliance costs for manufacturers, it is important to note that prices evolve over time even in the No-Action Alternative as manufacturers decide to adopt cost-effective technology. In Figure 8-73 we show the evolution of the sales weighted average MSRP between MY 2022 and MY 2038 in each of the regulatory alternatives. While prices generally rise throughout the 2020s under the current fuel efficiency standards, they do drop between MYs 2026 and 2029. This is the result of some manufacturers adopting technologies that lower their production costs in the early years, before adopting more expensive technologies that are cost-effective due to their impact on fuel cost savings. Following MY 2030, when the regulatory alternatives phase in, there is initially only variation from the No-Action Alternative in the most stringent scenario. Between 2032 and 2033, when prices rise in each of the alternatives, the average price in the HDPUV10 alternative also diverges, as compliance requires greater technology adoption. By the end of the period prices in the most stringent alternative are about $600 higher than the No-Action Alternative. Since the least stringent alternative, HDPUV4, never separates from the baseline, the technologies needed to comply with this alternative are also cost-effective. In the years following MY 2033, the costs associated with these technologies decline due to their assumed learning rates, and prices decline.

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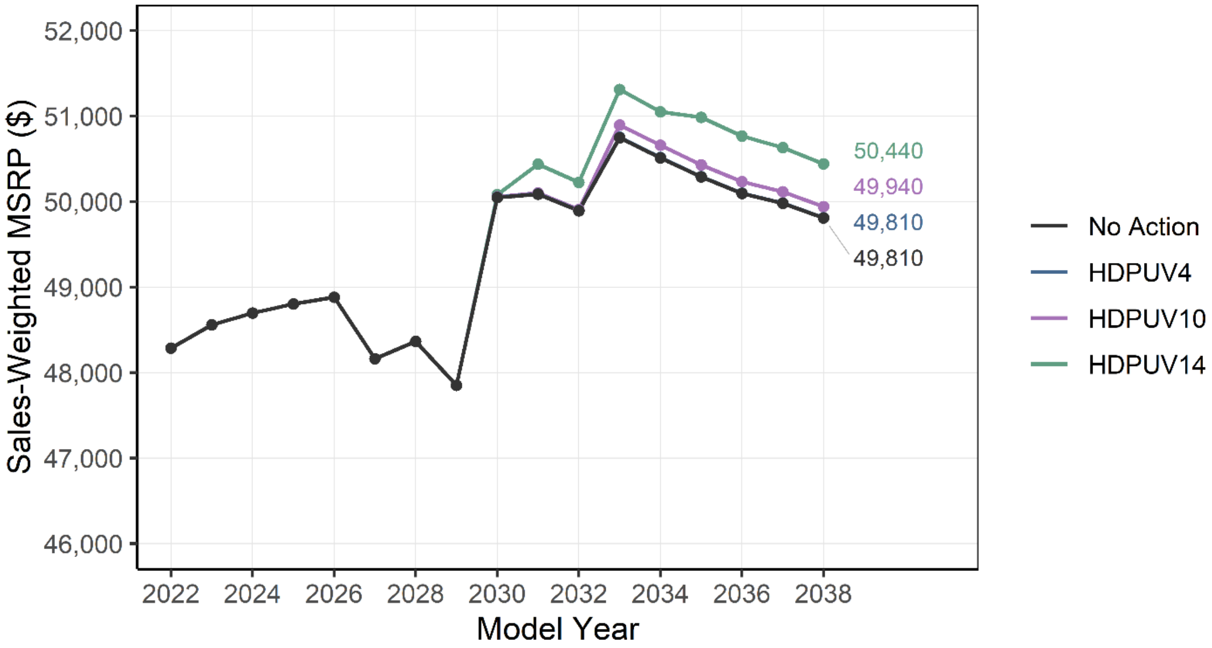
[188] While the MSRP reported here does not include the value of tax credits passed through to consumers, these credits are included in the sales model as discussed in Chapter 4 of the Draft TSD.

Figure 8-73: Sales-weighted MSRP for HDPUVs



8.3.3.2. Additional Buyer Purchasing Costs and Benefits

The CAFE Model computes the same categories of buyer costs and benefits for HDPUVs as it does for light-duty vehicles.[189] Table 8-18 presents a summary of these costs and benefits for MY 2030 and MY 2038 vehicles. The values presented represent per-vehicle aggregate values for the No-Action Alternative, and the incremental difference from the No-Action Alternative for each of the other regulatory alternatives.[190] As is the case for light-duty vehicles, the insurance cost and vehicle taxes and fees for HDPUVs are all derived as a portion of modeled MSRP levels and hence vary directly with MSRP across alternatives. Regulatory costs are composed of compliance costs due to technology application and therefore increase as alternative stringency increases. As shown in Table 8-18, this regulatory cost component increases by only a minimal amount over the No-Action Alternative for Alternative HDPUV4 and increases by around 40 percent for HDPUV14 in MY 2038.[191]

For HDPUV estimated private benefits include decreased fuel expenditures, time saved due to less frequent fueling, realized benefits from rebound travel miles, and any EV tax credits and battery tax credits that are passed on to buyers. In 2030, tax credits amount to $686 per vehicle in the No-Action Alterative, though additional incremental credits are minimal across alternatives. By 2038, both tax credits are fully phased out and thus are 0 by default in Table 8-18. As presented in Table 8-18, fuel savings benefits are substantially higher in the most stringent alternative in MY 2038. Overall, though the savings represent less than 10 percent of total fuel outlays in the No-Action Alternative for each of the regulatory alternatives in both years.

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[189] As is the case with light-duty vehicles, the buyer costs and benefits reported represent only private costs and benefits. Chapter 8.3.4 presents the model's results for costs and benefits attributable to society as a whole.

[190] Results for additional regulatory fleet aggregations and discount rates is included in Appendix I and II.

[191] In its sensitivity analysis NHTSA explored the possibility that for commercial operators any increase in the net private benefits of buyers related to fuel efficiency are offset by a decrease in the other attributes of the vehicle which are not modeled, however, this is not included in the central analysis.

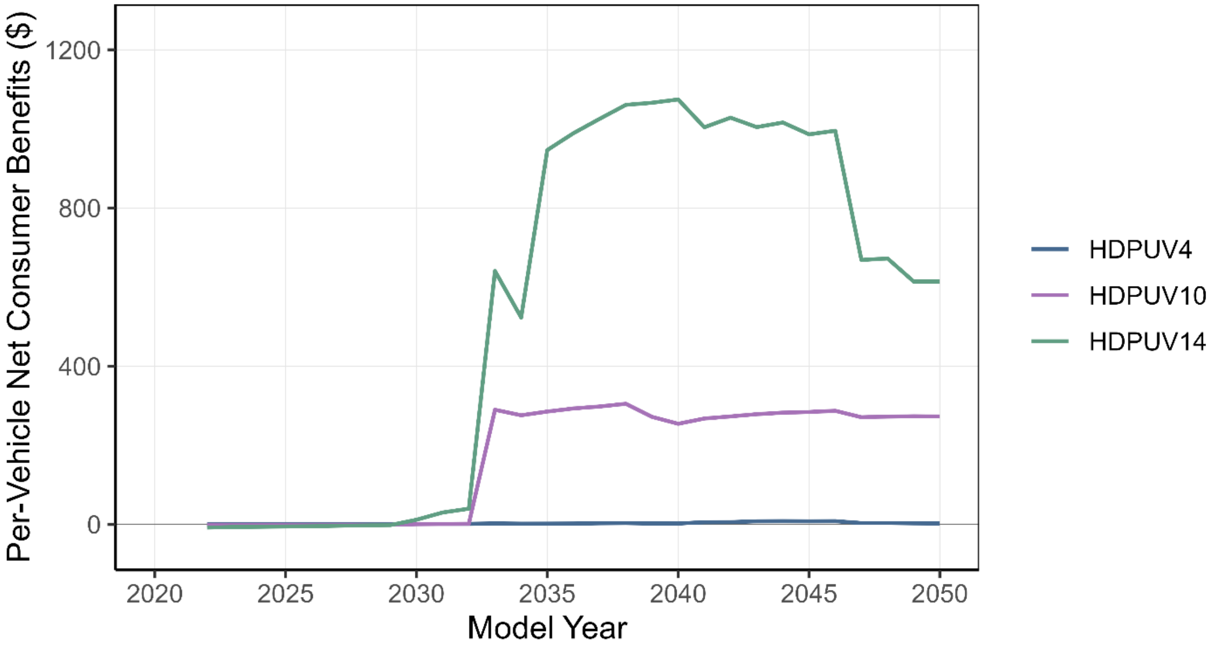
Table 8-18: Per-vehicle HDPUV Buyer Costs and Benefits (2021$, 3 Percent DR)

	MY 2030				MY 2038			
	No Action	Relative to No Action			No Action	Relative to No Action		
		HDPUV4	HDPUV10	HDPUV14		HDPUV4	HDPUV10	HDPUV14
HDPUV buyer costs								
Regulatory cost	1,760	3	8	33	1,520	3	131	633
Insurance cost	4,721	0	1	3	4,698	0	12	60
Ownership taxes and fees	2,733	0	0	2	2,720	0	7	35
Foregone consumer sales surplus	0	0	0	0	0	0	0	0
Total HDPUV buyer costs		3	10	38		5	151	728
HDPUV buyer benefits								
Retail fuel cost	32,626	-6	-19	-39	26,751	-12	-439	-2,117
Refueling time cost	6,600	3	13	-7	8,795	5	7	448
Mobility benefit	686	0	1	5	1,050	1	24	119
EV tax credit	697	0	2	-1	0	0	0	0
EV battery tax credit	946	1	2	-1	0	0	0	0
Total HDPUV buyer benefits		4	10	50		7	456	1,789
Net benefits		1	1	12		3	305	1,061

Note: Negative retail fuel cost and refueling time cost relative to the No-Action alternative indicate net savings (i.e., benefits) from the HDPUV buyer perspective and hence enter benefit totals as positive values. Values may not sum exactly to net benefit totals due to rounding.

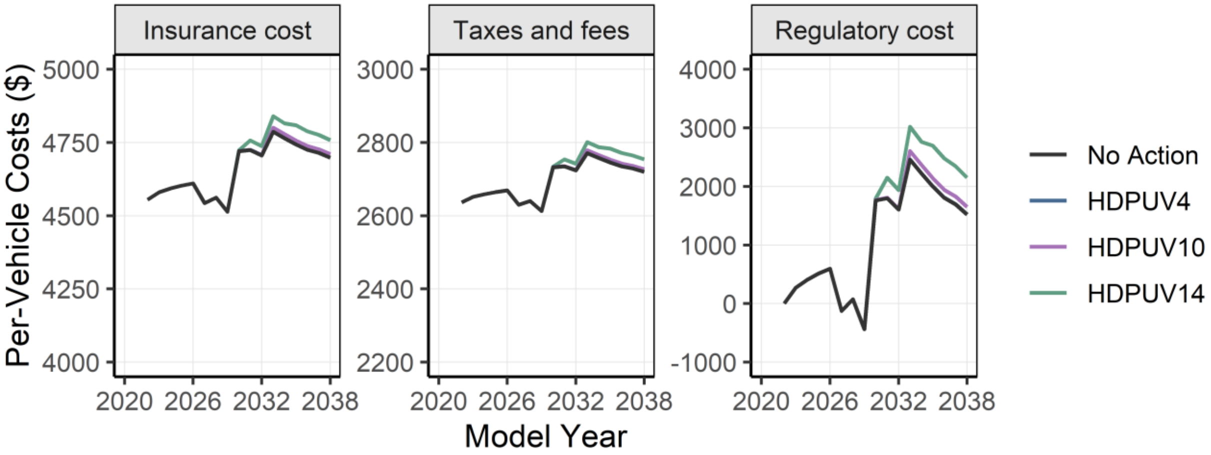
As shown in Figure 8-74 private net consumer benefits from HDPUV purchases are higher in each of the regulatory alternatives than the No-Action Alternative throughout the time period following the institution of new proposed fuel efficiency standards. Net-benefits are only marginal in the least stringent alternative, a reflection of the limited additional technology adoption required to comply with these standards. This is also the case in the first few years for the HDPUV10 regulatory alternative, though they quickly increase in MY 2033 and remain around $300 per vehicle in the following years. In the most stringent alternative, the growth in net-benefits is uneven over time reflecting the path of technology costs over time. While incremental net-benefits grow to over $1,000 per vehicle in this alternative, they eventually fall to under $700 by the late 2040s. This is not the case for the HDPUV10 alternative. Chapter 9 of this document explores the sensitivity of these results to alternate modeling assumptions.

Figure 8-74: Private Consumer Net Benefits, HDPUVs, 3 Percent DR



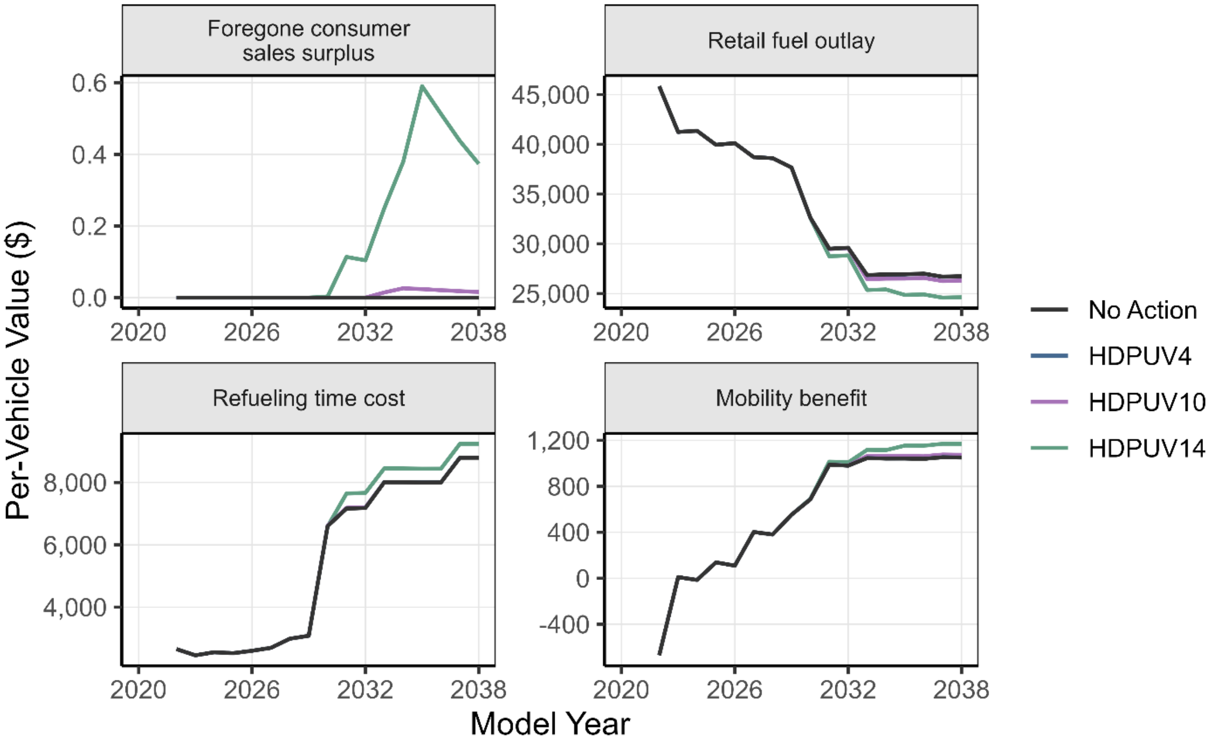
We next show the trends in each of the components of buyer costs that relate to MSRP for HDPUVs. In Figure 8-75 we show per vehicle insurance cost, taxes and fees, and regulatory costs for each of the regulatory alternatives. Patterns are similar for each, with sharp increases in the late 2020s, and the early 2030s, followed by a gradual decline through much of the 2030s. These are all driven by technology costs, since insurance costs, taxes and fees all scale proportionately with MSRP. The first increase in costs is driven by the adoption of technologies that manufacturers can adopt in a cost-effective manner. This increase occurs before the implementation of new fuel efficiency standards. However, the most stringent alternative does induce some additional technology adoption immediately after implementation. The later spike shows a more significant effect of the regulatory alternatives on costs.

Figure 8-75: HDPUV MSRP-based Buyer Costs, 3 Percent Social DR



We next examine buyer benefits and the remaining buyer costs in Figure 8-76. We find that fuel costs savings due to technology adoption begin occurring in the early-2020s. This continues in the early-2030s and is amplified significantly in the most stringent alternative. Refueling time costs increase significantly in the late-2020s as a result of electrification of the fleet. These costs more than double in the late-2020s. Incremental refueling time costs only show up in the most stringent alternative. Benefits related to additional driving as a result of improvements in fuel economy increase throughout the 2020s to over $1,000 per vehicle. The additional benefits of all but the most stringent alternative are minimal during this period.

Figure 8-76: HDPUV Buyer Costs and Benefits, 3 Percent Social DR



8.3.3.3. Total Cost of Ownership Payback Period

To compare the impact of different stringencies of fuel efficiency regulations on buyer costs and benefits, NHTSA also determines the time required for owners to realize positive net benefits on average for vehicles produced in each model year under the different regulatory alternatives. To estimate the payback period for TCO changes, the model aggregates regulatory costs net of any tax credits. It then compares these to a running total of fuel savings and ownership cost changes (e.g., vehicle taxes and fees, finance and insurance costs) relative to the initial state of a given vehicle.[192] The age at which the running total of cost savings outweigh the additional costs represents the payback period length. Figure 8-77 shows the HDPUV distribution of payback periods for all vehicles in the MY 2030 and MY 2038 fleets.

Figure 8-77: HDPUV Distribution of Vehicle TCO Payback for MYs 2030 and 2038

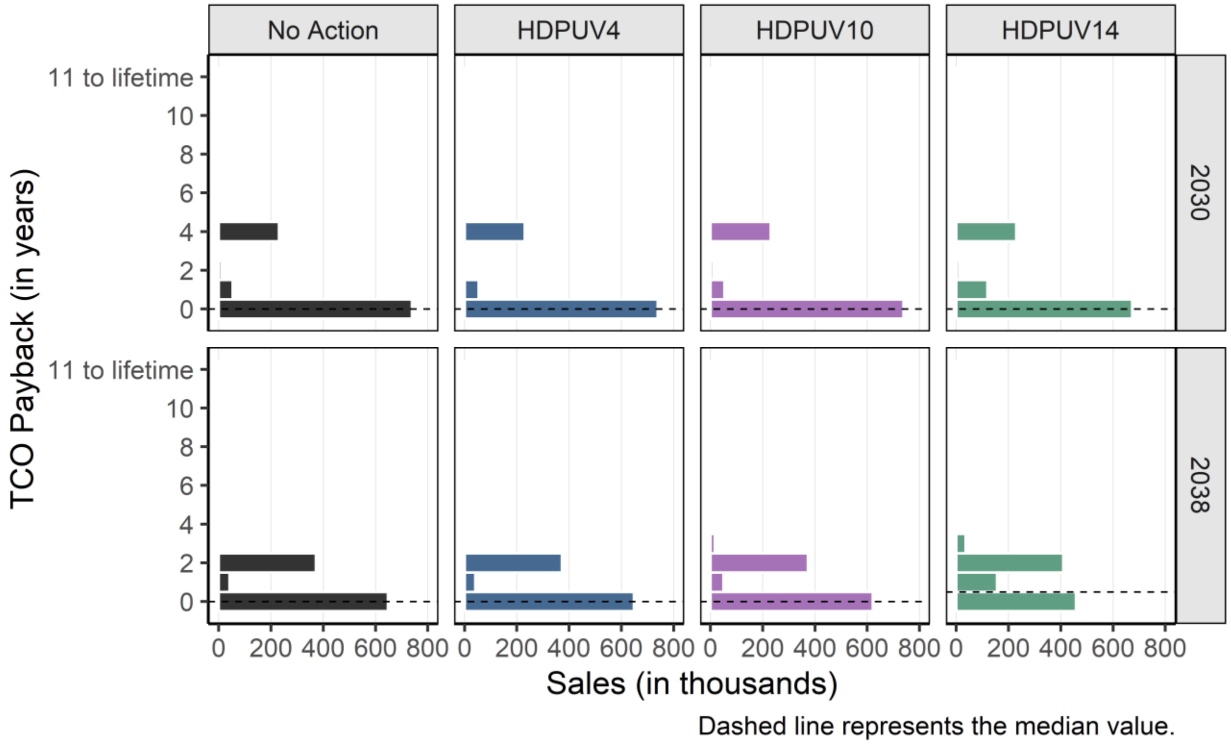


Figure 8-77 summarizes payback periods for undiscounted costs from the CAFE Model's vehicles report.[193] Across regulatory alternatives payback period length does not exceed 3 years for any of the vehicles. In contrast with the light-duty fleet, where several vehicles do not payback the costs of technology adoption over their lifetimes, the HDPUVs generally do so in the first two years of ownership. Indeed, in the No-Action Alternative, the average payback period in MY 2038 is less than two-thirds of the length for light-duty vehicles in the same year. In Figure 8-77 we see that across alternatives a significant share of the fleet shifts from having a payback period of 4 years in 2030, to having a payback period of 2 years in 2038. However, except for the most stringent alternative in MY 2038, the majority of vehicles pay back their costs of ownership within the first year. Table 8-19 summarizes these results and shows that more stringent alternatives on average require longer horizons to produce positive returns. The difference between the least stringent and most stringent alternatives increases only slightly, from around one-tenth of a year in MY 2030 to about one-quarter of a year by MY 2038. This affirms that a significant share of the technology adoption appears to take place in the No-Action Alternative, especially in the earlier year. The overall differences between alternatives, and the change in these differences over time is much smaller than the light-duty fleet. This points to the fact that tech adoption costs are more smoothly distributed across larger light-duty fleet.

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[192] The "initial state" of each vehicle is based on the vehicle's technology status in MY 2022.
[193] Unlike light duty vehicles, there are no instances in which costs outweight benefits over the full vehicle lifetime.

Table 8-19: HDPUVs Payback Times by Regulatory Class (in Years)

	MY 2030				MY 2038			
	No Action	HDPUV4	HDPUV10	HDPUV14	No Action	HDPUV4	HDPUV10	HDPUV14
Mean	1.1	1.1	1.1	1.2	0.8	0.8	0.9	1.1
Median	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5

8.3.4. Effects on Society

This chapter discusses social benefits and costs associated with the different rulemaking alternatives, including external benefits and costs pertaining to the following: GHGs, criteria pollutant emissions, congestion, noise, energy security, and safety. The following chapters (8.3.4.1 through 8.3.4.5) discuss the external effects to society. Chapter 8.3.4.6 summarizes the full accounting of both these external costs and benefits and the costs and benefits experienced by society as a whole, including the effects on consumers and manufacturers described in Chapter 8.3.2 and Chapter 8.3.3.

The CAFE Model records costs and benefits for particular model years but also reports these measures over the lifetime of the vehicle and allows for the accounting of costs and benefits across CYs. Examining program effects through this lens illustrates the temporal differences in overall societal costs and benefits. Figure 8-78 displays annual costs and benefits from CYs 2022-2050. Benefits exceed costs in the mid-2030s using the 3 percent and 7 percent DRs under both Alternative HDPUV10 and Alternative HDPUV14. Prior to these CYs, costs exceed benefits, driven mostly by the costs associated with applying efficiency-improving technologies.

Under alternative HDPUV4, the differences between costs and benefits are small relative to the other action alternatives. Figure 8-79 reports the cost and benefit metrics as computed in Figure 8-78 but does so for Alternative HDPUV4 in *millions* of dollars. The general pattern of costs and benefits across CYs remains similar; under Alternative HDPUV4, costs exceed benefits until CY 2037 using the 3 percent DR, and until CY 2036 using the 7 percent DR. The scale of these costs and benefits ranges from tens of thousands to single-digit millions depending on the CY, in contrast with the billions of dollars of costs and benefits experienced in the other two alternatives.

Figure 8-78: Annual Costs and Benefits on a CY Basis, All Action Alternatives

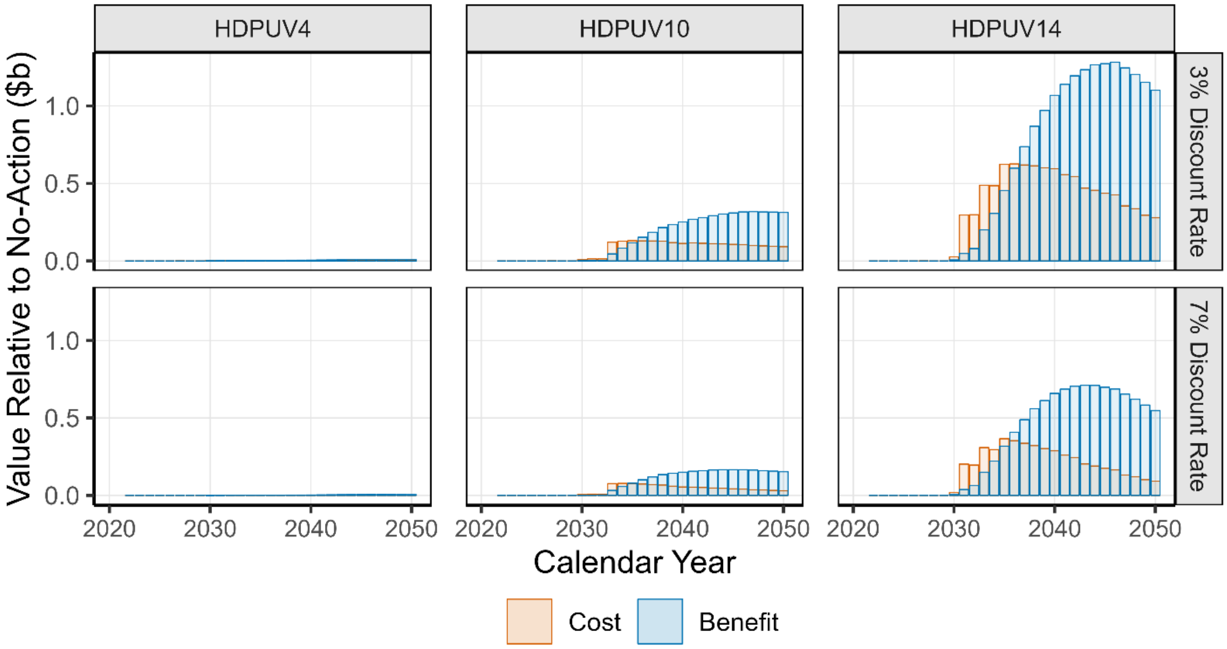
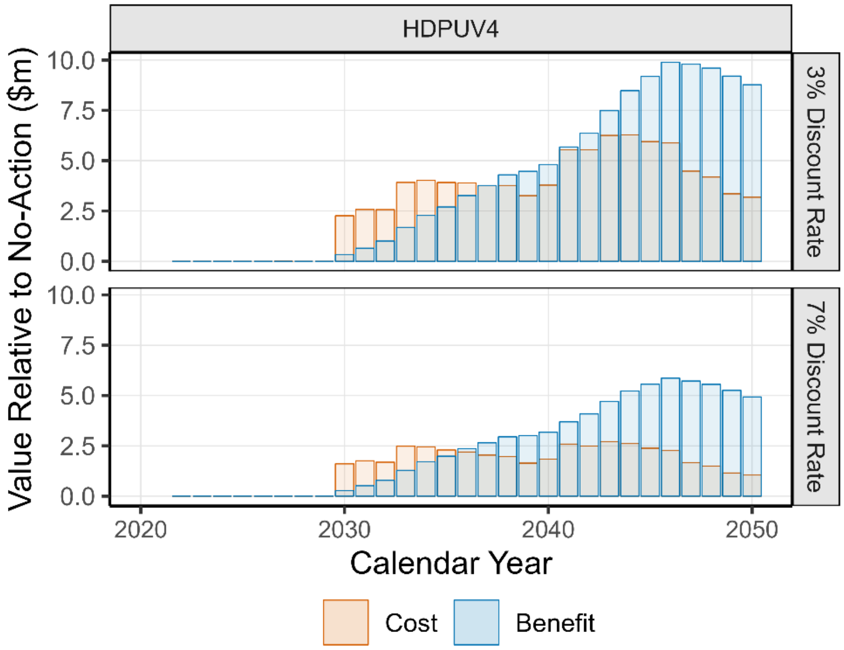


Figure 8-79: Annual Costs and Benefits on a CY Basis, Alternative HDPUV4



Unlike CAFE standards for the light-duty fleet, HDPUV FE standards continue in perpetuity until they are amended. Since the HDPUV FE standards remain in place, we only analyze the effects of the HDPUV standards on a CY basis.[194] Figure 8-80 aggregates annual cost and benefit streams to produce cumulative net benefits, by CY, for the three modeled alternatives. Cumulative net benefits remain low in all years under Alternative. Cumulative net benefits become positive under Alternatives HDPUV10 and HDPUV14 in CY 2038 and CY 2040 respectively using the 3 percent DR. Under the 7 percent DR, cumulative net benefits under these alternatives become positive earlier in 2039 under Alternative HDPUV14.

The depth of the decline in cumulative net benefits in the mid-2030s is greater for Alternative HDPUV14 than either of the other action alternatives, and the cumulative net benefits also grow at a faster rate once they turn positive. Under Alternative HDPUV10, the cumulative net benefits do not decline dramatically at any point, but consistently rise through CY 2050, although not to the same magnitudes as the Alternative HDPUV14 values (over $2 billion compared to approximately $8 billion). The relative rate of this deviation beyond the years in which the proposed standards increase is even more prominent in the HDPUV fleet than under the proposed CAFE standards in the LD fleet. This is the result of numerous factors, including cost assumptions, vehicle sales and use modeling, and constraints on the regulatory analysis.

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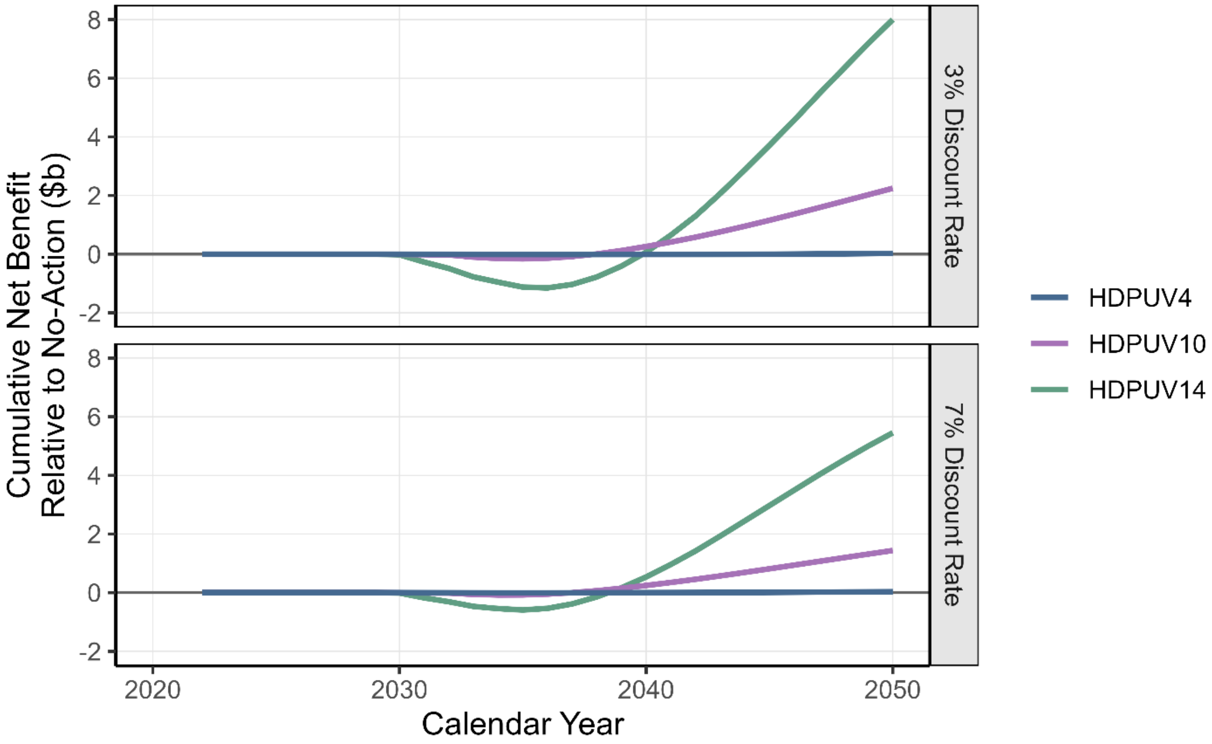
[194] For more discussion on the decision to only display effects by calendar year and the differences between calendar year and model year accounting, see Chapter 5.4 of this PRIA.

Figure 8-80: Cumulative Net Benefits, CY 2022-2050



8.3.4.1. Social Benefits of Reducing GHG Emissions

Table 8-20 lists the total costs of GHG emissions by alternative, for CYs 2022-2050, based on the four different SC-GHG DRs. All values in Table 8-20 are in absolute terms, monetizing the incurred costs of emissions in billions of dollars. SC-GHG decrease for all GHGs as stringency increases across the alternatives.[195]

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[195] Climate benefits are based on changes (reductions) in CO_2, CH_4, and N_2O emissions and are calculated using four different estimates of the SCC, SC-CH_4, and SC-N_2O (model average at 2.5 percent, 3 percent, and 5 percent discount rates; 95th percentile at 3 percent discount rate). We emphasize the importance and value of considering the benefits calculated using all four estimates. For simplicity, most tables throughout this analysis pair the 3 percent and 7 percent social discount rates of non-GHG related effects with a 3 percent discount rate for the SCs of GHGs.

Table 8-20: Total Social Costs of GHG Emissions Across Alternatives (2021$, in billions)

	No Action	HDPUV4	HDPUV10	HDPUV14
5% SC-GHG discount rate				
CO_2	53.9	53.9	53.7	53.0
CH_4	3.7	3.7	3.7	3.7
N_2O	0.8	0.8	0.8	0.8
3% SC-GHG discount rate				
CO_2	212.8	212.7	211.8	208.5
CH_4	9.8	9.8	9.8	9.6
N_2O	2.9	2.9	2.8	2.8
2.5% SC-GHG discount rate				
CO_2	325.0	325.0	323.6	318.5
CH_4	13.3	13.3	13.2	13.1
N_2O	4.4	4.4	4.3	4.2
95th percentile at 3% SC-GHG discount rate				
CO_2	646.6	646.4	643.7	633.6
CH_4	26.0	26.0	25.9	25.6
N_2O	7.6	7.6	7.6	7.4

Figure 8-81 and Figure 8-82 show how the SCs of the three GHGs change over time from the CY perspective (2022-2050) in the baseline. Regardless of the SC-GHG DR applied, the costs decrease significantly from over $10 billion in 2022 to approximately $5 billion in 2050. Although CH_4 and N_2O have substantially higher SCs per ton compared to CO_2, the quantity of CO_2 emissions is much higher (see Chapter 8.3.5.2), accounting for the large difference between the three total SC amounts. Comparing the two figures shows the extent to which DRs matter for these emissions costs; using the highest SC estimate (95th percentile values discounted at 3 percent), damage costs due to GHG emissions peak at over 30 billion dollars per year and then decline from there. In contrast, the lowest estimates (discounted at 5 percent) amount to approximately 3 billion dollars per year at their highest point, and then decline in future years. These decreases over time and the relative proportions of the different GHG costs occur in each of the action alternatives as well.

Figure 8-81: Social Costs of GHGs (CO_2, CH_4, and N_2O combined) in the No-Action Alternative Across CYs (2022-2050), Discounted at 3% and 5%

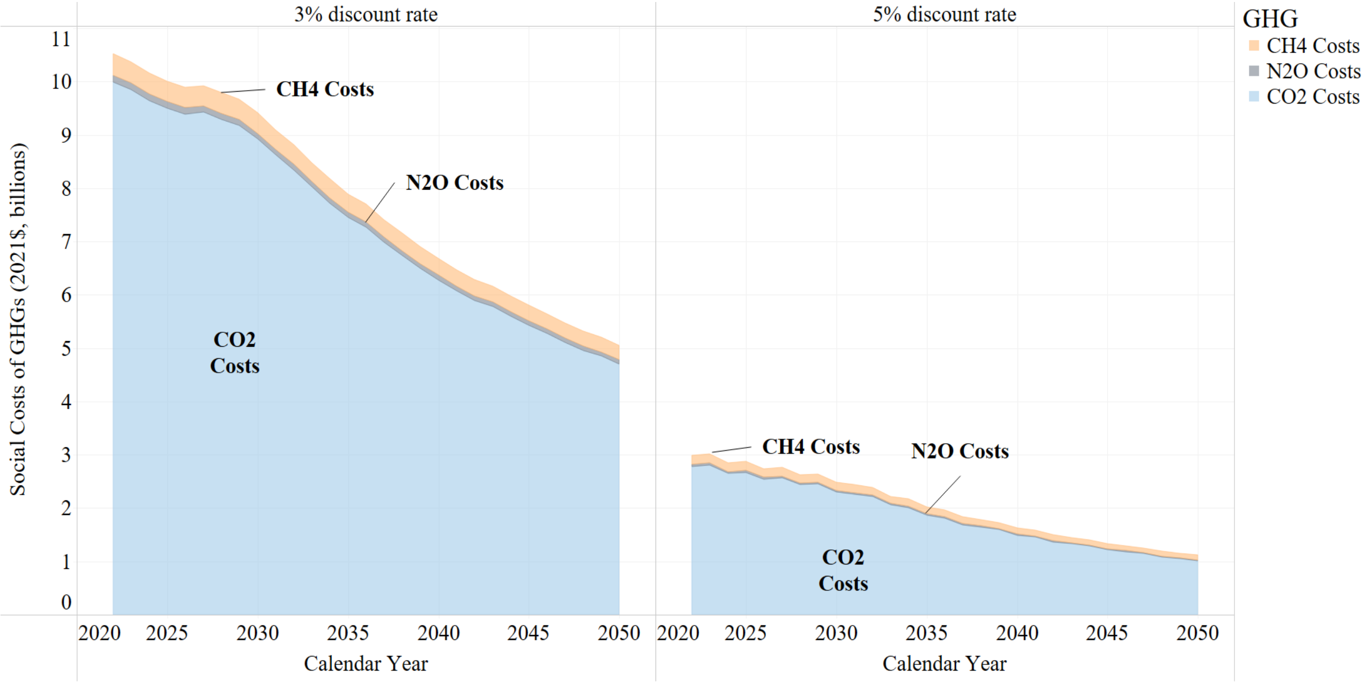
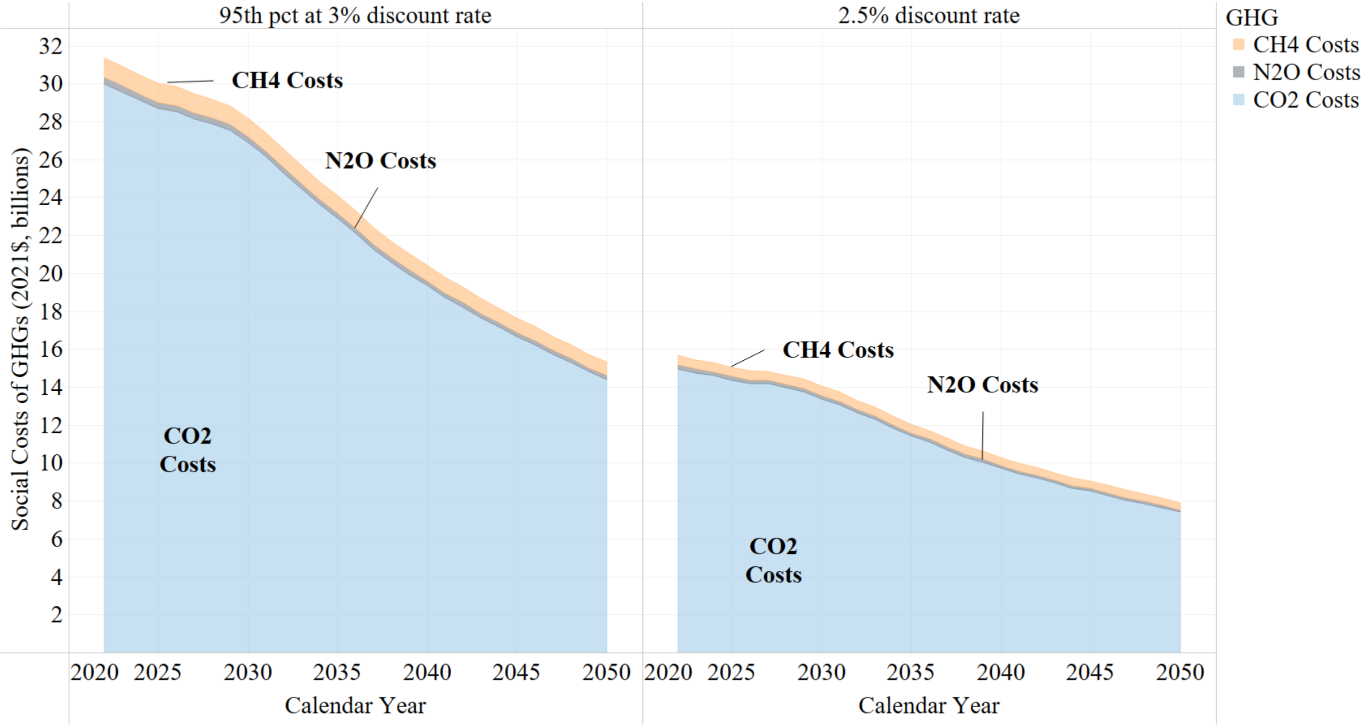


Figure 8-82: Social Costs of GHGs (CO_2, CH_4, and N_2O combined) in the No-Action Alternative Across CYs (2022-2050), Discounted at 2.5% and the 95th Pct values at 3%



Relative to the No-Action Alterative, the action alternatives produce social benefits through the reduction of GHG costs (corresponding to the reduction of tons of GHGs emitted, described in Chapter 8.3.5.2). Figure 8-83 and Figure 8-84 represent the benefits of reduced GHG costs across alternatives, split by SC-GHG DR. The more stringent the HDPUV alternative, the larger the increases in GHG cost reductions. The figures split the benefits by seven-year time span groupings to highlight the differences in magnitude of short-term vs longer-term benefits.

Figure 8-83: GHG Benefits Across Alternatives (Relative to the No-Action Alternative), by Selected CY Cohorts (2021$, in billions), discounted at 3% and 5%

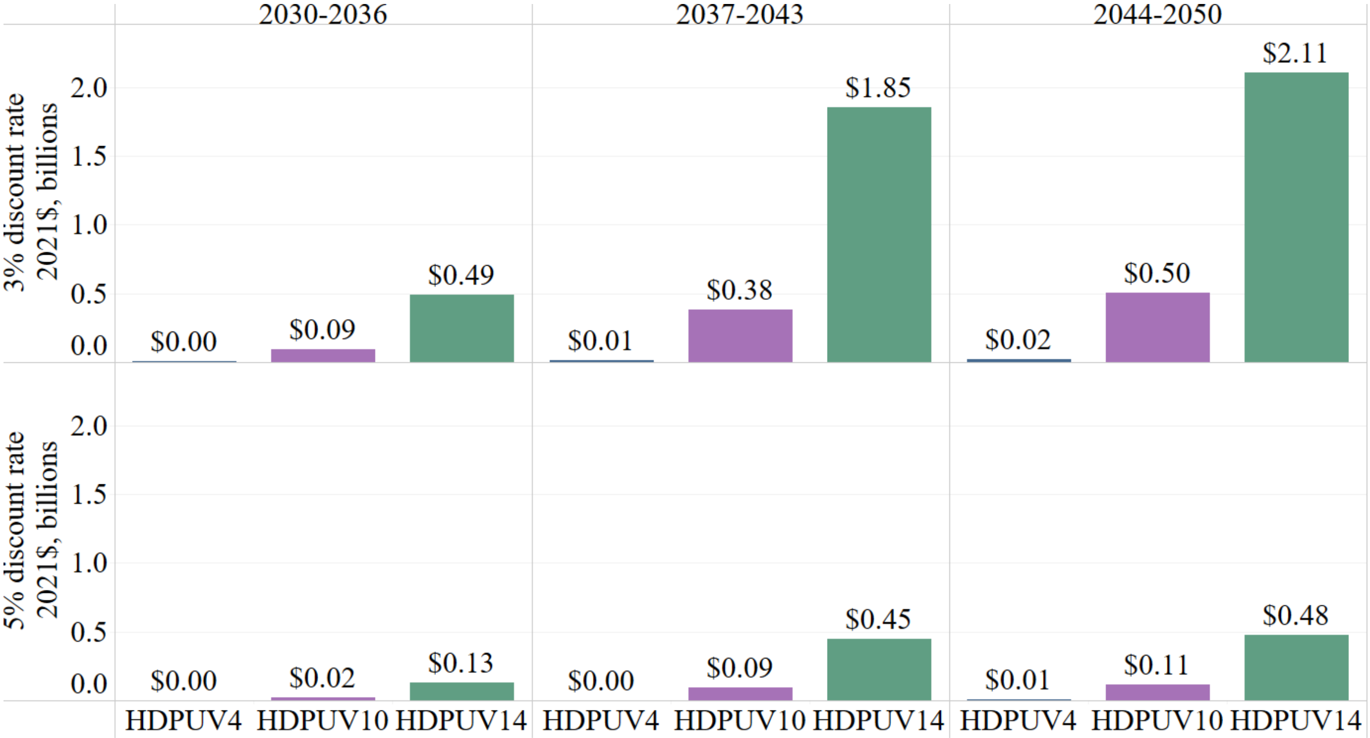
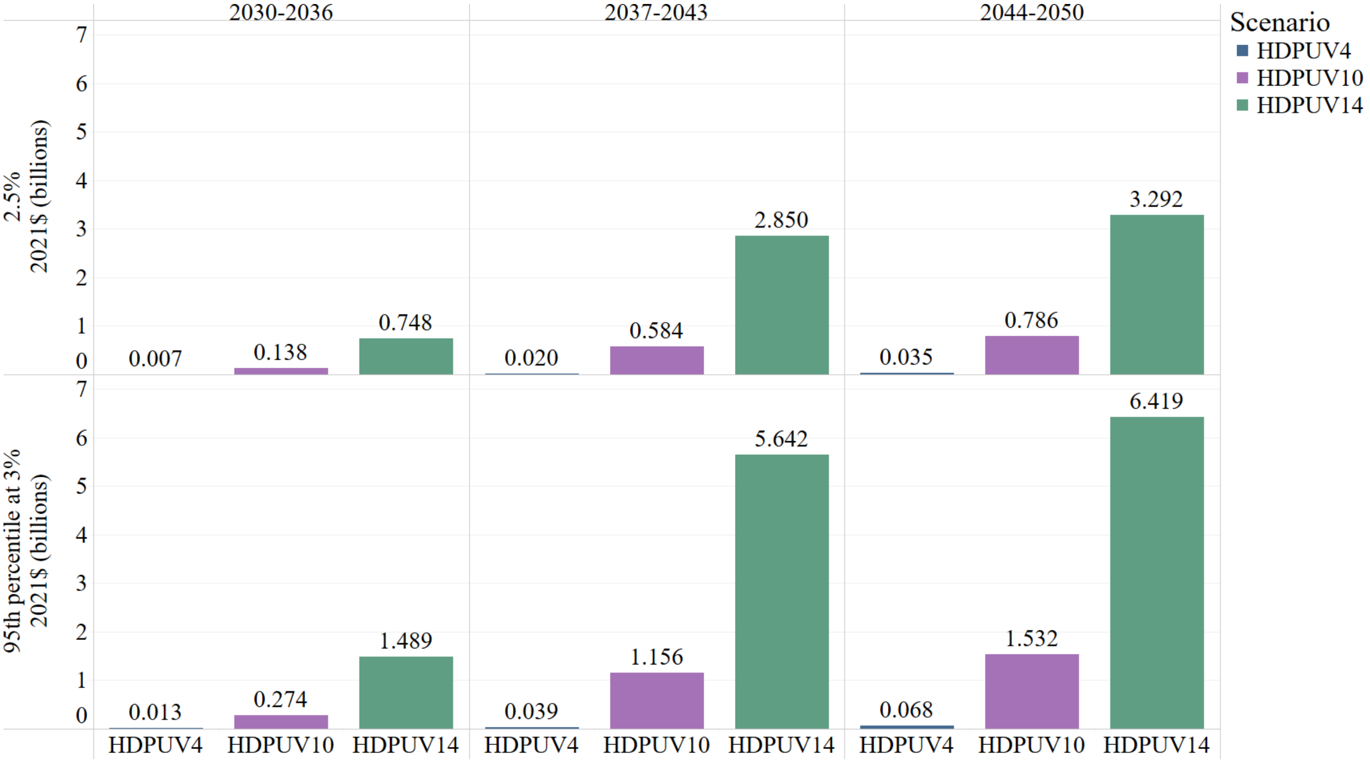


Figure 8-84: GHG Benefits Across Alternatives (Relative to the No-Action Alternative), by Selected CY Cohorts (2021$, in billions), discounted at 2.5% and the 95th percentile values discounted at 3%



8.3.4.2. Social Benefits of Reducing Criteria Pollutant Emissions

The criteria pollutant emissions computed by the CAFE Model—NO_X, SO_X, $PM_{2.5}$—are linked to various health impacts (see Draft TSD Chapter 5.4).[196] The model contains per-ton monetized health impact values corresponding to these health impacts (see Draft TSD Chapter 6.2.2). The CAFE Model calculates the total criteria pollutant emissions associated with the fleet in different alternatives, based on the emissions inventory discussed in Draft TSD Chapter 5, and the monetized health impact values per ton are then multiplied by the total tons in the emissions inventory.[197] The resulting total costs associated with criteria pollutant emissions can be found in the CAFE Model outputs. For further information pertaining to these criteria pollutant emissions, see also Chapter 4 in the Draft EIS.

Table 8-21 shows the SCs of criteria pollutants in the baseline and three alternatives from the CY perspective, by social DR. Increases in NOx across alternatives stem from the higher level of NOx upstream emissions relative to downstream emissions. With higher levels of electricity usage in the more stringent HDPUV alternatives come increased upstream emissions. In the case of NOx and SO_2, the decreases in downstream emissions due to higher fuel efficiency are not large enough to offset the increases in upstream emissions from electricity. However, in the case of PM2.5, the impact of decreases in PM due to downstream emissions is greater than the increase in electricity upstream emissions. See Chapter 8.3.5.3 for details on the split between downstream and upstream emissions in each CY.

Table 8-21: Social Costs of Criteria Pollutants Across Alternatives (CYs 2022-2050, 3% SC-GHG DR, 2021$, in billions)

	No Action	HDPUV4	HDPUV10	HDPUV14
3% Discount Rate				
NO_X	19.39	19.40	19.41	19.45
SO_X	14.69	14.70	14.77	15.02
$PM_{2.5}$	70.12	70.11	69.98	69.51
7% Discount Rate				
NO_X	13.44	13.44	13.45	13.47
SO_X	7.64	7.64	7.67	7.78
$PM_{2.5}$	45.50	45.50	45.45	45.26

Overall, the decreases in $PM_{2.5}$ costs are greater than the increases in NOx and SO2 costs due to both the significantly higher scale of tons involved and the higher costs per ton associated with PM2.5. This point is further shown in Figure 8-85 which presents combined criteria pollutant benefits split across seven-year CY groupings. In the first panel, from CYs 2030-2036, benefits are negative since the decreases in downstream emissions relative to the baseline are lower than the increases in upstream emissions relative to the baseline. The majority of the benefits occur in later CYs.

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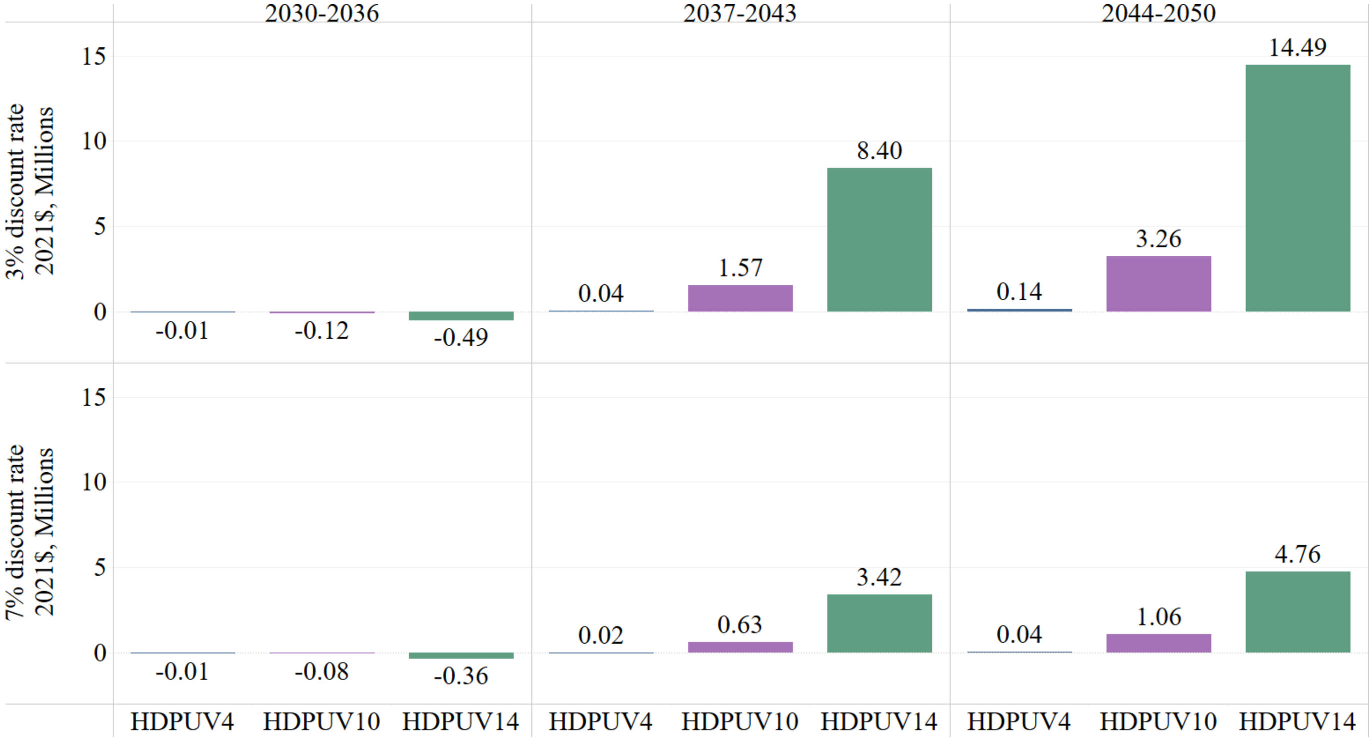
[196] The morbidity health impacts included in the per-ton monetized values are: acute bronchitis, asthma exacerbation, cardiovascular hospital admissions, lower respiratory symptoms, minor restricted activity days, non-fatal heart attacks, respiratory emergency room visits, respiratory hospital admissions, upper respiratory symptoms, and work loss days.

[197] At the time of NHTSA's analysis, the latest upstream emission factors (EFs) available were from GREET 2022, which are based on AEO 2022 forecasts of the electricity generation mix. We understand AEO 2023 forecasts assume faster rates of grid decarbonization than previous releases and include some recent IRA and BIL provisions that are expected to impact emissions results associated with future CAFE standards, in particular including provisions that would reduce SO2 emissions from upstream sources. For these reasons, we anticipate updating our upstream analyses with projections from GREET 2023 and AEO 2023 or other relevant forecasts as the final rule schedule permits.

Figure 8-85: Criteria Pollutant Benefits Across Alternatives Relative to Baseline, by Selected CY Cohorts (2021$, in millions)



8.3.4.3. Social Costs of Changes to Congestion and Road Noise

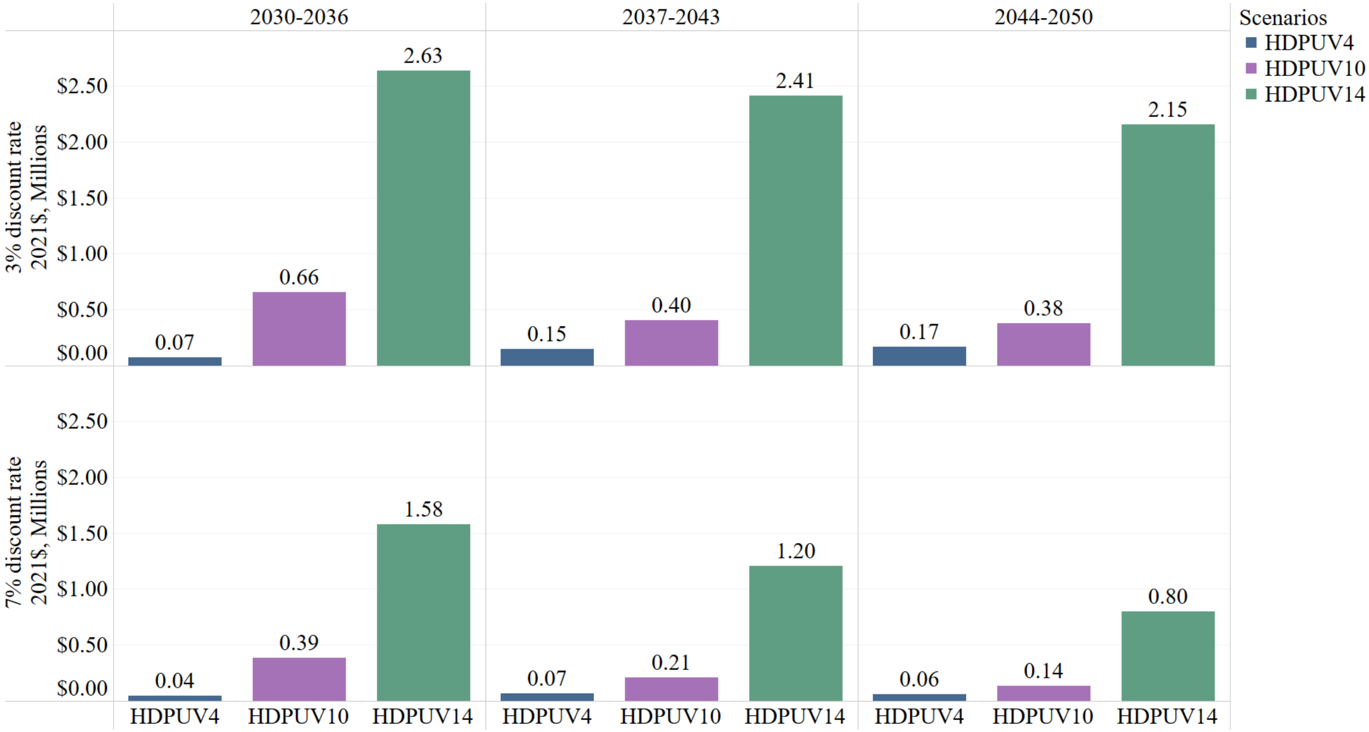
Table 8-22 reports the incremental SCs of congestion and noise for the action alternatives alongside the aggregate SCs for these categories in the No-Action alternative. Congestion cost and noise costs are both functions of VMT, and the increases in these costs therefore parallel increases in VMT (see Chapter 8.3.5.1). For information regarding the calculation of congestion and noise costs in the CAFE Model, and how these relate to VMT and other inputs, see Chapter 6.2.3 in the accompanying Draft TSD. Costs of both noise and congestion increase consistently as the alternatives become more stringent.

Table 8-22: Social Costs of Congestion and Noise across Alternatives for CYs 2022-2050 (2021$, in millions)

	3% Discount Rate				7% Discount Rate			
	No Action	Relative to No Action			No Action	Relative to No Action		
		HDPUV4	HDPUV10	HDPUV14		HDPUV4	HDPUV10	HDPUV14
Congestion	488,648	3.82	14.29	71.30	302,543	1.76	7.29	35.46
Noise	4,891	0.04	0.14	0.71	3,028	0.02	0.07	0.36

Figure 8-86 presents the noise and congestion costs combined across CYs, split into seven-year time spans. The cost increases relative to the baseline are greater in the earlier CYs, but the relative changes between the time intervals are not very pronounced. Noise and congestion costs increases relative to the baseline have a significantly greater magnitude under Alternative HDPUV14 compared to the other two action alternatives.

Figure 8-86: Congestion and Noise Incremental Costs Across Alternatives, by Selected CY Cohorts (2021$, in millions)



8.3.4.4. Benefits of Increased Energy Security

The CAFE Model accounts for benefits of increased energy security by computing changes in SCs of petroleum market externalities. These SCs represent the risk to the U.S. economy incurred by exposure to price shocks in the global petroleum market that are not accounted for oil prices and area direct function of gallons of fuel consumed. Chapter 6.2.4 in the accompanying Draft TSD describes the inputs involved in calculating these petroleum market externality costs.

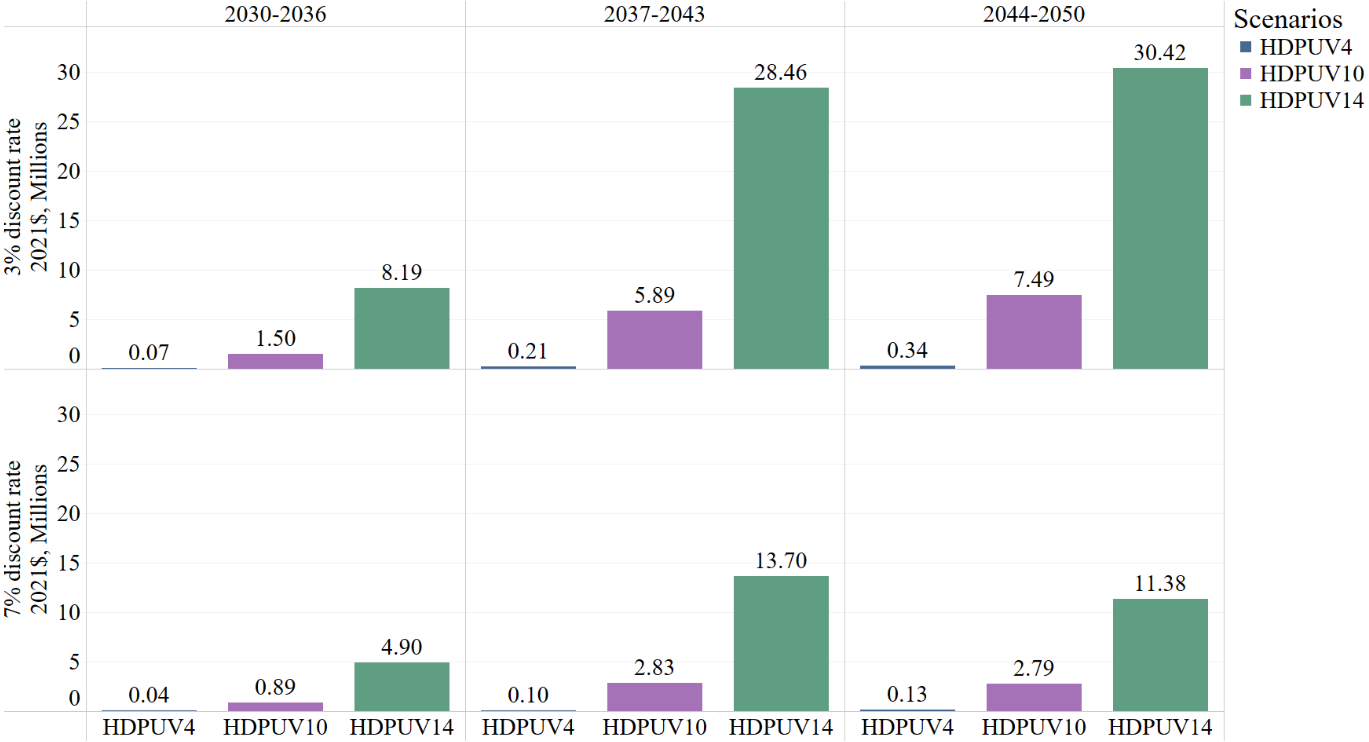
Table 8-23 presents the sum of total energy security costs in all model years of the analysis (1983-2038), across alternatives. These costs decrease slightly as the alternatives become more stringent, with the largest increase occurring under Alternative HDPUV14.

Table 8-23: Total Energy Security Costs Across Alternatives, CYs 2022-2050 (2021$, billions)

	No Action	HDPUV4	HDPUV10	HDPUV14
3% discount rate	25.26	25.25	25.11	24.59
7% discount rate	16.67	16.66	16.60	16.37

Figure 8-87 focuses on the decreases between the alternatives, presenting the changes in costs as incremental benefits relative to the baseline. The figure splits the benefits across seven-year time spans to highlight when the largest share of benefits are accrued, in this case the last CYs of the analysis period. The benefits with the highest magnitude occur in Alternative HDPUV14.

Figure 8-87: Energy Security Benefits Across Alternatives, by Selected CY Cohorts (2021$, in millions)



8.3.4.5. Safety Effects (Economic) of Changing Standards

Table 8-24 through Table 8-26 summarize the safety impacts of each alternative broken down by safety factor for HDPUVs. These impacts are summed over the lifetimes of vehicles from CYs 2022-2050. Fatality, non-fatal injury, and PDO counts are undiscounted. The safety differences between alternatives relative to the baseline scenario are small in absolute magnitudes.

As noted previously, safety impacts are driven by changes in vehicle mass (vehicles are made lighter to improve fuel efficiency), by added exposure from rebound miles driven in response to reduced driving costs that result from improved fuel efficiency, and by changes in fleet composition resulting from the impact of higher prices on new and used vehicle sales. There is no change in HDPUV mass across alternatives since much of the HDPUV fleet electrifies due to the Inflation Reduction Act prior to rule setting years. Many vehicles in this class as a result are in compliance with new standards even before they take effect. Increasing the stringency of fuel economy standards does result in additional VMT for HDPUVs. This creates the positive rebound effects found in Table 8-27.

Generally, we would expect the stricter alternative requirements to have increasing safety impacts. Changes to improve levels of fuel efficiency reduce driving costs and produce more rebound driving. Higher prices resulting from higher CAFE requirements slow fleet turnover. These composition changes reflect fewer new vehicles being purchased, older vehicles being retained longer and used more frequently, and a shift towards larger vehicles become more cost-efficient to operate. The turnover of the HDPUV fleet almost completely offsets the increased fatalities, injuries, and PDO from increased VMT. This result is caused by the increased prevalence of ADAS on HDPUVs. Again, since much of the HDPUV fleet comes into compliance with standards set in MY 2030 and 2035 due to the IRA, only the most stringent of standards affect sales and vehicle turnover in the fleet.

Since mass reduction is applied in the No-Action Alternative, and no further mass reduction is applied in the action alternatives, the mass effect is zero. The total fatal crash, total non-fatal crash, and total property damage crash values are at most in the tens of millions.[198] The total social crash costs of these alternatives relative to the baseline range from are less than $100 million U.S. dollars (USD). Differences in fatalities

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[198] Many values presented in the tables are rounded down to zero due to their small magnitude.

across alternatives appear near or at zero, and the differences in non-fatal injuries and property damage across alternatives are also small in magnitude.

Table 8-24: Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 for HDPUV Fleet, 3% Percent DR, by Alternative

Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 for HDPUV Fleet, 3% Percent DR, by Alternative			
Alternative	**HDPUV4**	**HDPUV10**	**HDPUV14**
Fatality Costs ($b)			
Fatality Costs From Mass Changes	0	0	0
Fatality Costs From Rebound Effect	0	0	0.2
Fatality Costs from Sales/Scrappage	0	0	-0.2
Total - Fatality Costs	0	0	0
Non-Fatal Crash Costs ($b)			
Non-Fatal Crash Costs From Mass Changes	0	0	0
Non-Fatal Crash Costs From Rebound Effect	0	0.1	0.4
Non-Fatal Crash Costs from Sales/Scrappage	0	-0.1	-0.3
Total - Non-Fatal Crash Costs	0	0	0.1
Property Damage Costs ($b)			
Property Damage Costs From Mass Changes	0	0	0
Property Damage Costs From Rebound Effect	0	0	0.1
Property Damage Costs From Sales/Scrappage	0	0	-0.1
Total - Property Damage Costs	0	0	0
Societal Crash Costs ($b)			
Crash Costs from Mass Changes	0	0	0
Crash Costs from Rebound Effect	0	0.1	0.7
Crash Costs from Sales/Scrappage	0	-0.1	-0.6
Total - Societal Crash Costs	0	0	0.1

Table 8-25: Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 for HDPUV Fleet, 7% Percent DR, by Alternative

Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 for HDPUV Fleet, 7% Percent DR, by Alternative			
Alternative	**HDPUV4**	**HDPUV10**	**HDPUV14**
Fatality Costs ($b)			
Fatality Costs From Mass Changes	0	0	0
Fatality Costs From Rebound Effect	0	0	0.1
Fatality Costs from Sales/Scrappage	0	0	-0.1
Total - Fatality Costs	0	0	0

Non-Fatal Crash Costs ($b)			
Non-Fatal Crash Costs From Mass Changes	0	0	0
Non-Fatal Crash Costs From Rebound Effect	0	0	0.2
Non-Fatal Crash Costs from Sales/Scrappage	0	0	-0.1
Total - Non-Fatal Crash Costs	0	0	0
Property Damage Costs ($b)			
Property Damage Costs From Mass Changes	0	0	0
Property Damage Costs From Rebound Effect	0	0	0
Property Damage Costs From Sales/Scrappage	0	0	0
Total - Property Damage Costs	0	0	0
Societal Crash Costs ($b)			
Crash Costs from Mass Changes	0	0	0
Crash Costs from Rebound Effect	0	0.1	0.3
Crash Costs from Sales/Scrappage	0	0	-0.2
Total - Societal Crash Costs	0	0	0.1

Table 8-26: Change in Change in Fatalities, Non-Fatal Injuries, and PDO from Alternative 0 (Baseline) for CY 2022-2050 for HDPUV Fleet, by Alternative

Change in Safety Parameters from Alternative 0 (Baseline) for CY 2022-2050 by Alternative			
Alternative	**HDPUV4**	**HDPUV10**	**HDPUV14**
Fatalities			
Fatalities From Mass Changes	0	0	0
Fatalities from Rebound Effect	0	6	33
Fatalities from Sales/Scrappage	0	-5	-27
Total Changes in Fatalities	0	1	6
Non-Fatal Crashes			
Non-Fatal Crash From Mass Changes	0	0	0
Non-Fatal Crash From Rebound Effect	42	1033	5360
Non-Fatal Crash from Sales/Scrappage	10	-878	-4493
Total - Non-Fatal Crash	52	155	867
Property Damaged Vehicles			
Property Damage Vehicles From Mass Changes	0	0	0
Property Damage Vehicles From Rebound Effect	147	3609	18609
Property Damage Vehicles From Sales/Scrappage	28	-3155	-15845
Total - Property Damage Vehicles	175	454	2764

8.3.4.6. Summary of Social Benefits and Costs

Table 8-27 describes the costs and benefits of increasing HDPUV FE standards in each alternative, as well as the party to which they accrue. Manufacturers are directly regulated under the program and incur additional production costs when they apply technology to their vehicle offerings in order to improve their fuel efficiency. We assume that those costs are fully passed through to HDPUV buyers, in the form of higher prices.

While incremental maintenance and repair costs would accrue to buyers of new cars and trucks affected by more stringent HDPUV FE standards, we do not carry these costs in the analysis. They are difficult to estimate for emerging technologies but represent real costs (and benefits in the case of alternative fuel vehicles (AFVs) that may require less frequent maintenance events). They may be included in future analyses as data become available to evaluate lifetime maintenance costs. This analysis assumes that drivers of new vehicles internalize 90 percent of the risk associated with increased exposure to crashes when they engage in additional travel (as a consequence of the rebound effect).

Private benefits are dominated by the value of fuel savings, which accrue to new HDPUV buyers at retail FPs (inclusive of federal and state taxes). In addition to saving money on fuel purchases, new vehicle buyers also benefit from the increased mobility that results from a lower cost of driving their vehicle (higher fuel economy reduces the per-mile cost of travel) and fewer refueling events. The additional travel occurs as drivers take advantage of lower operating costs to increase mobility, and this generates benefits to those drivers – equivalent to the cost of operating their vehicles to travel those miles, the consumer surplus, and the offsetting benefit that represents 90 percent of the additional safety risk from travel. In its sensitivity analysis, NHTSA explored including an offset for the net private benefits attributed to commercial operators within the HDPUV fleet. This Commercial Operator Implicit Opportunity Cost is not included in our central analysis.

In addition to private benefits and costs—those borne by manufacturers, buyers, and owners of HDPUVs—there are other benefits and costs from increasing HDPUV FE standards that are borne more broadly throughout the economy or society, which the agency refers to as SCs.[199] Of these SCs, the largest is the loss in fuel tax revenue that occurs as a result of falling fuel consumption.[200] Buyers of new HDPUVs produced in model years subject to increasing HDPUV FE standards save on fuel purchases that include federal, state, and sometimes local or tribal taxes, so revenues from these taxes decline; because that revenue funds maintenance of roads and bridges as well as other government activities, the loss in fuel tax revenue represents a SC.[201] The additional driving that occurs as new vehicle buyers take advantage of lower per-mile fuel costs is a benefit to those drivers, but the congestion (and road noise) created by the additional travel also imposes a small additional SC to all road users.

Among the purely external benefits created when HDPUV FE standards are increased, the largest is the reduction in damages resulting from GHG emissions. Table 8-27 shows the different SC results that correspond to each GHG DR. The associated benefits related to reduced health damages from criteria pollutants and the benefit of improved energy security are both significantly smaller than the associated change in GHG damages across alternatives.

The choice of GHG DR also affects the resulting benefits and costs. As the tables show, net social benefits are positive for all alternatives, and are greatest when SC-GHG DRs of 2.5 or 3 percent are used. Totals in the following table may not sum perfectly due to rounding.

Table 8-27: Incremental Benefits and Costs from CYs 2022-2050 (2021$ Billions), by Alternative

	3% Discount Rate			7% Discount Rate		
Alternative	**HDPUV4**	**HDPUV10**	**HDPUV14**	**HDPUV4**	**HDPUV10**	**HDPUV14**
Private Costs						

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[199] Some of these external benefits and costs result from changes in economic and environmental externalities from supplying or consuming fuel, while others do not involve changes in such externalities but are similar in that they are borne by parties other than those whose actions impose them.
[200] Changes in tax revenues are a transfer and not an economic externality as traditionally defined, but we group these with SCs instead of private costs since that loss in revenue affects society as a whole as opposed to impacting only consumers or manufacturers.
[201] It may subsequently be replaced by another source of revenue, but that is beyond the scope of this rulemaking to examine.

	3% Discount Rate			**7% Discount Rate**		
Alternative	**HDPUV4**	**HDPUV10**	**HDPUV14**	**HDPUV4**	**HDPUV10**	**HDPUV14**
Technology Costs to Increase Fuel Economy	0.05	1.28	5.81	0.02	0.64	3.02
Increased Maintenance and Repair Costs	0.00	0.00	0.00	0.00	0.00	0.00
Sacrifice in Other Vehicle Attributes	0.00	0.00	0.00	0.00	0.00	0.00
Consumer Surplus Loss from Reduced New Vehicle Sales	0.00	0.00	0.00	0.00	0.00	0.00
Safety Costs Internalized by Drivers	0.00	0.12	0.64	0.00	0.05	0.28
Subtotal - Private Costs	0.05	1.41	6.45	0.03	0.69	3.30
Social Costs						
Congestion and Noise Costs from Rebound-Effect Driving	0.00	0.01	0.07	0.00	0.01	0.04
Safety Costs Not Internalized by Drivers	0.00	-0.10	-0.50	0.00	-0.04	-0.21
Loss in Fuel Tax Revenue	0.03	0.75	3.41	0.01	0.33	1.54
Subtotal - Social Costs	0.04	0.67	2.98	0.02	0.30	1.37
Total Social Costs	0.09	2.07	9.43	0.04	0.99	4.67
Private Benefits						
Reduced Fuel Costs	0.12	2.98	13.79	0.05	1.30	6.15
Benefits from Additional Driving	0.01	0.26	1.36	0.00	0.11	0.60
Less Frequent Refueling	-0.06	-0.09	-3.06	-0.03	-0.04	-1.45
Subtotal - Private Benefits	0.07	3.15	12.09	0.03	1.38	5.30
External and Governmental Benefits						
Reduction in Petroleum Market Externality	0.01	0.15	0.67	0.00	0.07	0.30
Reduced Health Damages	0.00	0.05	0.22	0.00	0.02	0.08
SC-GHG @ 5% DR[202]	0.01	0.23	1.05	0.01	0.23	1.05
SC-GHG @ 3% DR	0.04	0.97	4.45	0.04	0.97	4.45
SC-GHG @ 2.5% DR	0.06	1.51	6.89	0.06	1.51	6.89
SC-GHG @ 95th pctile at 3% DR	0.12	2.96	13.55	0.12	2.96	13.55
Total Social Benefits						
SC-GHG @ 5% DR	0.08	3.58	14.03	0.04	1.69	6.73
SC-GHG @ 3% DR	0.11	4.32	17.43	0.07	2.43	10.12
SC-GHG @ 2.5% DR	0.14	4.85	19.87	0.09	2.97	12.56
SC-GHG @95th pctile at 3% DR	0.19	6.31	26.53	0.15	4.42	19.23
Net Social Benefits						
SC-GHG @ 5% DR	-0.005	1.50	4.61	-0.001	0.69	2.05
SC-GHG @ 3% DR	0.03	2.25	8.00	0.03	1.44	5.45
SC-GHG @ 2.5% DR	0.05	2.78	10.44	0.05	1.97	7.89

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[202] DR = Discount rate.

	3% Discount Rate			7% Discount Rate		
Alternative	**HDPUV4**	**HDPUV10**	**HDPUV14**	**HDPUV4**	**HDPUV10**	**HDPUV14**
SC-GHG @ 95th pctile at 3% DR	0.11	4.24	17.10	0.11	3.43	14.55

8.3.5. Physical and Environmental Effects

For today's analysis, NHTSA has adapted the 2022 AEO projections for estimating production volumes in future model years for the HDPUV fleet under the No Action Alternative.[203] These projections show a moderate growth in new vehicle sales for MYs 2022 – 2029 (average of 2.8%/year), followed by slower increases thereafter (average of 0.4%/year). When combined with the CAFE Model's fleet turnover (or scrappage rate) estimates, the overall on-road HDPUV fleet is assumed to experience a net annual growth, as new vehicle models are introduced into the population faster than the existing ones are expected to retire.

Additionally, when considering the more stringent standards proposed by the action alternatives, NHTSA assumes that buyers will respond positively to improvements in vehicle's fuel efficiency (by valuing fuel savings resulting from the first 35,000 miles of travel), while also eliciting a negative response to increases in the purchase price of new vehicle models. Hence, as the cost of compliance under the action alternatives is expected to go up with respect to the baseline scenario (the No-Action Alternative), the new vehicle sales are expected to decrease if the resulting fuel savings do not outweigh those added costs. As a result, the on-road population under the action alternatives is expected to decrease with respect to the baseline.

However, as will be presented throughout this chapter, the general lack of substantial differences between most alternatives is the combination of (1) the significant compliance benefit to the HDPUV fleet resulting from application of the PHEV and the BEV technologies; (2) the inclusion of the federal tax incentives for the PHEVs and the BEVs, which offset the added cost of the underlying electrifying technology; (3) the inclusion of the increasing requirements from the ZEV mandate as part of the CAFE Model simulation; and (4) the project cost savings of the P2 SHEV technology over diesel engines. This leads to the baseline scenario, along with all the action alternatives, adopting a similarly high degree of SHEV, PHEV, and BEV technologies throughout the analysis, albeit at a slightly varying cadence.

While the differences between alternatives in today's analysis are minor, the annual impacts seen for each alternative are considerable. This occurs because improving the fuel efficiency of new HDPUV vehicle models sold during future model years is assumed to decrease the overall consumption of various fuel sources, as well as to reduce the emissions of CO_2 (the primary GHG released during vehicle operation). As a consequence of reduced overall fuel consumption, the on-road fleet also generates fewer emissions resulting from criteria air pollutants. This, in turn, leads to a reduction in adverse health incidents caused by exposure to these pollutants.

The following table and figure demonstrate the cumulative impacts over the next three decades for all alternatives. Since the first model year evaluated for today's analysis begins in MY 2022, the first decade in the table and figure cover the range of CYs between CYs 2022 and 2030, while the latter two encompass effects over the full ten-year period. As such, the values shown for the first decade are marginally lower (by comparison) than what they would have been if the entire ten-year horizon was available. Nevertheless, the cumulative impacts are presented in such a way to provide a reader with a snapshot of the overall results of the analysis, while also demonstrating the relative differences between the decades. Meanwhile, the later chapters present this information in a disaggregated manner, by focusing on the effects during the individual CYs.

Table 8-28: Cumulative Impacts for All Alternatives

	No Action	HDPUV4	HDPUV10	HDPUV14
On-Road Fleet (Million Units)				
2022 – 2030	152	152	152	152

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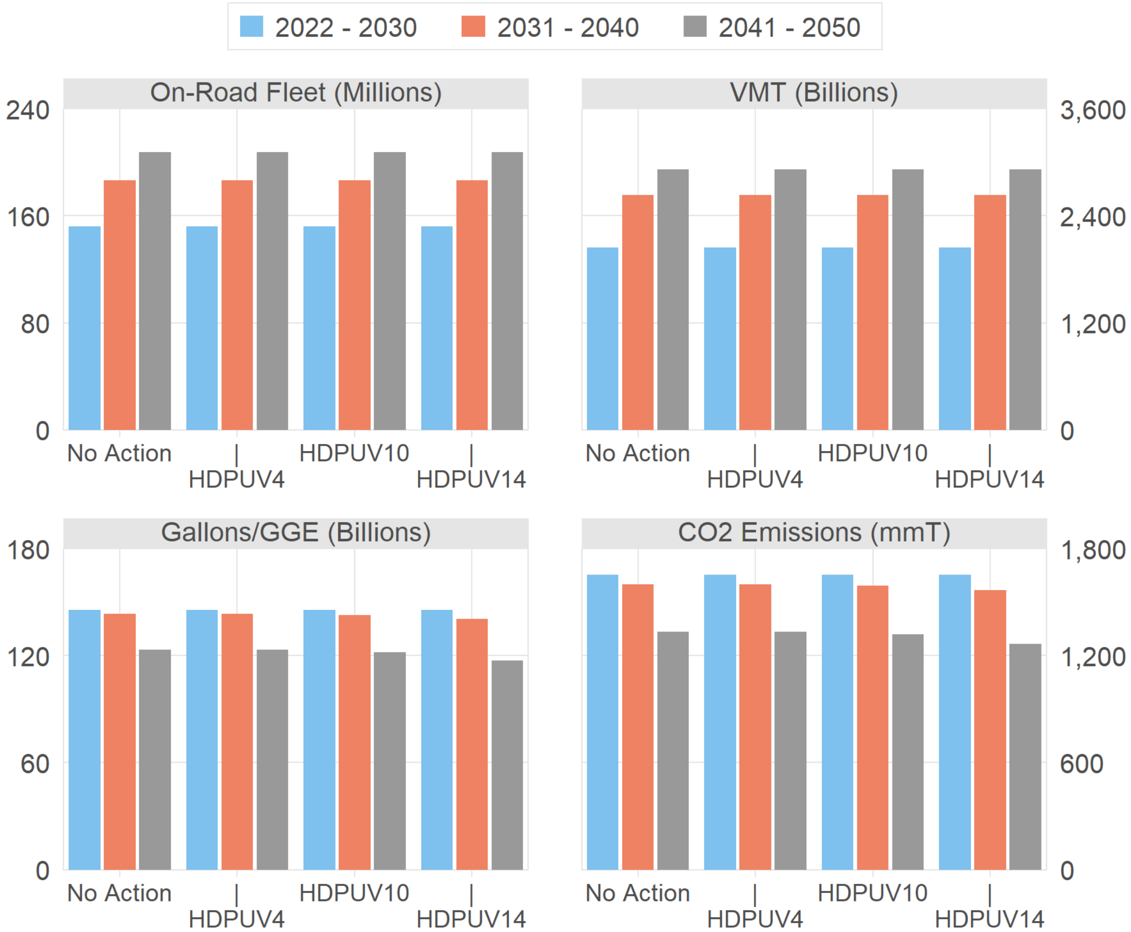
[203] Refer to Draft TSD Chapter 4.2.1.2 for more detail on the way NHTSA has modeled projections to HDPUV sales during the future years under the baseline (No Action) and the action alternatives.

2031 – 2040	187	187	187	187
2041 – 2050	208	208	208	207
Vehicle Miles Traveled (Billion Miles)				
2022 – 2030	2,040	2,040	2,040	2,040
2031 – 2040	2,629	2,629	2,630	2,630
2041 – 2050	2,922	2,922	2,922	2,922
Fuel Consumption (Billion Gallons/GGE)				
2022 – 2030	146	146	146	146
2031 – 2040	143	143	143	141
2041 – 2050	123	123	122	117
CO_2 Emissions (mmT)				
2022 – 2030	1,652	1,652	1,652	1,652
2031 – 2040	1,599	1,598	1,593	1,569
2041 – 2050	1,335	1,335	1,319	1,264

Figure 8-88: Cumulative Impacts for All Alternatives



As Table 8-28 and Figure 8-88 show, the differences between alternatives are mostly minor, with only the most stringent option (HDPUV14) showing marginal differences in the amount of aggregate fuel consumed and CO_2 emitted. As noted above, this lack of differences is the result of the baseline scenario absorbing most of the improvements from the adoption of SHEV, PHEV, and BEV technologies, dampening the magnitude of incremental changes observed in the actional alternatives. Conversely, for the No-Action Alternative and all the action alternatives, there is significant growth in the projected cumulative on-road fleet and VMT between the decades, while at the same time fuel consumption and CO_2 emissions see a noticeable decline during the last decade (covering CY 2041 to 2050). These annual increases to the fleet and VMT occur due to NHTSA's assumption that the new HDPUV vehicle sales will continue to grow moderately through MY 2029 (and gradually afterwards), while the sizable reductions in fuel consumption and CO_2 emissions are the result of the rapidly increasing presence of SHEVs, PHEVs, and BEVs within the fleet.

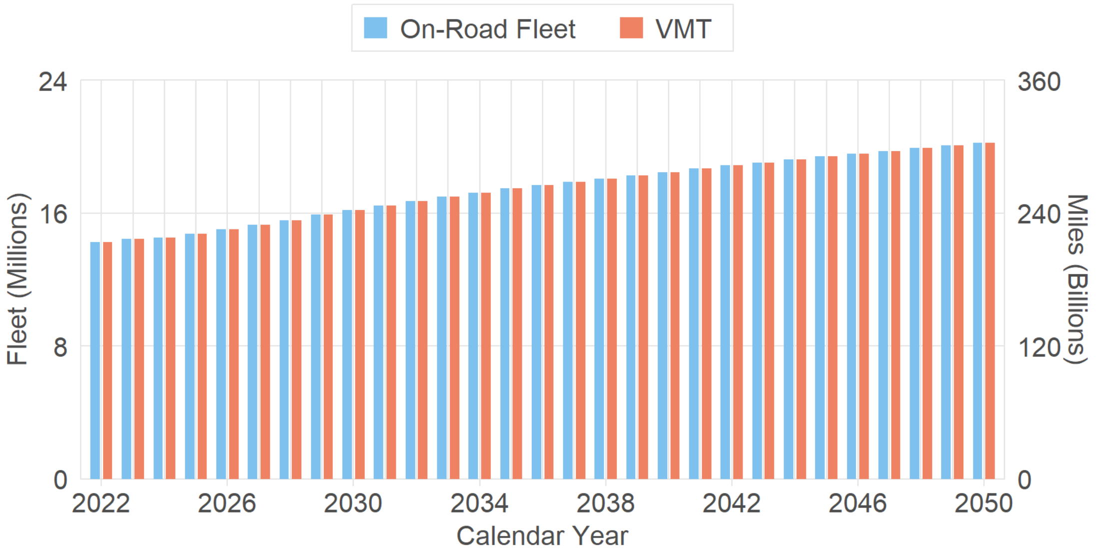
The chapters that follow provide additional detail of the aforementioned effects, while comparing the outcomes of the action and No Action alternatives.

8.3.5.1. Changes to On-Road Fleet and Vehicle Miles Traveled

For today's analysis, the CAFE Model relies on a predetermined forecast of new HDPUV vehicle sales when evaluating the No-Action Alternative. As such, changes to vehicle prices and fuel efficiencies do not produce a direct response in manufacturers' production decisions, when viewed from the perspective of the CAFE Model. Instead, the forecast is formulated with the intent of producing the same *baseline* that is representative of the future outlook of the aggregate HDPUV fleet. When evaluating the action alternatives, however, the CAFE Model simulates a response of the increasing vehicle prices and improvements to fuel efficiency on the sale of new vehicle models as well as the ancillary impacts these changes pose to the existing vehicle fleet. As HDPUV fuel efficiency standards become more stringent, the cost of new vehicles is expected to rise, which would cause a decline in sales if consumers perceived that the present value of fuel savings did not justify the increase in price. In such a case, this would extend to an overall slowing in the annual growth of the on-road fleet. At the same time, introducing more fuel-efficient options into the vehicle population (whether in the No Action or the action alternatives) is assumed to produce a net marginal increase to the total VMT as the cost of travel becomes cheaper.

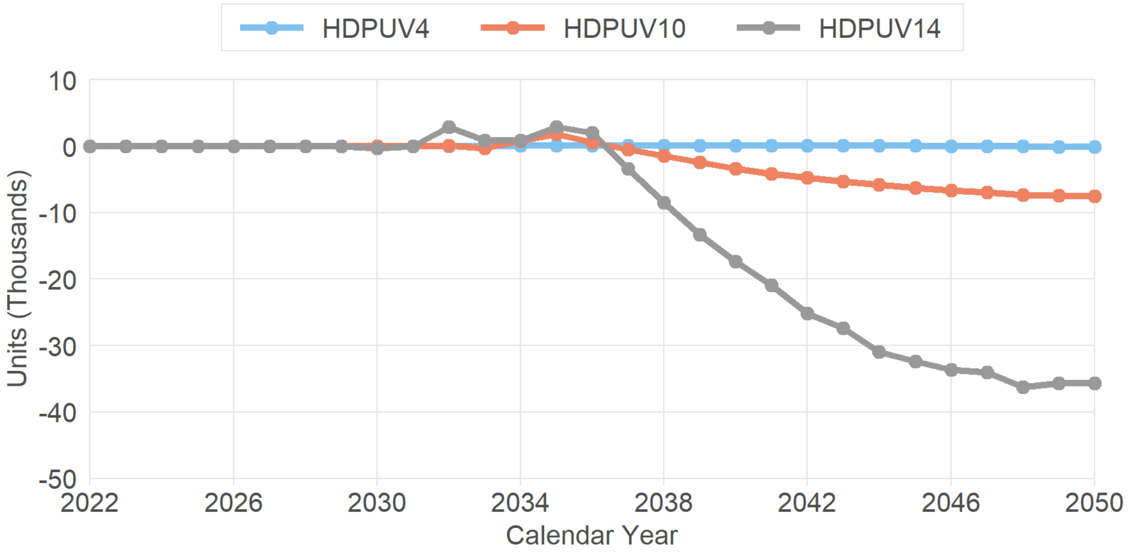
Figure 8-89 presents the size of the on-road HDPUV fleet through 2050, along with the total amount of miles the fleet is expected to travel under the No Action Alternative. The vertical bars with *sky-blue* coloring in the figure denote the annual progression of the fleet (in millions), while the vertical bars with *salmon* coloring correspond to the year over year growth in the associated VMT (in billions). As demonstrated by Figure 8-89, both the on-road fleet and the VMT increase in proportion to one-another, with VMT growth within the HDPUV sector being mostly a reflection of the rapidly increasing on-road population.

Figure 8-89: Total On-Road Fleet and VMT in the Baseline Scenario



With most of the costs and improvements from the fuel saving technologies being absorbed by the No Action Alternative, the increases in stringency from the action alternatives do not generate a significant difference to the number of new vehicles produced and sold during future model years.[204] As a result, the on-road population does not differ significantly, with only the most stringent alternative (HDPUV14) showing minor variances when compared to the baseline scenario. Figure 8-90 shows these incremental differences to the on-road fleet for each action alternative. Note, however, that the differences presented by the figure were magnified for illustrative purposes, where the changes are presented in thousands of units, while the baseline population is measured in millions.[205]

Figure 8-90: Changes in On-Road Fleet Compared to Baseline



Along with the on-road HDPUV fleet that does not differ meaningfully between alternatives, the total miles driven by that fleet does not produce significant differences as well. However, while the total on-road

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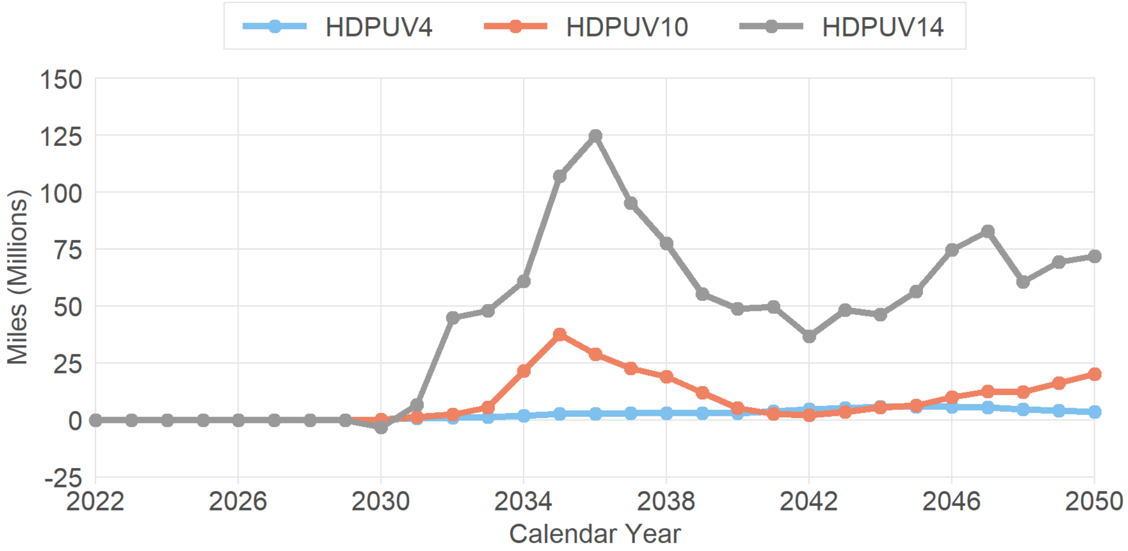
[204] Alternative HDPUV4 shows no meaningful differences in new vehicle sales when compared to the No Action Alternative. Alternative HDPUV10 shows an insignificant change over the baseline, with a maximum decline in sales of 0.07% observed in MY 2034. Alternative HDPUV14 shows the largest difference in sales, though still marginal, having a maximum decrease of 0.32% during MY 2035.

[205] As with the new vehicle sales, Alternative HDPUV4 shows no meaningful differences in the on-road population compared to the baseline. For Alternatives HDPUV10 and HDPUV14, the changes remain insignificant at a maximum decline of 0.03% and 0.17% respectively.

population generally sees a very minor decline under some action alternatives, the amount of total miles traveled increases marginally. Figure 8-91 presents the incremental changes to VMT for each CY, with the differences being magnified substantially for clarity and to depict the general trends of alternatives.[206]

Figure 8-91: Changes in VMT Compared to Baseline



8.3.5.2. Changes to Fuel Consumption and Emissions of GHGs

Improving the efficiency of new vehicle models reduces the total amount of fuel consumed, as more fuel-efficient vehicles enter the market, displacing the older and less efficient models. With the aging fleet gradually turning over with each subsequent CY, the benefits of more efficient vehicles introduced during earlier model years become even more apparent, as the annual fuel consumption of the U.S. HDPUV fleet declines further. Moreover, with the rise of AFVs, specifically PHEVs and BEVs, the presence of conventional gasoline- and diesel-powered ICE vehicles within the HDPUV fleet is gradually supplanted by electricity-powered variants. At the same time, as the utilization of gasoline SHEV options increases, the use of diesel as a fuel source diminishes further. Figure 8-92 presents the consumption of various fuel types in each CY for the No Action Alternative. In Figure 8-92, the consumption of gasoline, E85, and diesel are denominated in gallons of the native fuel (e.g., gallons of E85), while electricity and hydrogen are specified as GGE.

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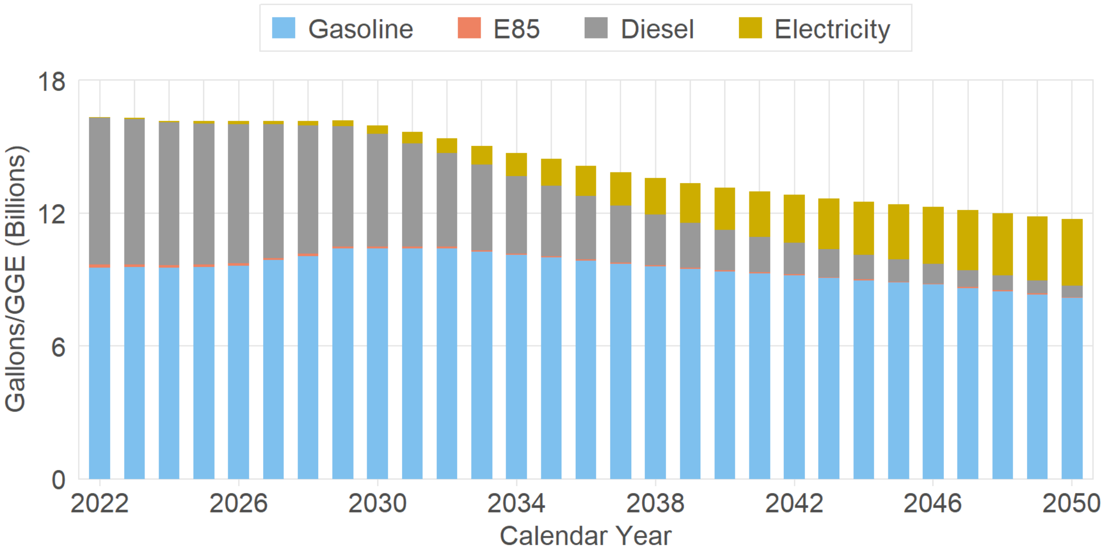
[206] The VMT differences in Figure 8-91 are denominated in millions of miles, while the VMT in the baseline (as shown by Figure 8-92) is measured in billions of miles. As such, the incremental changes seen under the action alternatives are insignificant, with the largest observed difference being 0.05% across all calendar years and alternatives.

Figure 8-92: Fuel Consumption in the Baseline Scenario



As illustrated by Figure 8-92, consumption of gasoline remains mostly steady under the No-Action Alternative, showing only small decreases between CY 2022 and CY 2050. This behavior is generally attributed to the adoption of SHEVs into the fleet during earlier model years, which brings with it the additional demand for gasoline in place of diesel, along with the moderate annual increases to the on-road fleet (as discussed earlier). Therefore, even though the average fuel efficiencies of the gasoline vehicles improve over time, the increased size of the on-road gasoline fleet mostly offsets any benefit from individual models. However, with the fleet gradually converting to SHEVs, PHEVs, and BEVs, the use of diesel greatly diminishes throughout the years. Meanwhile, electricity consumption rapidly increases year over year, culminating in about one quarter of the total amount of fuel consumed (on GGE basis) being attributed to electricity by CY 2050. Lastly, although E85 fuel is still present within the HDPUV fleet, it only makes up an insignificant fraction of the total energy consumed during each CY.[207]

Since consumption of fuel by the fleet directly releases CO_2, reducing overall energy consumption also reduces emissions of CO_2. Equally, emissions attributed to the other GHGs – CH_4 and N_2O – see an annual decline as well. Figure 8-93 displays the amount of annual GHG emissions generated by the HDPUV fleet under the standards defined by the No-Action Alternative. In the figure, the emissions of CO_2, CH_4, and N_2O are combined and presented using a cumulative total. The amount of CO_2 is measured using million metric tons (mmT), while emissions coming from CH_4 and N_2O are scaled by the GWP multipliers of 25 and 298 respectively,[208] and are denominated using mmT of CO_2 equivalent emissions. However, CO_2 remains the predominant contributor of GHGs, making up approximately 86.1 percent of total GHG upstream emissions and 99.2 percent of GHG exhaust emissions.[209] As shown in Figure 8-93, the upstream emissions, which are attributed to the production and distribution of various types of fuel, increase moderately throughout the years in response to the growing on-road population and increasing use of electricity as a fuel source.[210] The downstream emissions, which occur during vehicle operation, see a large declining trend similar to what was observed for the overall annual consumption of fuel.

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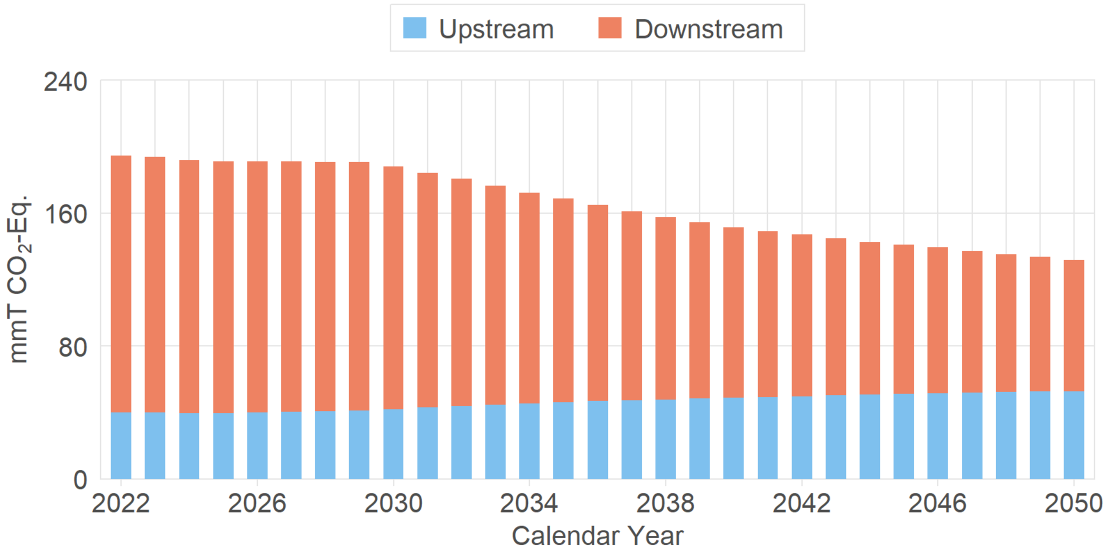
[207] In CY 2022, the total amount of E85 fuel consumed by the on-road fleet is 0.8 percent in the No Action Alternative. By CY 2050, that number declines to 0.3 percent.

[208] GWP multipliers here are derived from the 4th IPCC Report; NHTSA is aware that the 5th IPCC report changes these values slightly, but tentatively concludes that the difference is not meaningful for purposes of Figure 8-93. NHTSA calculates emissions of CH_4 and N_2O directly in terms of tons emitted for benefits purposes.

[209] Depending on calendar year being considered, the CO_2 share of GHG upstream emissions varies by up to 3.1 percent, while the share of downstream emissions varies by about 0.1 percent.

[210] At the time of NHTSA's analysis, the latest upstream emission factors (EFs) available were from GREET 2022, which are based on AEO 2022 forecasts of the electricity generation mix. We understand AEO 2023 forecasts assume faster rates of grid decarbonization than previous releases and include some recent IRA and BIL provisions that are expected to impact emissions results associated with future CAFE standards, in particular including provisions that would reduce SO2 emissions from upstream sources. For these reasons, we anticipate updating our upstream analyses with projections from GREET 2023 and AEO 2023 or other relevant forecasts as the final rule schedule permits.

Figure 8-93: Emissions of GHG in the Baseline Scenario



Fleet-wide fuel consumption and GHG emissions continue to decline further under the more stringent action alternatives in response to higher fuel efficiency standards. Figure 8-94 presents the incremental differences to the overall and fuel-specific energy consumption for each action alternative, as compared to the baseline scenario. For each alternative in the figure, note that the scale along the *y-axis* differs substantially, with the least stringent alternative (HDPUV4) being magnified 100 times compared to the most stringent option (HDPUV14). Figure 8-94 shows the same general pattern over the years for all alternatives, where gasoline consumption declines faster than an associated increase to electricity use, leading to an overall reduction in energy consumption. As was the case under the No-Action Alternative, gasoline remains the dominant source of fuel for the HDPUV fleet in all CYs, and for all action alternatives. At the same time, annual use of electricity continues to increase, while consumption of diesel and E85 remains largely unaffected. However, considering that the consumption of fuel in the No-Action Alternative is measured in billions of gallons/GGE, the incremental differences for Alternative HDPUV4 are small,[211] are only marginal for Alternative HDPUV10, and are moderate for Alternative HDPUV14. These changes in the alternatives are mostly attributed to the varying adoption rates of PHEV and BEV technologies. For example, in Alternative HDPUV4, the same utilization of PHEVs and BEVs as was seen under the baseline standards lead to inconsequential differences to fuel consumption. Meanwhile, under Alternative HDPUV14, PHEVs and BEVs were adopted at a slightly higher rate, which (when propagated to the on-road population over the years) lead to moderate reductions in fuel use.

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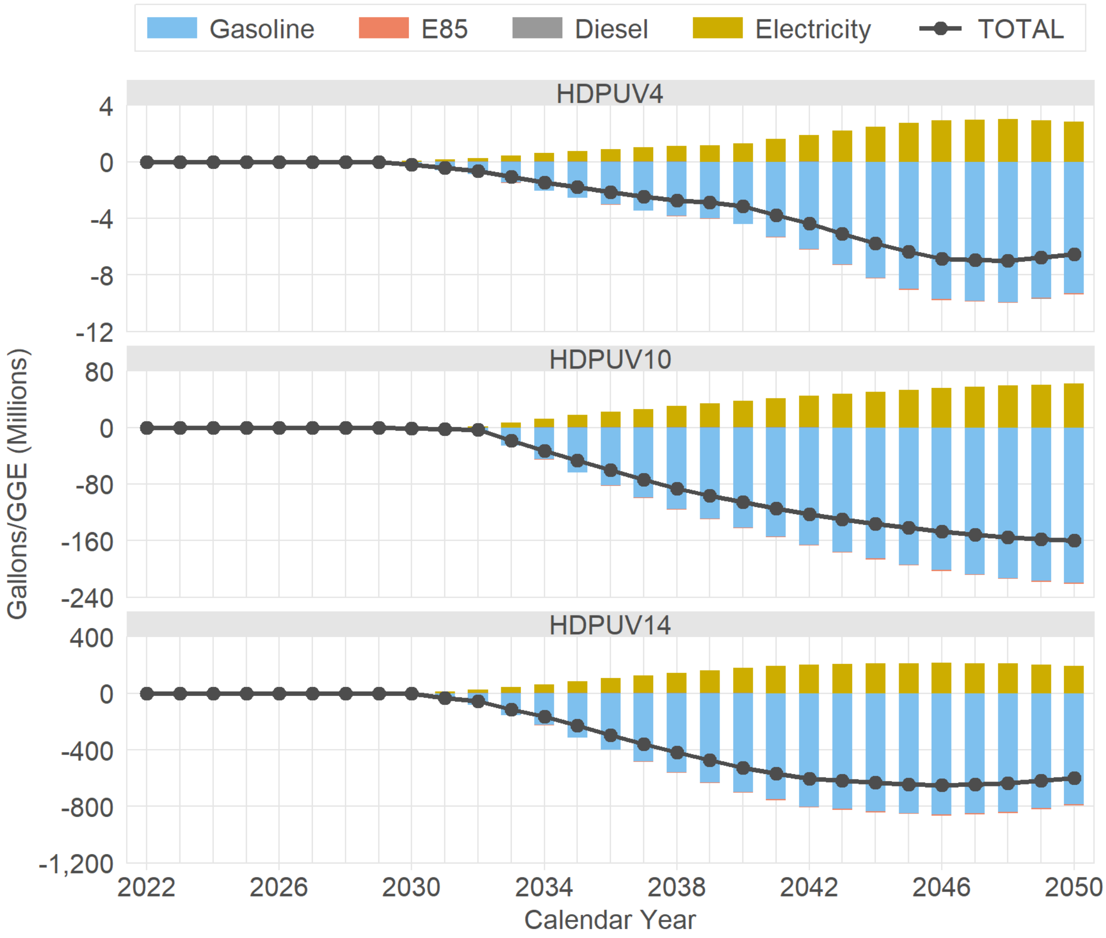
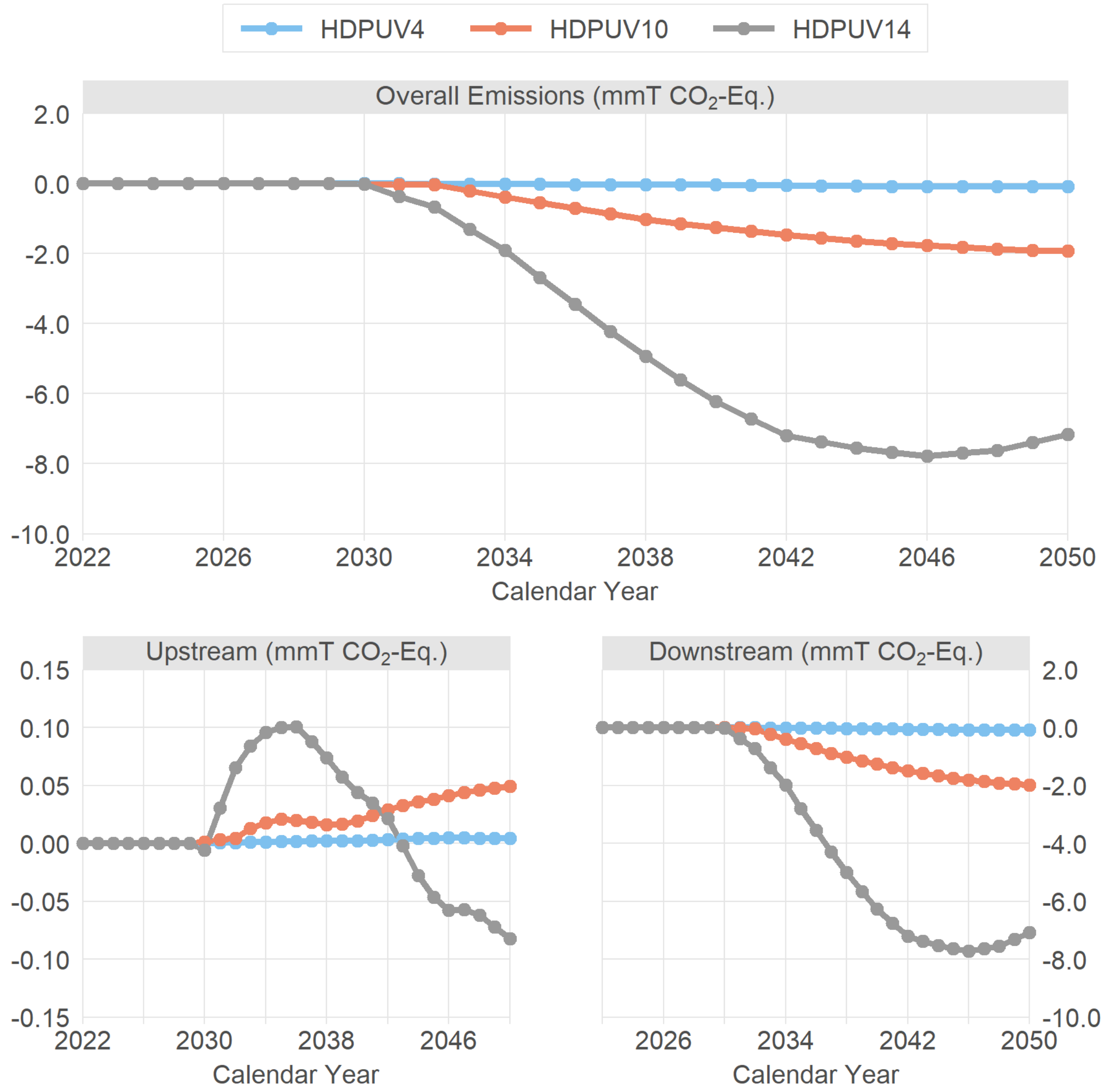
[211] However, note that the fuel consumption differences betwen Alternative HDPUV4 and the No Action Alternative are exaggerated in Figure 8-94 for illustrative purposes.

Figure 8-94: Changes in Fuel Consumption Compared to Baseline



Along with the reduction of fuel use, the GHG emissions generated by the on-road fleet also decline in each action alternative, with the magnitude of the changes being proportional to the overall decreases in fuel consumption. Figure 8-95 presents the incremental changes to emissions of GHG as compared to the No-Action Alternative. The larger chart at the top presents the overall emissions of GHG, while the left and right portions at the bottom provide deconstructed views of upstream and downstream components, respectively. In each case, the incremental emissions of GHGs decrease at a greater rate as the standards defined by the action alternatives increase in stringency. However, as was the case for incremental differences of fuel consumption, the changes to GHG emissions range from insignificant under Alternative HDPUV4 to moderate under Alternative HDPUV14.

Figure 8-95: Changes in GHG Emissions Compared to Baseline



8.3.5.2.1. Impacts of Select Sensitivity Cases on Fuel Consumption and GHG Emissions

Varying certain input assumptions, such as FPs, may change the mix of technologies that the CAFE Model selects in order to achieve compliance. Additionally, the degree of voluntary over-compliance may be affected if, for example, the cost of technology application becomes cheaper or fuel savings increase with respect to the reference input assumptions.[212] As a result, fuel consumption and emissions of GHGs may change as well. In this chapter, the impacts of several sensitivity cases are examined and compared to the central analysis (or the RC). The selected sensitivity cases were chosen in an effort to examine some of the important factors related to fuel consumption and emissions. Specifically, two cases with different FP forecasts are considered, two cases where the learning rate of battery costs is either decreased or increased by 20 percent, and one additional case where upstream emissions factors use lower input assumptions compared to the central case. These and other sensitivity analysis cases are described in greater detail in Chapter 9. The following listing provides brief summaries of the cases presented here, along with the abbreviations used by the various figures throughout this chapter.

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[212] Here fuel savings refers to the portion of fuel savings assumed to be valued by consumers. In the RC this represents the first 30 months of fuel savings. This assumption is discussed in greater detail in Draft TSD Chapter 4 and PRIA Chapter 2.

- Central: Central analysis case.
- Low FP: FPs from AEO 2022 low oil price forecast.
- High FP: FPs from AEO 2022 high oil price forecast.
- Battery -20%: Battery costs learn down at a 20 percent slower rate.
- Battery +20%: Battery costs learn down at a 20 percent faster rate.
- Clean Grid: Upstream emissions factors from AEO 2022 low renewables costs projections.

Among the sensitivity cases selected, the first four cases (with varying FPs and battery costs) will produce different compliance decisions, therefore, affecting the fleet's overall fuel consumption and GHG emissions. Conversely, the last case with lower upstream emissions factors will only differ in the amount of GHG (and other pollutants) that are emitted into the atmosphere. This is because the inputs that influence the model's technology selection under this *clean grid* case (along with the resulting on-road fleet, VMT, and fuel consumption) remain unaffected when compared to the central case.

Figure 8-43 shows a comparison of fuel consumption between sensitivity cases for the No Action Alternative. The overall consumption from all fuel types is presented in the larger chart at the top, while the left and right portions at the bottom provide separate views of gasoline/diesel and electricity consumption, respectively. For all sensitivity cases, the HDPUV fleet begins by consuming gasoline and diesel as the dominant sources of fuel. However, in four of the sensitivity cases presented here, the use of one or both of these fuels quickly declines as vehicle fuel efficiency improves and diesel use is supplanted by electricity.[213] In this figure, the outcomes of the central analysis are displayed using a thicker gray line, with bullet point markers, while the sensitivity cases are shown with thinner lines and asterisk markers (and with varying colors). Since fuel consumption does not change between the *clean grid* case and the central analysis, the trends from the *clean grid* results are presented as overlapping the central analysis.

The *high FP* case shows the fastest annual reduction to the overall fuel consumption, while the *low FP* case fluctuates slightly, ending with a marginal increase in CY 2050. These differences can be attributed to the degree of voluntary over-compliance that the CAFE Model employees during analysis. Under the *high FP* case, the fuel savings resulting from technology application increase, leading to a greater selection of cost-effective technologies[214] and to additional over-compliance. At the same time, when gasoline and diesel prices are high, the HDPUV fleet sees an even greater adoption of electric-powered vehicles (PHEVs and BEVs), which translates to electricity eventually becoming the dominant source of fuel within the fleet. For the *low FP* case, however, the potential for fuel savings diminishes, which, in turn, reduces the amount of voluntary over-compliance. Since the on-road HDPUV fleet and VMT undergo a net annual growth (as was previously presented by Figure 8-89), the fuel efficiency improvements under the No Action Alternative, and for the *low FP* case, offset the additional demand for travel just enough to hold the overall fuel consumption steady.

As shown in Figure 8-96, the *faster battery cost learning* case results in the slightly higher reduction to overall annual fuel consumption, as compared to the central case, while also having a slight increase to the adoption of electric-powered vehicles. This marginal deviation from the central analysis is attributed to cheaper battery costs leading to more cost-effective application of PHEV and BEV options. However, since the regulatory provisions and the input assumptions employed for the central analysis already result in the CAFE Model heavily favoring PHEV and BEV adoption (e.g., a "zero" compliance rating for electric operation and the use of Federal Incentives [tax credits]), further decreasing the cost of batteries produces an only marginal effect on compliance. Meanwhile, the *slower battery cost learning* case performs worse than the central analysis, resulting in higher consumption of gasoline and diesel, and lower electricity use. In this case, the added cost of batteries stands to negate the benefit of Federal Incentives, resulting in mass adoption of PHEVs and BEVs to be delayed until such time that these technologies become more economical.

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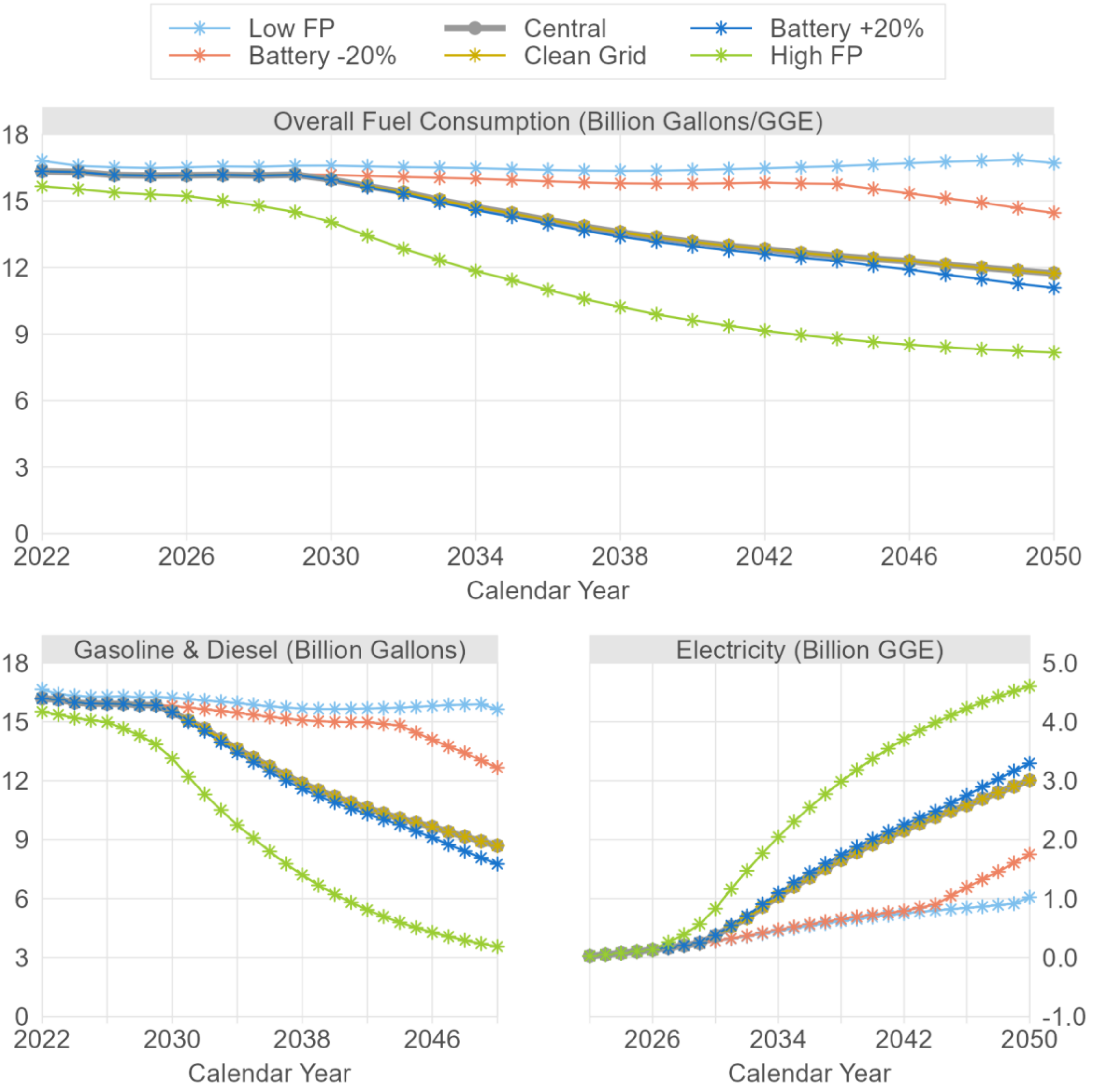
[213] Although not shown explictly in Figure 8-43, consumption of gasoline under the *clean grid* and *faster battery cost learning* cases holds mostly steady, following identical or nearly identical pattern that was shown for the central analysis in Figure 8-92 earlier. Likewise, diesel use for these two sensitivity cases shows the same or similar rapid decline that was observed the central analysis as well. Conversely, under the *high fuel price* case, gasoline consumption sees further substantial annual decline (which was not obseverd for the central analysis) in addition to the rapid decline of diesel use.

[214] Cost-effective technologies are defined as those where fuel savings resulting from application of a specific technology are greater than the cost of that technology. For more information on how the CAFE Model calculates cost-effectiveness refer to Chapter 2, Section S5.3.2 of the CAFE Model Documentation.

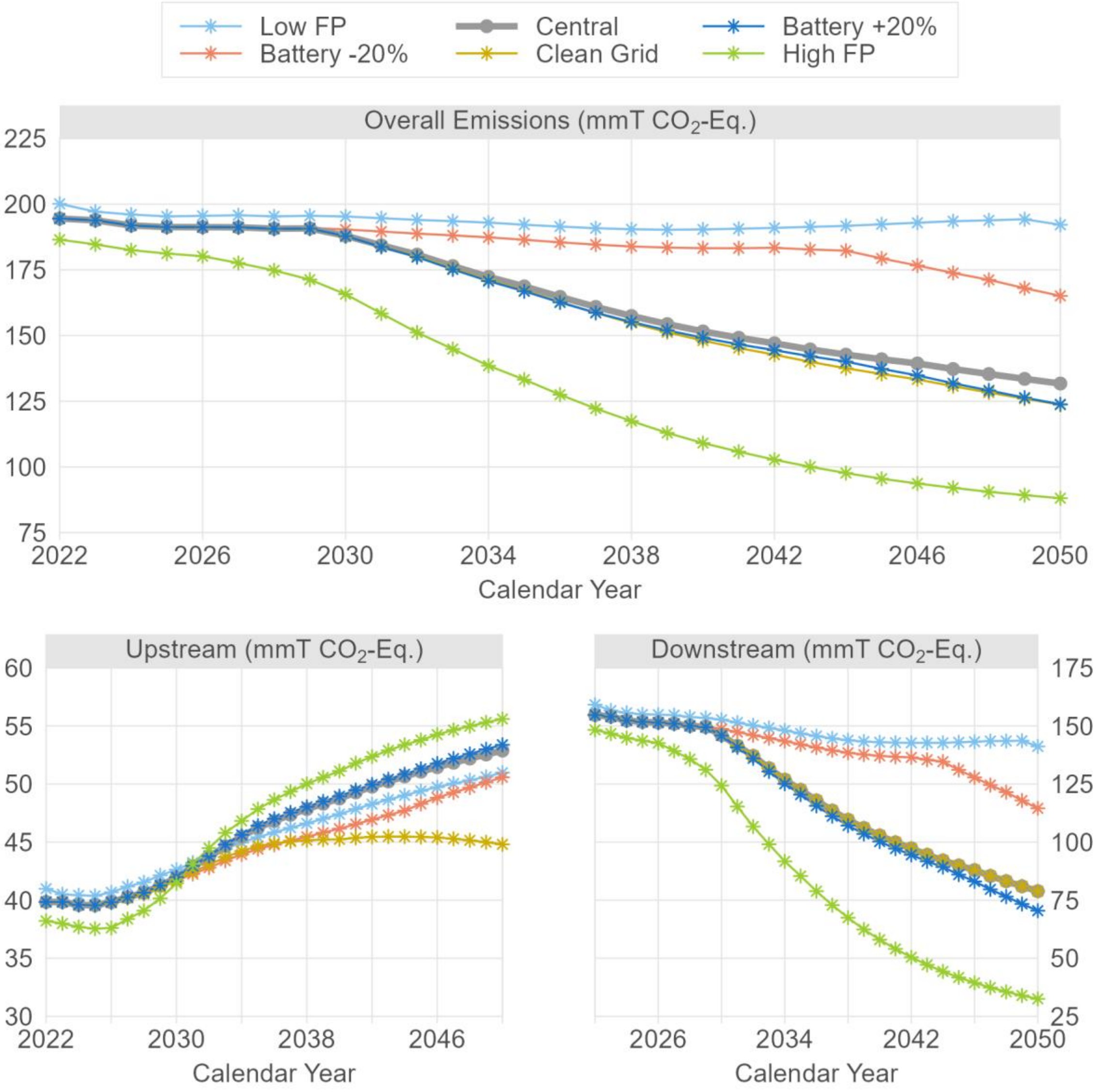
Figure 8-96: Comparison of Fuel Consumption Across Sensitivity Cases in the Baseline Scenario



As noted earlier, fuel consumed by the on-road fleet during vehicle operation emits GHGs. Hence, as demonstrated in Figure 8-97, the overall and downstream GHG emissions for all sensitivity cases under the No Action Alternative show similar patterns and annual trends that were observed for the total fuel consumption. However, under the *clean grid* case as compared to the central analysis, the additional reductions to overall GHG emissions are the result of using lower input assumptions for the upstream emissions factors.

When looking at the upstream GHG emissions (bottom-left chart in Figure 8-97), the *clean grid* case outpaces all other sensitivities (and the central analysis) in terms of the annual reduction of emissions beginning with CY 2036. This behavior occurs because, under the *clean grid* case and starting at around the same timeframe, upstream emissions factors of CO_2 and other GHGs (from all stages of production and distribution) are decreased by much greater margins for electricity generation than for gasoline production. At the same time, the significant increases to the demand for electricity under the *high FP* case, and, conversely, the equally significant reduction of electricity use under the *low FP* and *slower battery cost learning* cases, leads to these two sensitivities generating slightly more upstream GHG emissions for the "*high*" case and slightly less for the other two cases. As was the case with fuel consumption results for the *higher battery cost learning* case, the subsequent GHG upstream emissions (as well as downstream and overall) are not significantly different from the central analysis.

Figure 8-97: Comparison of GHG Emissions Across Sensitivity Cases in the Baseline Scenario



For the action alternatives, when considering the values on an absolute basis, the patterns of behavior and relative ordering of sensitivity cases were identical to the No Action Alternative, although with lower overall fuel consumption and GHG emissions. Figure 8-98 and Figure 8-99 present the comparison of cumulative impacts to fuel consumption and GHG emissions over the next three decades for all sensitivity cases and action alternatives.[215] In both figures, note that the fuel consumption and GHG emissions spikes between the first two decades under the *low FP* and *slower battery cost learning* cases for Alternatives HDPUV4 and HDPUV10 are the artifacts of binning the data into decades, rather than actual extensive increases to fuel consumption or GHG emissions. Here, the spikes are visible mostly due to the exclusion of CY 2021 during the first decade and because of the relative lack of variation in annual trends during roughly the first 20 CYs covered by the analysis.

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[215] As discussed at the introduction to Chapter 8.2.5, the first decade in all figures presented by this chapter cover the range of years between CYs 2022 and 2030, while the latter two encompass effects over the full ten-year period. While this marginally reduces the magnitude of cumulative fuel consumption and GHG emissions occurring during the first decade (as compared to the following ones), the figures still demonstrate the relative differences and a declining trend between the decades.

Figure 8-98: Comparison of Fuel Consumption Across Sensitivity Cases in the Action Alternatives

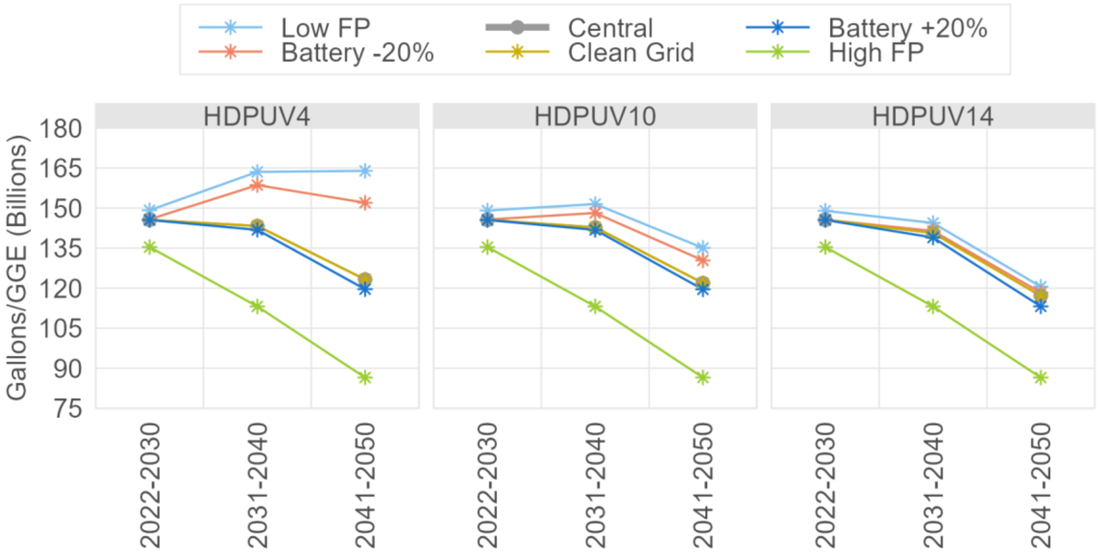
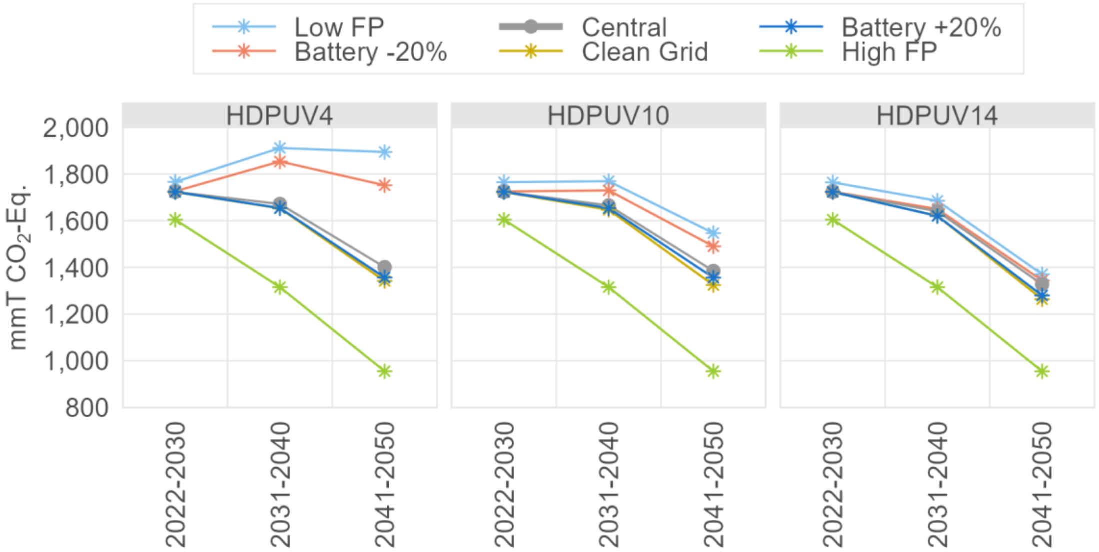


Figure 8-99: Comparison of GHG Emissions Across Sensitivity Cases in the Action Alternatives



When considering the incremental changes in fuel consumption and GHG emissions compared to the No Action Alternative, the relative ordering of sensitivity cases generally reverses as illustrated by Figure 8-100 and Figure 8-101. Here, the *high FP* case is shown as having no meaningful difference to fuel consumption and GHG emissions when compared to the baseline scenario, while the *low FP* and *lower battery learning rate* cases show the greatest reduction for both values. Under the *high FP* case, as the No Action Alternative absorbs practically all of the cost-effective technologies due to voluntary over-compliance, the potential for improvements in the action alternatives (with respect to the baseline scenario) all but disappears. Hence, the *high FP* case produces virtually no changes to fuel consumption and GHG emissions. Conversely, for the *low FP* and *lower battery learning rate* cases, as the degree of voluntary over-compliance or the cost of compliance under the No Action Alternative declines, the potential for improvements in the action alternatives increases. Thus, the incremental changes go up in each alternative in these two cases. Lastly, the incremental differences for fuel consumption and GHG emissions in the *clean grid* and *faster battery cost learning* cases show no to little variation compared to the central analysis.

Figure 8-100: Comparison of Changes in Fuel Consumption Across Sensitivity Cases

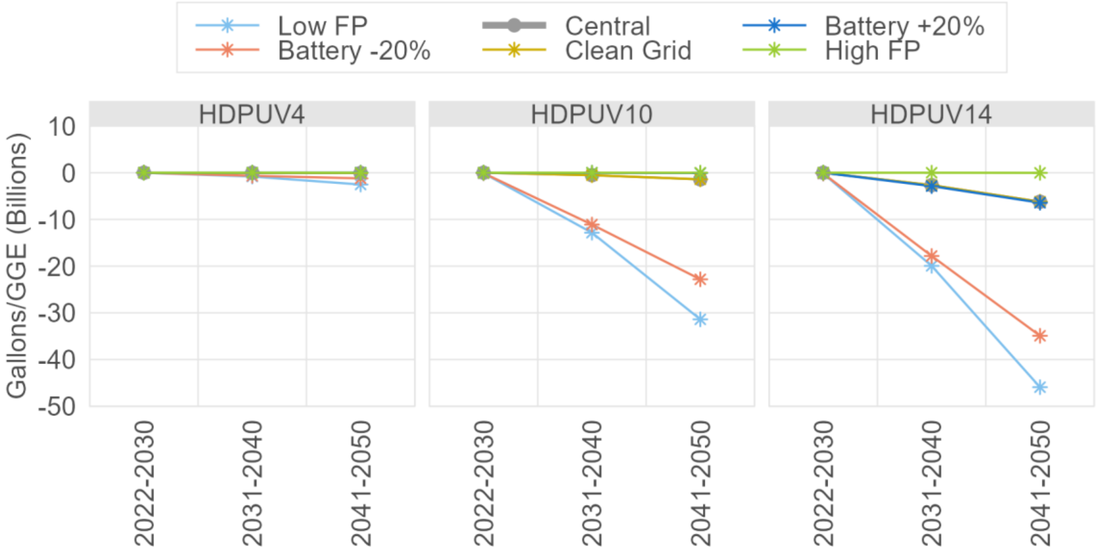
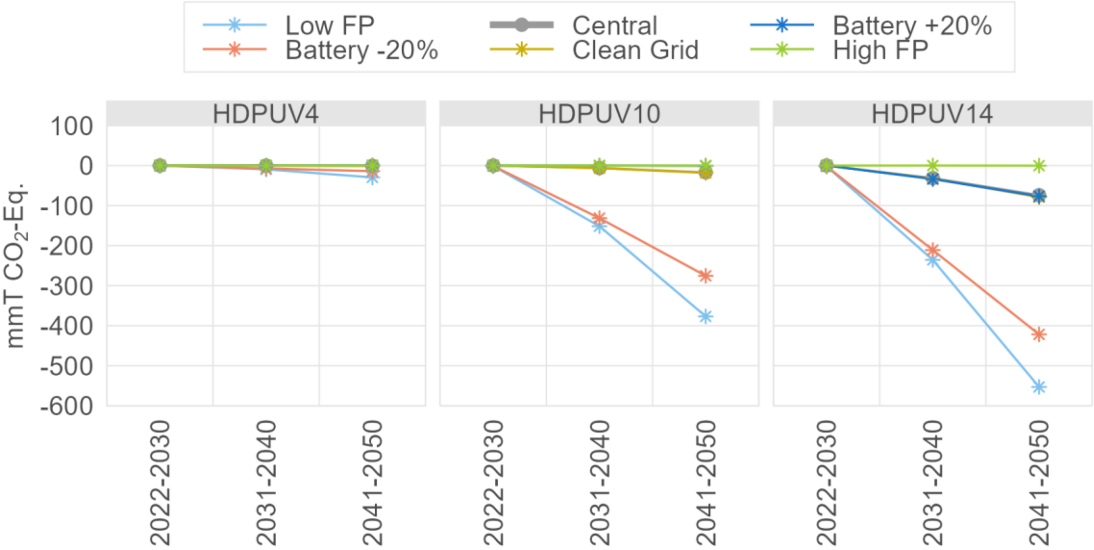


Figure 8-101: Comparison of Changes in GHG Emissions Across Sensitivity Cases



8.3.5.3. Changes to Emission of Criteria Air Pollutants

Reduction in the total amount of fuel consumed by the on-road vehicle fleet may result in either increases or decreases to upstream emissions from criteria air pollutants. These upstream changes depend mainly on the magnitude by which the alternative fuel sources (specifically electricity) supplant gasoline and diesel use in the HDPUV fleet. Since the production and distribution of gasoline in the United States is significantly cleaner than generation of electricity for most pollutants according to GREET, introducing even small volumes of PHEVs and BEVs into the on-road population tends to have a disproportionally negative impact on the *upstream* emissions resulting from criteria air pollutants.[216] Conversely, stricter vehicle emission standards, which are defined on a per-mile basis and are adopted by the new fleet, greatly reduce the amount of

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[216] At the time of NHTSA's analysis, the latest upstream emission factors (EFs) available were from GREET 2022, which are based on AEO 2022 forecasts of the electricity generation mix. We understand AEO 2023 forecasts assume faster rates of grid decarbonization than previous releases and include some recent IRA and BIL provisions that are expected to impact emissions results associated with future CAFE standards, in particular including provisions that would reduce SO2 emissions from upstream sources. For these reasons, we anticipate updating our upstream analyses with projections from GREET 2023 and AEO 2023 or other relevant forecasts as the final rule schedule permits.

downstream pollutants that are emitted into the atmosphere from vehicle operation. This chapter presents changes in emissions for a subset of criteria air pollutants that are supported by the CAFE Model. Specifically, upstream and downstream emissions related to NO_X, SO_X, and $PM_{2.5}$ are examined. As a consequence of changes to emissions, the magnitude of adverse health incidents caused by exposure to these pollutants typically reduces, as discussed in Chapter 8.3.5.4.

Figure 8-102 and Figure 8-103 present annual upstream and downstream emissions of NO_X and $PM_{2.5}$ respectively, which are attributed to the HDPUV fleet under the standards defined by the No-Action Alternative. In the case of $PM_{2.5}$, downstream emissions are split and presented separately for emissions related to BTW and vehicular emissions originating at a vehicle's exhaust. As the older vehicles are retired and replaced by models compliant with stricter emissions standards, a rapid decline of NO_X and $PM_{2.5}$ downstream emissions can be seen from both figures. Given that vehicles operating on electricity do not emit criteria pollutants at the exhaust, the increased presence of PHEVs and BEVs within the No-Action Alternative further contribute to the accelerated reduction of downstream exhaust-based emissions shown in the figures. However, since the BTW emissions are defined at a constant rate, rather than varying by vehicle production year and age, downstream BTW emission of $PM_{2.5}$ are shown to increase proportionally as the HDPUV on-road population and the associated demand for travel go up.

The relative impacts on upstream emissions for both pollutants are comparatively less pronounced, however, they still indicate substantial annual increases. The annual upsurge in upstream emissions is congruent with the increases in the HDPUV fleet and VMT (see Figure 8-89), and correlates with the higher demand for electricity, as more vehicles are gradually converted to PHEVs and BEVs during each subsequent year (as was presented by Figure 8-92). Although there is a sharp decline in diesel consumption under the No-Action Alternative, with significant portions of the diesel fleet being converted to more fuel-efficient SHEVs, the growth to the overall HDPUV population, and a significant shift to electric-powered vehicles throughout the analysis, outweigh the larger cumulative savings resulting from reduction in diesel use. As such, Figure 8-102 and Figure 8-103 show an annual increase to the upstream emissions of NO_X and $PM_{2.5}$.

Figure 8-102: Emissions of NO_X in the Baseline Scenario

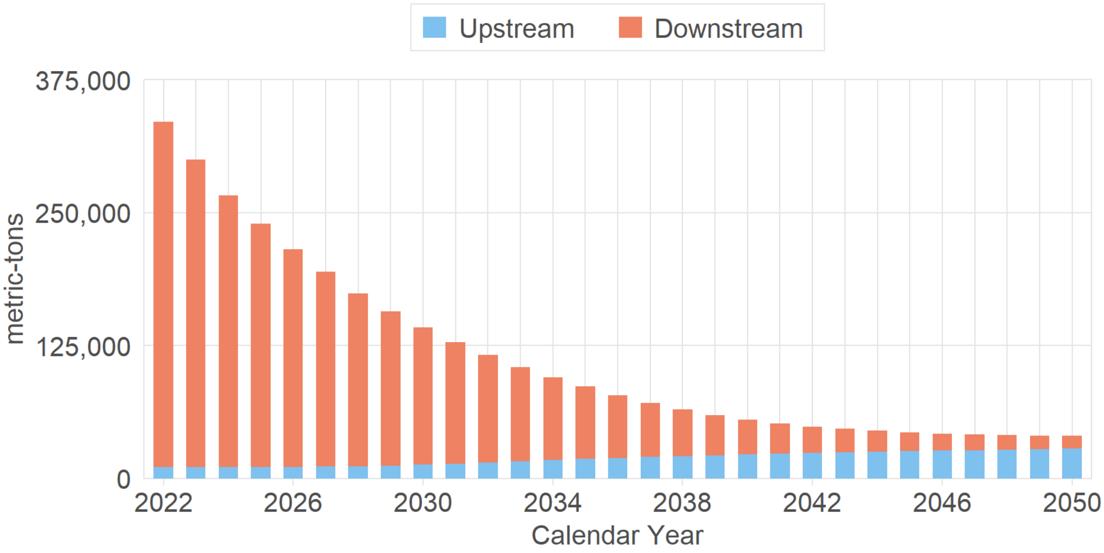


Figure 8-103: Emissions of $PM_{2.5}$ in the Baseline Scenario

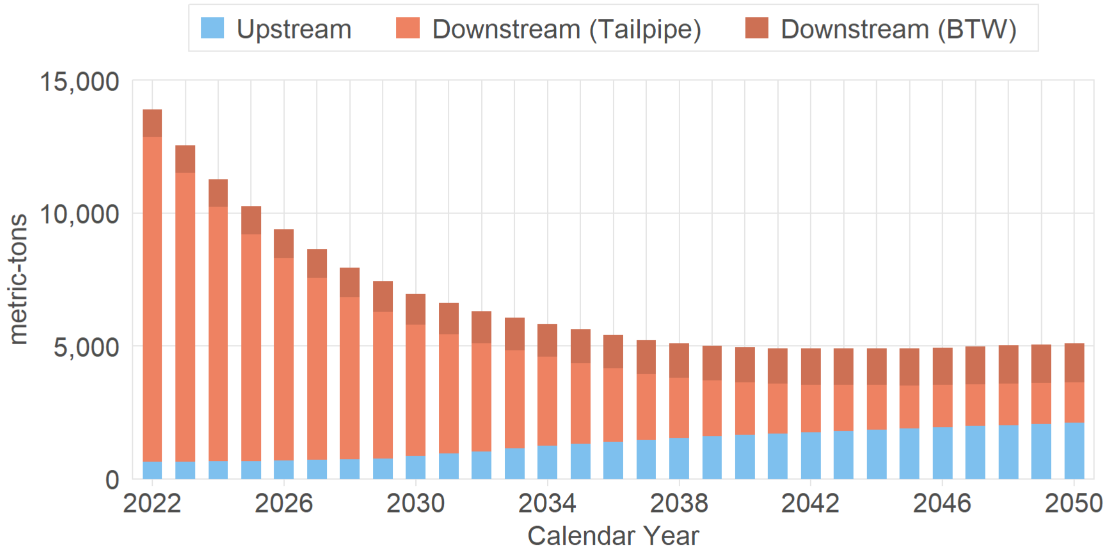
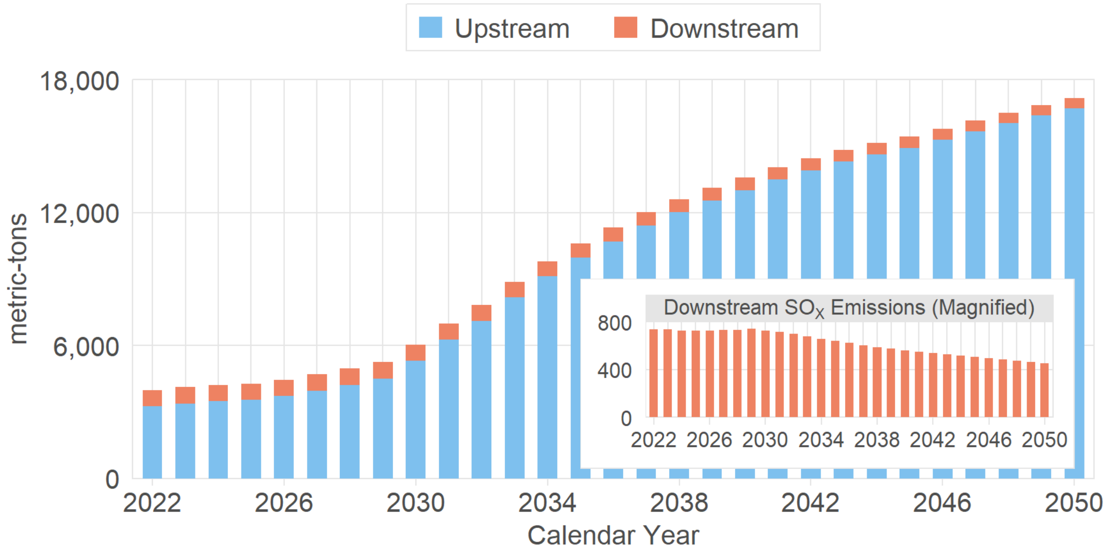


Figure 8-104 shows the annual SO_X emissions for the on-road fleet under the No Action Alternative. Contrary to the previous two pollutants, downstream emissions of SOX are measured based on the consumption of fuel, rather than on a per-mile basis dictated by the vehicle emissions standards. Hence, SO_X emissions are influenced directly by changes to the amount of fuel consumed, rather than the total miles traveled by the HDPUV fleet. Figure 8-104 shows the downstream component provides a marginal contribution to the overall SO_X emissions, and generally undergoes a downward trend as the overall fuel consumption decreases. The inner plot in the bottom-right corner of the figure presents a magnified view of the downstream SO_X emissions for clarity. The upstream SO_X emissions see a similar pattern as was observed for NO_X and $PM_{2.5}$ pollutants. Here, emissions increase significantly year over year due to a larger HDPUV fleet and a greater presence of electric-powered vehicles within it.

Figure 8-104: Emissions of SO_X in the Baseline Scenario



As demonstrated in the next several figures, increases to the HDPUV fuel efficiency standards only lead to meaningful differences under the most stringent alternative (HDPUV14) that was evaluated for today's analysis. The changes in Alternative HDPUV4 were insignificant for all pollutants, while Alternative HDPUV10 showed minor differences in overall emissions of NO_X and $PM_{2.5}$, and only marginal variances to total SO_X

emissions when compared to the baseline scenario. All alternatives, however, showed an increase to the upstream emissions, while also presenting a decrease in downstream. The net changes to emissions, though, depend on the CY and pollutant being considered, where overall values may show an increase or a decrease in total emissions generated.

While the figures below show general trends in emissions and compare the outcomes of each alternative, they do not necessarily clarify the significance of those changes with respect to the No-Action Alternative. Hence, Table 8-29 is provided as a way to underscore the maximum magnitude of the variances that were observed within each action alternative when compared to the baseline. In each case, the CY where the greatest difference in emissions occurred for each pollutant and category was taken. As such, for each combination (e.g., NO_X Total) a different CY may have been selected. As the table demonstrates, even at its greatest point of differentiation, Alternative HDPUV4 shows little to no contrast to the baseline scenario, with regard to the amount of emissions of criteria air pollutants.

Table 8-29: Maximum Observed Change in Emissions Compared to Baseline

	HDPUV4	HDPUV10	HDPUV14
NO_X Total	0.0%	0.3%	0.8%
NO_X Upstream	0.1%	0.9%	3.6%
NO_X Downstream	-0.1%	-1.3%	-4.3%
$PM_{2.5}$ Total	-0.0%	-0.1%	-0.7%
$PM_{2.5}$ Upstream	0.1%	1.1%	4.4%
$PM_{2.5}$ Downstream	-0.1%	-2.0%	-6.8%
SO_X Total	0.1%	1.4%	6.0%
SO_X Upstream	0.1%	1.6%	6.6%
SO_X Downstream	-0.1%	-2.6%	-9.5%

Figure 8-105 shows the incremental changes to NO_X emissions in the action alternatives verses the baseline scenario. The larger chart at the top displays the overall emissions of NO_X, while the left and right portions at the bottom provide deconstructed views of upstream and downstream components, respectively. The upstream emissions show an increasing trend over the baseline, while the downstream emissions decline over time. As new electric-powered vehicles are gradually phased into the population, the amount of net upstream emissions due to increased demand of electricity goes up. At the same time, since consumption of electricity does not generate emissions of criteria pollutants during vehicle operation, the amount of downstream NO_X emission decreases. These variances between alternatives occur mostly due to the PHEVs and/or BEVs being adopted at a slightly faster rate under Alternatives HDPUV10 and HDPUV14 than in the baseline.

Figure 8-105: Changes in NO_X Emissions Compared to Baseline

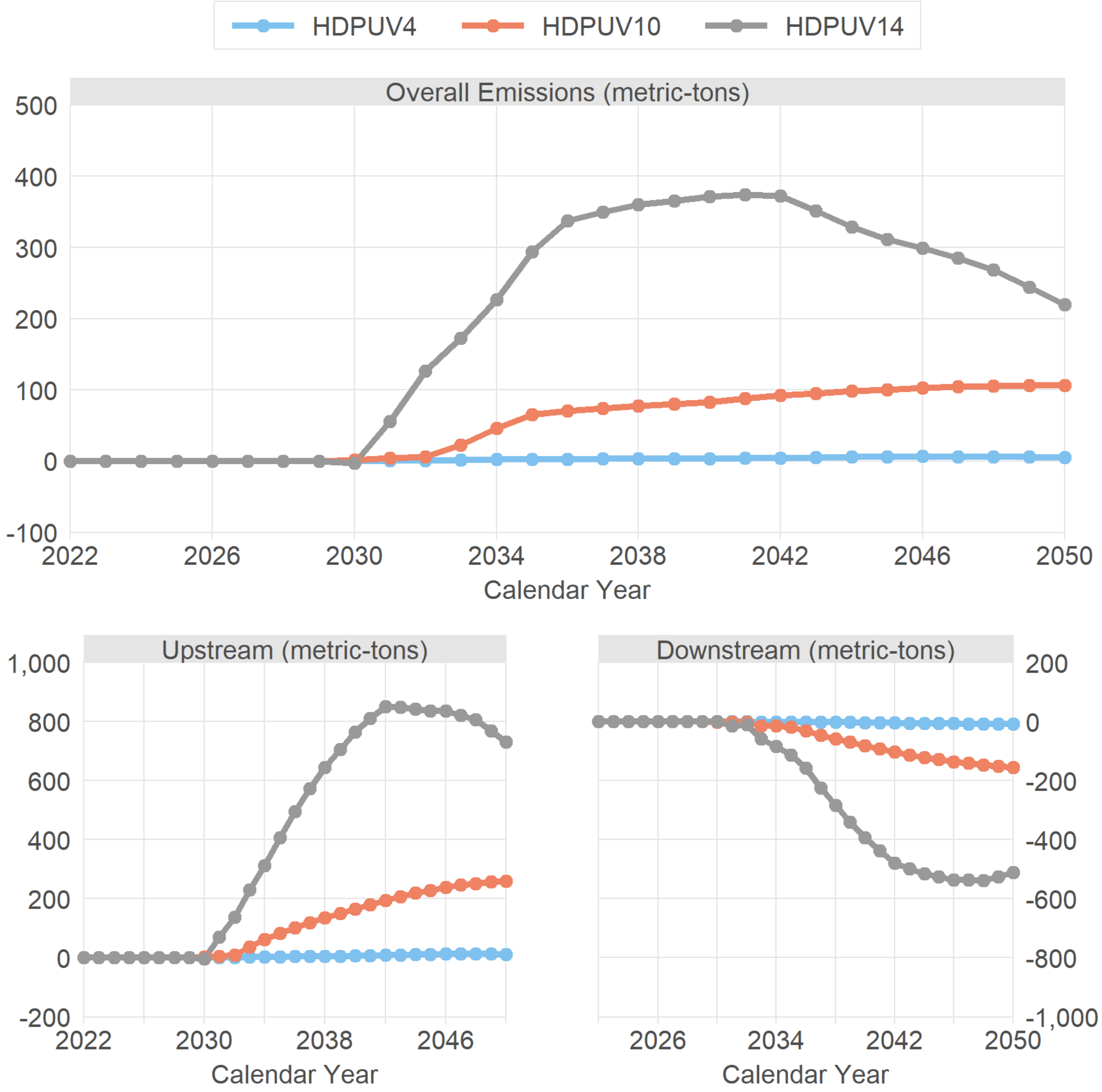


Figure 8-106 presents the incremental changes to $PM_{2.5}$ emissions in the action alternatives as compared to the baseline scenario. The upstream and downstream emissions trends for $PM_{2.5}$ criteria air pollutant are similar to that of NO_X, while also having the same underlying root causes for the observed behavior. In the case of $PM_{2.5}$, however, the downstream portion represents a combination of vehicle exhaust and BTW emissions.

Figure 8-106: Changes in $PM_{2.5}$ Emissions Compared to Baseline

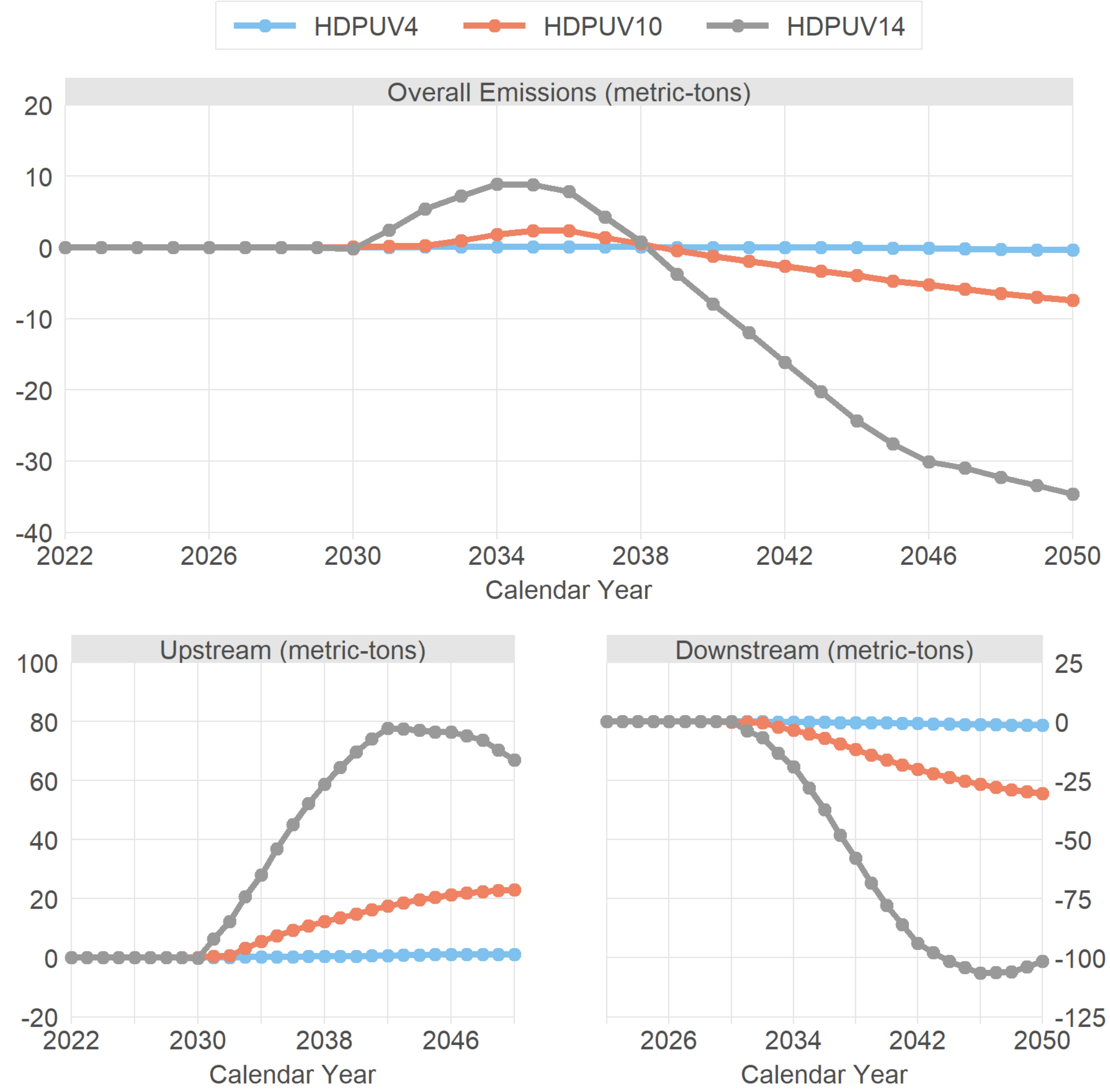
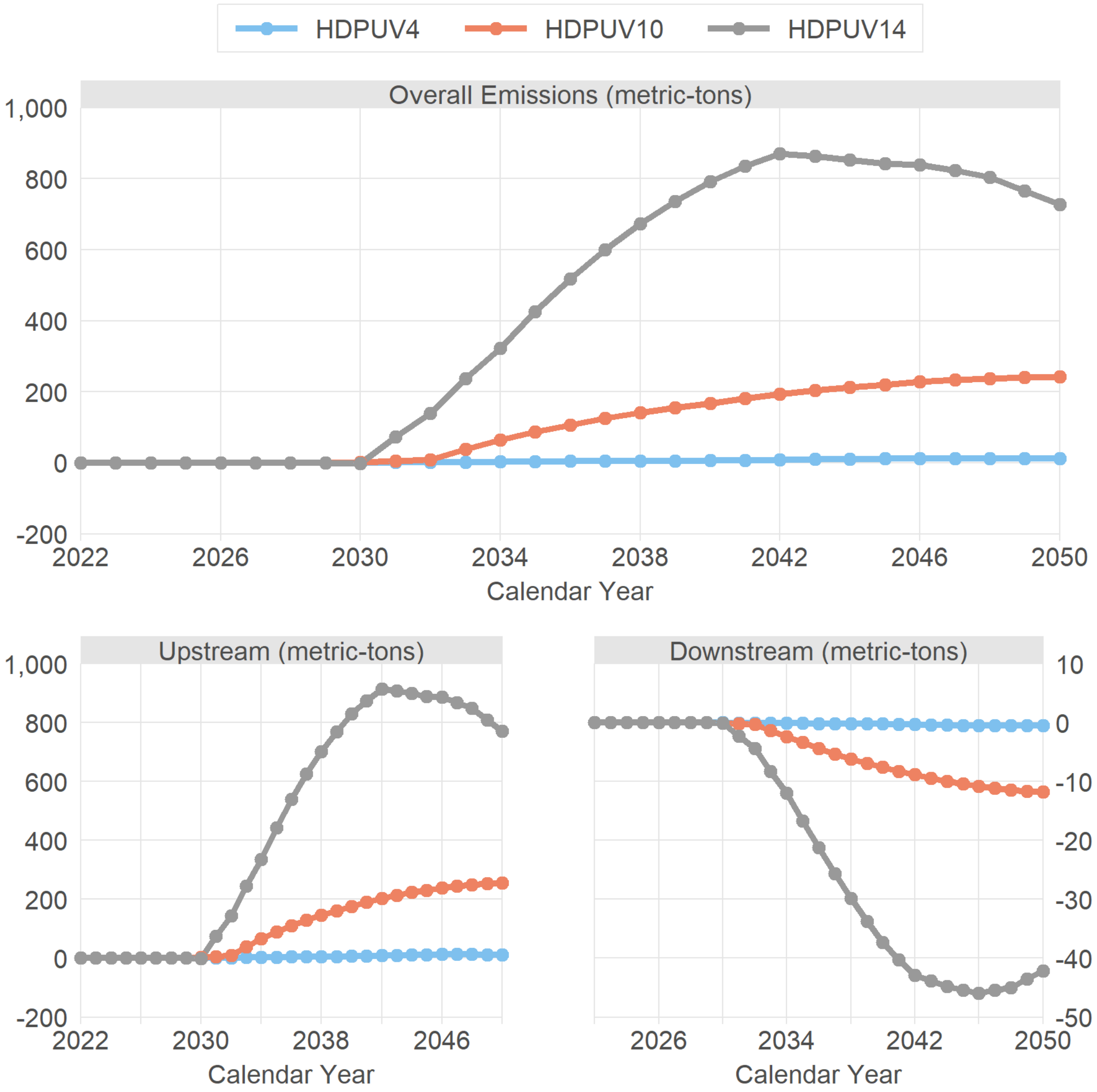


Figure 8-107 illustrates the incremental emission changes for SO_X for the action alternatives versus the baseline. As was noted earlier, the SO_X downstream emissions are measured based on the total consumption of fuel, rather than on per-mile basis. Thus, the marginal to moderate reductions in fuel use in the action alternatives leads to proportionally marginal to moderate decreases of the downstream emissions when compared to the No Action Alternative. Conversely, as was the case for the other two criteria air pollutants, the upstream emissions of SO_X are higher than the baseline in all action alternatives. This also leads to a net increase in the overall SO_X emissions over the baseline.

Figure 8-107: Changes in SO_X Emissions Compared to Baseline



8.3.5.4. Changes to Adverse Health Outcomes Caused by Exposure to Criteria Pollutants

The magnitude of adverse health incidents caused by exposure to criteria air pollutants reduces as the consumption of gasoline by the HDPUV fleet drops between CYs (and to a certain extent, between alternatives). Table 8-30 presents the number of incidents and proportions for each of the various emission health impacts, which were considered during this proposed rulemaking, occurring during CY 2022. Since CY 2022 corresponds to the initial year evaluated for today's analysis (MY 2022), and since the CAFE Model does not apply any fuel saving technologies during that initial year, the health impacts shown in the table are the same across all alternatives.

Table 8-30: Emission Health Impacts in CY 2022

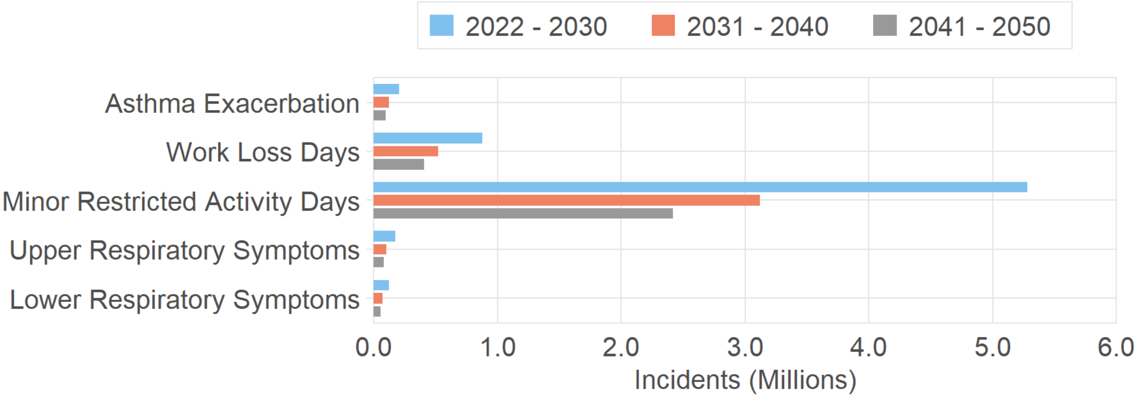
	Incidents (Units)	Share of Total
High Incident Counts		
Asthma Exacerbation	32,157	3.1%
Work Loss Days	137,738	13.1%

Minor Restricted Activity Days	830,188	79.0%
Upper Respiratory Symptoms	27,324	2.6%
Lower Respiratory Symptoms	19,236	1.8%
Low Incident Counts		
Non Fatal Heart Attacks (All Others)	116	0.01%
Non Fatal Heart Attacks (Peters)	1,078	0.10%
Respiratory Hospital Admissions	260	0.02%
Cardiovascular Hospital Admissions	274	0.03%
Acute Bronchitis	1,514	0.14%
Respiratory Emergency Room Visits	582	0.06%
Premature Deaths	1,041	0.10%

As demonstrated by Table 8-30, the “Minor Restricted Activity Days” category significantly outweighs the cumulative total of all the other health-related incidents. Conversely, the respiratory and cardiovascular hospital admissions categories are least significantly affected by exposure to emissions from criteria air pollutants. Throughout the analysis of all alternatives, the proportions of each category remained mostly the same during each CY, although these proportions moderately decline with each subsequent year.

The emission health impacts attributed to the No-Action Alternative for the remainder of the CYs are presented as cumulative impacts over the next three decades in Figure 8-108 and Figure 8-109.[217] The figures were split into subsets of major incident counts (above ten thousand per year) and minor incident counts (below ten thousand) to aid with interpretation. As shown in both figures, the health-related outcomes in every single category follow a significant downward trend between the decades in response to significantly declining overall emission of the NO_X and $PM_{2.5}$ pollutants (discussed in Chapter 8.3.5.3).

Figure 8-108: Cumulative Emission Health Impacts in the Baseline Scenario (Part 1)



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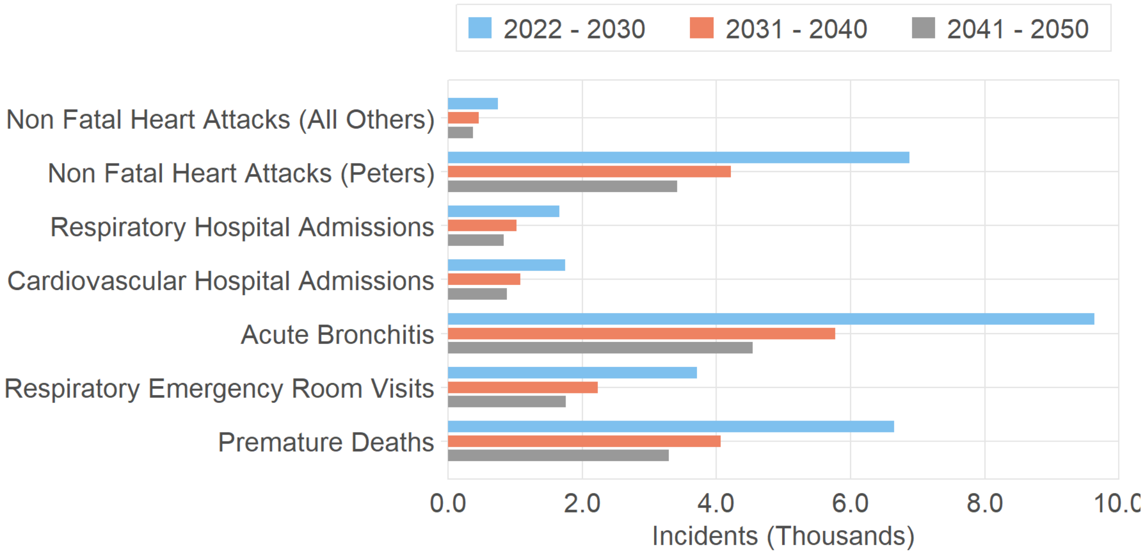
[217] As discussed at the introduction to Chapter 8.3.5, the first decade in all figures presented by this chapter cover the range of calendar years between CYs 2022 and 2030, while the latter two encompass effects over the full ten-year period. While this marginally reduces the magnitude of cumulative incidents occurring during the first decade (as compared to the following ones), the figures still demonstrate the relative differences and a declining trend between the decades.

Figure 8-109: Cumulative Emission Health Impacts in the Baseline Scenario (Part 2)



With increasing fuel efficiency standards under the action alternatives, health-related incidents are further decreased in response to an even greater reduction of fuel consumed. However, as was observed for criteria air pollutants, the least string alternative (HDPUV4) does not show any practical deviation from the baseline, while Alternatives HDPUV10 and HDPUV14 display marginal to moderate differences. Although the net emissions of SO_X and NO_X increase in some action alternatives, the decreases in fine $PM_{2.5}$ emissions, the reduction in the consumption of gasoline, and the subsequent reduction in exposure to upstream and downstream emissions attributed to gasoline fuel use, lead to an eventual decline in adverse health outcomes. Figure 8-110 and Figure 8-111 illustrate the incremental changes in emission health impacts for each alternative over the baseline scenario for the next three decades. However, considering that MY 2030 is the first year of regulatory action for the HDPUV fleet, the differences between all alternatives during the first decade (CY 2022-2030) are, therefore, virtually non-existent.

Figure 8-110: Changes in Cumulative Emission Health Impacts Compared to Baseline (Part 1)

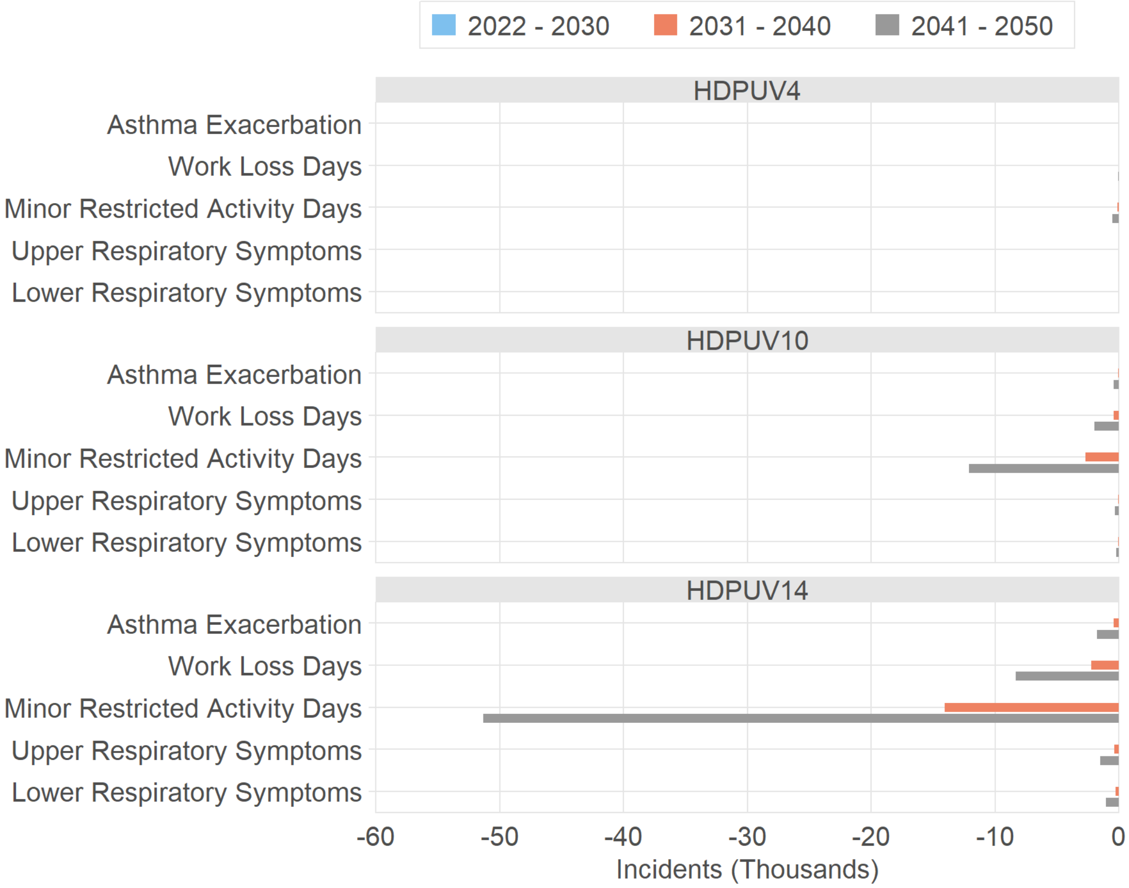
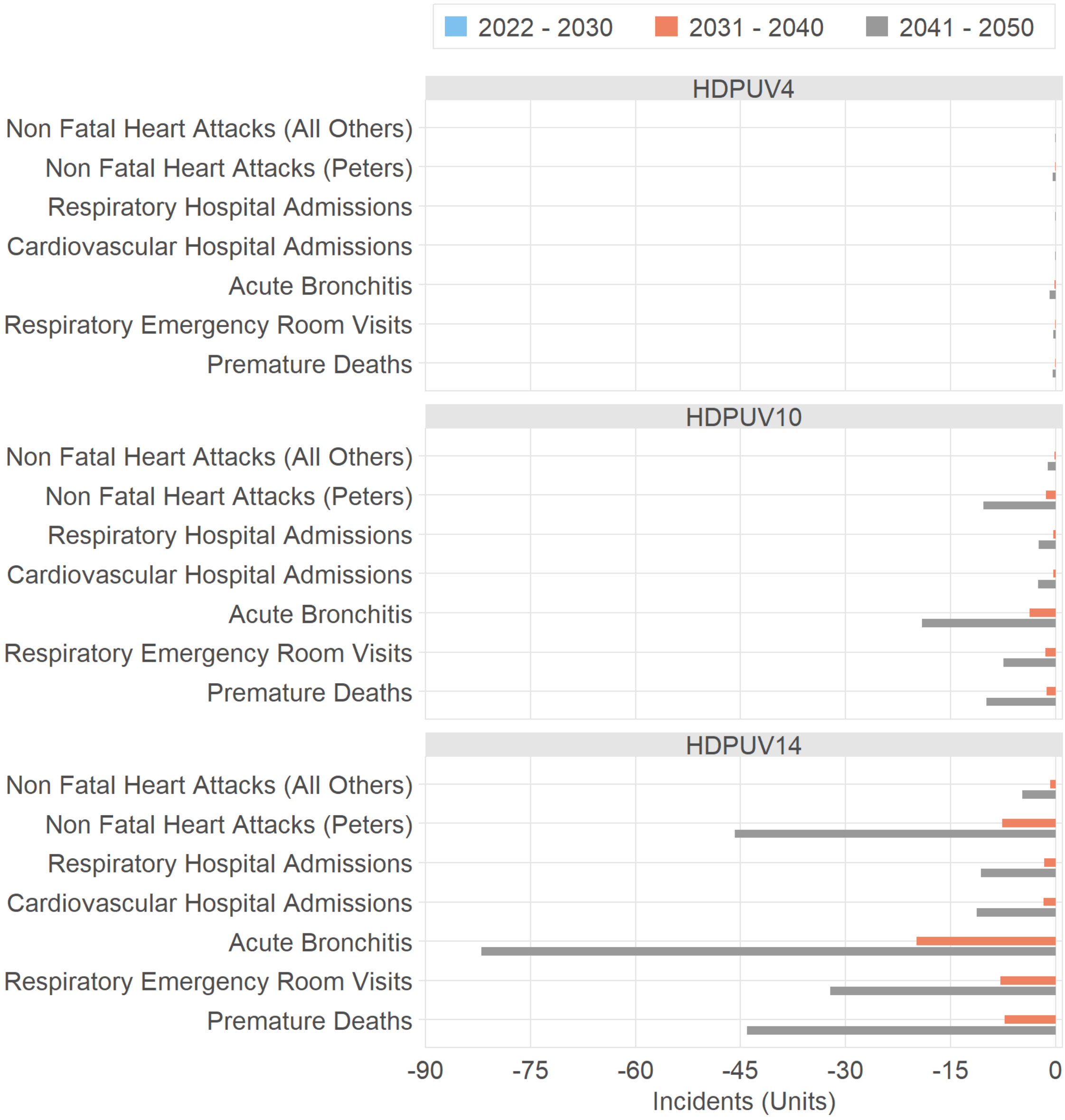


Figure 8-111: Changes in Cumulative Emission Health Impacts Compared to Baseline (Part 2)



9. Expanded Sensitivity Analysis

9.1. Description of Sensitivity Cases

CAFE Model Files Referenced in this Chapter

Below is a list of CAFE Model Files referenced in this chapter. See TSD Chapter 2.1.9 Where can I find the internal NHTSA files? for a full list of files referenced in this document and their respective file locations.

- Market Data Input File

Results presented in this analysis reflect the agency's best judgments regarding many different factors. As with all the past LD CAFE and HDPUV FE rulemakings, NHTSA recognizes that some analytical inputs are especially uncertain, some are likely to exert considerable influence over specific types of estimated impacts, and some are likely to do so for the bulk of the analysis. Additional model runs with alternative assumptions explored a range of potential inputs and the sensitivity of estimated impacts to changes in model inputs. Sensitivity cases in this analysis span assumptions related to technology applicability and cost, economic conditions, consumer preferences, and externality values, among others. In contrast to an uncertainty analysis, where many assumptions are varied simultaneously, the sensitivity analyses included here typically vary a single assumption and provide information about the influence of each individual factor, rather than suggesting that an alternative assumption would have justified a different Preferred Alternative. This analysis contains hundreds of assumptions and most of them are uncertain – particularly several years in the future. However, assumptions are inevitable in analysis, generally, and a sensitivity analysis can identify two critical pieces of information: *how big an influence* does each parameter exert on the analysis, and *how sensitive are the model results* to that assumption?

For example, if the cost of battery packs for BEVs are higher or lower due to deviation from the RC learning rate assumptions, then incremental technology costs are affected slightly, and net benefits are affected somewhat. By contrast, if FPs are either higher or lower than the projections in the central case (represented by the EIA high and low oil price cases in AEO 2022), the set of alternatives considered today produce significantly different results across a variety of metrics, including net social benefits. In that respect, it might be said that the learning rate for batteries turns out to exert less influence on the analysis, as technology costs, the primary metric affected by application of hybrid and PHEV technologies for the MY in question, are not much affected by the alternative assumptions. By contrast, the FP cases demonstrate that many different metrics are affected by alternative FP projections – market adoption of fuel economy improving technologies, the value of gallons saved, buyer payback periods for fuel economy investments, and VMT. The sensitivity analysis thus demonstrates that FPs can have significant effects on a number of relevant metrics (i.e., model results are sensitive to this assumption), and alternative assumptions can change the sign on measures like net benefits and consumer costs – meaning that this assumption *significantly* influences the analysis. That said, influence is different from likelihood. NHTSA does not mean to suggest that any one of the sensitivity cases presented here is inherently more likely than the collection of assumptions that represent the RC in the figures and tables that follow. Nor is this sensitivity analysis intended to suggest that only one of the many assumptions made is likely to prove off-base with the passage of time or new observations. It is more likely that, when assumptions are eventually contradicted by future observation (e.g., deviations in observed and predicted FPs are nearly a given), there will be *collections* of assumptions, rather than individual parameters, that simultaneously require updating. For this reason, we do not interpret the sensitivity analysis as necessarily providing justification for alternative regulatory scenarios to be preferred. Rather, the analysis simply provides an indication of which assumptions are most impactful, and the extent to which future deviations from central analysis assumptions could affect the actual future costs and future benefits of this rule. For a full discussion of how this information relates to NHTSA's tentative determination of which regulatory alternatives would be maximum feasible, please see Preamble Section V.D.

Results of NHTSA's sensitivity analysis are summarized below, and detailed model inputs and outputs are available on the agency's website.[218] These are reported as incremental values for the rule relative to the

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[218] NHTSA. 2022. CAFE Compliance and Effects Modeling System: The Volpe Model. Last Revised: 2022. Available at: https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-compliance-and-effects-modeling-system. (Accessed: May 31, 2023).

baseline No-Action Alternative. They compare to the measures presented in the central analysis, above, using the RC assumptions. The RC values are also reported in the tables for easier comparison. It is important to note that results under both the No-Action Alternative and the Preferred Alternative (i.e., the proposed CAFE standards for LDVs and FE standards for HDPUVs) change for each sensitivity case; the incremental changes are not due solely to a change in the absolute outcomes of the regulatory alternative, but also due to changes in the absolute outcomes in the No-Action case. When interpreting the results of these sensitivity cases, this has implications for relative net benefits to the extent that the alternative assumptions alter the amount or pace of technology adoption within the baseline and action alternatives. For example, when technology adoption and fuel economy are greater in the baseline, this limits the additional costs required for manufacturers to comply with more stringent standards. However, since these technologies generate additional benefits to society, adopting them in the baseline both raises the baseline benefits, and lowers the incremental additional benefits generated in the action alternatives; when the technologies are net-beneficial to society, adopting them in the baseline lowers the additional net benefits generated in the action alternatives. This can sometimes lead to counterintuitive incremental impacts of changing some of the reference assumptions. We discuss these as they arise.

Table 9-1 lists and briefly describes the cases included in the sensitivity analysis. Some cases only apply to the LD fleet (e.g., scenarios altering assumptions about fleet share modeling) and others only affect the HDPUV FE analysis (e.g., commercial operator sales share), so the results tables only report results for relevant sensitivities by vehicle fleet. We did simulate other unique and minor sensitivities, but we did not provide a write up in this chapter because the impacts are minimal. Those sensitives are discussed further in the relevant preamble section, for example PHEV availability in HDPUV segment is discussed in Preamble Section II.D. For the LD analysis, all sensitivity cases with the exception of the Environmental Impact Statement RC (EIS-RC) are variants of the standard-setting RC that includes statutory restrictions (e.g., treatment of dedicated AFVs). The same statutory restrictions do not apply to HDPUVs and so both the RC and sensitivity analysis consider dedicated AFVs.

Table 9-1: Cases Included in the Sensitivity Analysis

Sensitivity Case	Description
RC	Reference case
EIS-RC	Reference case for Environmental Impact Statement (EIS)
Battery DMC +20%	Battery direct manufacturing cost (DMC) increased by 20 percent
Battery DMC -20%	Battery direct manufacturing cost (DMC) decreased by 20 percent
Battery learning rate +20%	Year-over-year percentage rate of learning increased by 20 percent
Battery learning rate -20%	Year-over-year percentage rate of learning decreased by 20 percent
BatPaC 90% cell yield	BatPaC model runs assume 90 percent cell yield
Annual vehicle redesigns	Vehicles redesigned every model year
Limited HCR skips	Removes all HCR skips
PHEV available MY 2025	Shifts initial HDPUV PHEV availability to MY 2025
PHEV available MY 2030	Shifts initial HDPUV PHEV availability to MY 2030
Oil price (AEO high)	Fuel prices from AEO 2022 High Oil Price case
Oil price (AEO low)	Fuel prices from AEO 2022 Low Oil Price case

Oil price (GI reference)	Fuel prices from Global Insights (GI) May 2022 Reference Case
High GDP + fuel (GI optimistic)	GDP and fuel prices from GI optimistic case
Low GDP + fuel (GI pessimistic)	GDP and fuel prices from GI pessimistic case
High GDP + fuel (AEO high)	GDP and fuel prices from AEO 2022 High Economic Growth case
Low GDP + fuel (AEO low)	GDP and fuel prices from AEO 2022 Low Economic Growth case
High GDP (GI optimistic)	GDP from GI optimistic case
Low GDP (GI pessimistic)	GDP from GI pessimistic case
Oil market externalities (low)	Price shock component set to 10th percentile of estimates.
Oil market externalities (high)	Price shock component set to 90th percentile of estimates.
No payback period	Payback period set to 0 months
24-month payback period	Payback period set to 24 months
30-month/70k miles payback	Valuation of fuel savings at 30 months for technology application, 70,000 miles for sales and scrappage models
36-month payback period	Payback period set to 36 months
60-month payback period	Payback period set to 60 months
Implicit opportunity cost	Includes a measure that estimates possible opportunity cost of forgone vehicle attribute improvements that exceed the central case 30-month payback period.
Rebound (5%)	Rebound effect set at 5 percent
Rebound (15%)	Rebound effect set at 15 percent
Sales-scrappage response (-0.1)	Sales-scrappage model with price elasticity multiplier of -0.1
Sales-scrappage response (-0.5)	Sales-scrappage model with price elasticity multiplier of -0.5
LDV sales (unadjusted)	No LD sales multiplier
LDV sales (2022 FR)	LD sales model coefficients equal to those used in the 2022 CAFE Final Rule
LDV sales (AEO 2022)	LD sales rate of change consistent with AEO 2022 Reference case
No fleet share price response	Fleet share elasticity estimate set to 0 (i.e., no fleet share response across alternatives)
Fixed fleet share, no price response	Fixed fleet share at AEO 2022 levels, fleet share elasticity set to zero
Fixed fleet share	Fleet share level fixed at 2022 value

HDPUV sales (AEO reference)	HDPUV sales based on AEO 2022 Reference Case (i.e., no initial sales ramp)
HDPUV sales (AEO low economic growth)	HDPUV sales based on AEO 2022 Low Economic Growth Case without initial sales ramp
HDPUV sales (AEO high economic growth)	HDPUV sales based on AEO 2022 High Economic Growth Case with initial sales ramp
Commercial operator sales share 100%	Assume all HDPUV vehicles are purchased by commercial operators. Applies commercial operator private net benefit offset.
Commercial operator sales share 50%	Assume half of all HDPUV vehicles are purchased by commercial operators. Applies commercial operator private net benefit offset.
Mass-size-safety (low)	The lower bound of the 95 percent confidence interval for all mass-size-safety model coefficients.
Mass-size-safety (high)	The upper bound of the 95 percent confidence interval for all mass-size-safety model coefficients.
Crash avoidance (low)	Lower-bound estimate of effectiveness of six current crash avoidance technologies at avoiding fatalities, injuries, and property damage
Crash avoidance (high)	Upper-bound estimate of effectiveness of six current crash avoidance technologies at avoiding fatalities, injuries, and property damage
2022 FR fatality rates	Fatality rates at 2022 CAFE Final Rule levels
Clean grid (low)	Upstream emissions factors based on AEO 2022 Low Renewables Costs projection of grid composition
Clean grid (high)	Upstream emissions factors based on NREL 95% Electrification by 2050 - 2021 Standard Scenario projection of grid composition
Adjusted MDPCS	Adjusted Minimum Domestic Passenger Car Standard (MDPCS) based on historical trends.
2023 revised civil penalty rate	Civil penalty set to values prescribed in 2023 Adjustment to Civil Penalties rule, 88 FR 6971(Feb. 2, 2023).
Standard-setting conditions to 2035	Applies standard-setting conditions for MY 2027-2035
Standard-setting conditions to 2050	Applies standard-setting conditions for MY 2027-2050
Standard-setting conditions all years	Applies standard-setting conditions for MY 2022-2050
No augural	No augural standards for MY 2032
No ZEV	Excludes modeling of ZEV program

EPA AC/OC approach	AC Leakage set to 0 for all vehicles for MY2027-MY2050; AC Efficiency Credits for BEVs set to 0 in MY2027-MY2050; AC/OC Credits for BEVs set to 0 in MY2027-2050; All Non-BEV vehicles have AC/OC credits gradually decline to 0 by MY 2031.
AC efficiency/OC BEV zero	Off-Cycle Credits and AC Efficiency Credits for BEVs set to 0 in MY2027-MY2050; AC Leakage is unchanged for all manufacturers
Original PEF value	PEF value used in prior CAFE rulemakings (82,049 Wh/gal)
No EV tax credits	All IRA EV tax credits removed
No AMPC	IRA Advanced Manufacturing Production tax credit (AMPC) removed
Consumer tax credit share 75%	Consumer tax credit share set to 75 percent (25 percent captured by manufacturers)
Consumer tax credit share 25%	Consumer tax credit share set to 25 percent (75 percent captured by manufacturers)
Maximum vehicle tax credit	Maximum value of IRA vehicle tax credit
Oil price (AEO 2023 high)	Fuel prices from the AEO 2023 High Oil Price Case
Oil price (AEO 2023 low)	Fuel prices from the AEO 2023 Low Oil Price Case
Oil price (AEO 2023 ref)	Fuel prices from the AEO 2023 Reference Case
High GDP (AEO 2023)	GDP from the AEO 2023 High Economic Growth case
Low GDP (AEO 2023)	GDP from the AEO 2023 Low Economic Growth case
Reference GDP (AEO 2023)	GDP from the AEO 2023 Reference case
Reference GDP (AEO 2022)	GDP from the AEO 2022 Reference case
High GDP + fuel (AEO 2023)	GDP and fuel prices from the AEO 2023 High Economic Growth case
Low GDP + fuel (AEO 2023)	GDP and fuel prices from the AEO 2023 Low Economic Growth case
Reference GDP + fuel (AEO 2023)	GDP and fuel prices from the AEO 2023 Reference case
Oil Market Externalities (AEO 2023)	Price shock component estimated using AEO 2023 oil market projections
LD Fleet Share (AEO 2023)	Fleet share based on AEO 2023 LD sales projection
Fixed fleet share (AEO 2023), no price response	Fleet share based on AEO 2023 LD sales projection, fleet share elasticity set to 0
HDPUV sales (AEO 2023)	HDPUV sales based on AEO 2023 Reference case projection (including sales ramp)
HDPUV sales (AEO 2023 reference)	HDPUV sales based on AEO 2023 Reference case projection (not including sales ramp)
HDPUV sales (AEO 2023 low economic growth)	HDPUV sales based on AEO 2023 Low Economic Growth case (including sales ramp)

HDPUV sales (AEO 2023 high economic growth)	HDPUV sales based on AEO 2023 High Economic Growth case (including sales ramp)

9.2. Summary of Sensitivity Results

9.2.1. Effect of Assumptions on Primary Cost and Benefit Measures

The sensitivity cases for this proposal can be grouped broadly into five categories based on the input parameter(s) they alter: technology, macroeconomics, payback/sales, policy, or social/environmental. This chapter includes figures that summarize the change in net benefits in each sensitivity case for the preferred alternative (Alternative PC2LT4 for LD and HDPUV10 for HDPUV) relative to the RC.[219] As stated previously, total SCs and benefits are computed on a model year basis for the LD fleet (MYs 1983-2032) and a CY basis for the HDPUV fleet (CYs 2022-2050).[220] Because fuel efficiency standards for HDPUV vehicles remain in place until new standards are set, HDPUV market benefits and costs are reported on a CY basis (i.e., CYs 2022-2050).

9.2.1.1. Light Duty

Figure 9-1 through Figure 9-5 illustrate the effect of varying an array of model input assumptions. The axis measuring net benefits is fixed across figures to ease comparison. The cases with some of the widest deviation in net benefits from the RC are those that modify oil prices and tax credit assumptions. Certain technology assumptions also produce large differences in benefits or costs, but—for reasons explained below—these scenarios test model logic more than represent likely real-world settings.

Table 9-2 and Table 9-3 present the full suite of sensitivity case results and summarize key output measures including fuel consumption and associated emissions, consumer costs and benefits, and aggregate social benefits, costs, and net benefits. Table 9-4 includes baseline technology penetration rates for a set of modeled technologies alongside the change in technology penetration rates under the preferred alternative. In this table, note that the technology penetration rates in the No-Action Alternative are not identical across scenarios because the assumptions in the sensitivity case affects behavior both in the No-Action Alternative and action alternatives, so comparing sensitivity cases must account for these baseline adjustments *and* the changes produced by the preferred alternative. Table 9-5 concludes the chapter and presents a subset of the columns of the three preceding tables, but with a social DR of seven percent.

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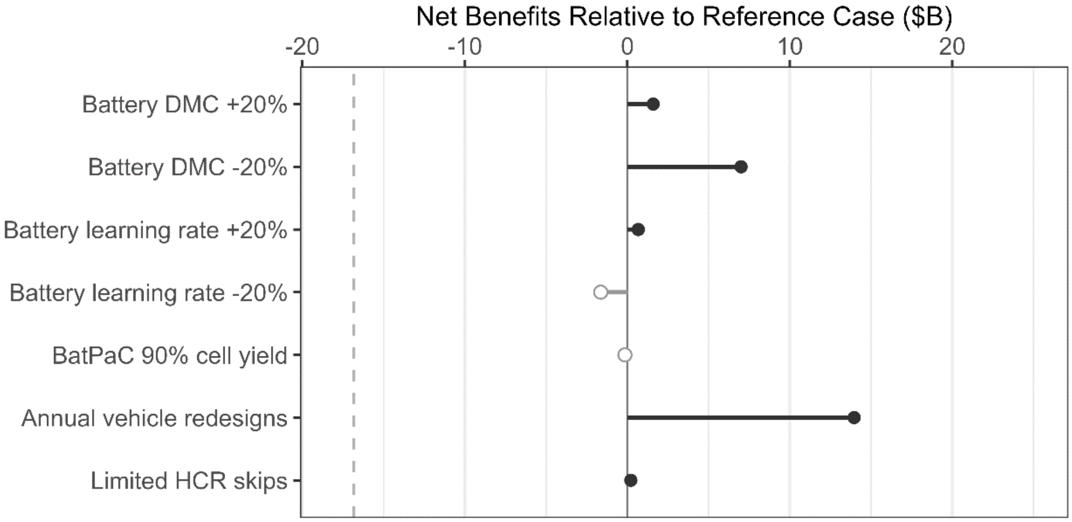
[219] The differences in net benefits may increase or decrease in other alternatives or discount rate assumptions, depending on the specific input being adjusted. Complete model outputs for these sensitivity cases are included in the online documentation, available at https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-compliance-and-effects-modeling-system.

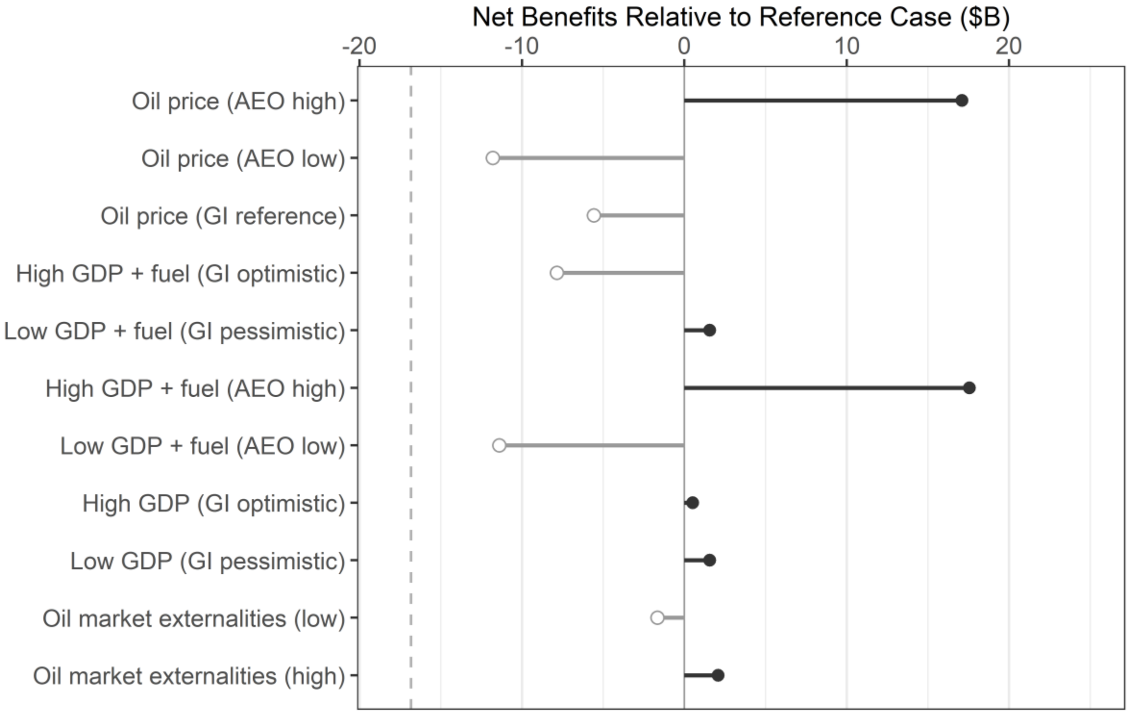
[220] Because HDPUV standards remain in place in perpetuity until adjusted, the analysis aggregates results for this fleet on a CY basis. Chapter 8.1 outlines the differences between *model year* analysis and *CY* analysis for the purposes of this proposal and discusses the use of the two methods in presenting results for the proposed CAFE standards.

Figure 9-1: Net Social Benefits, Alternative PC2LT4 Relative to the Reference Case, Technology Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



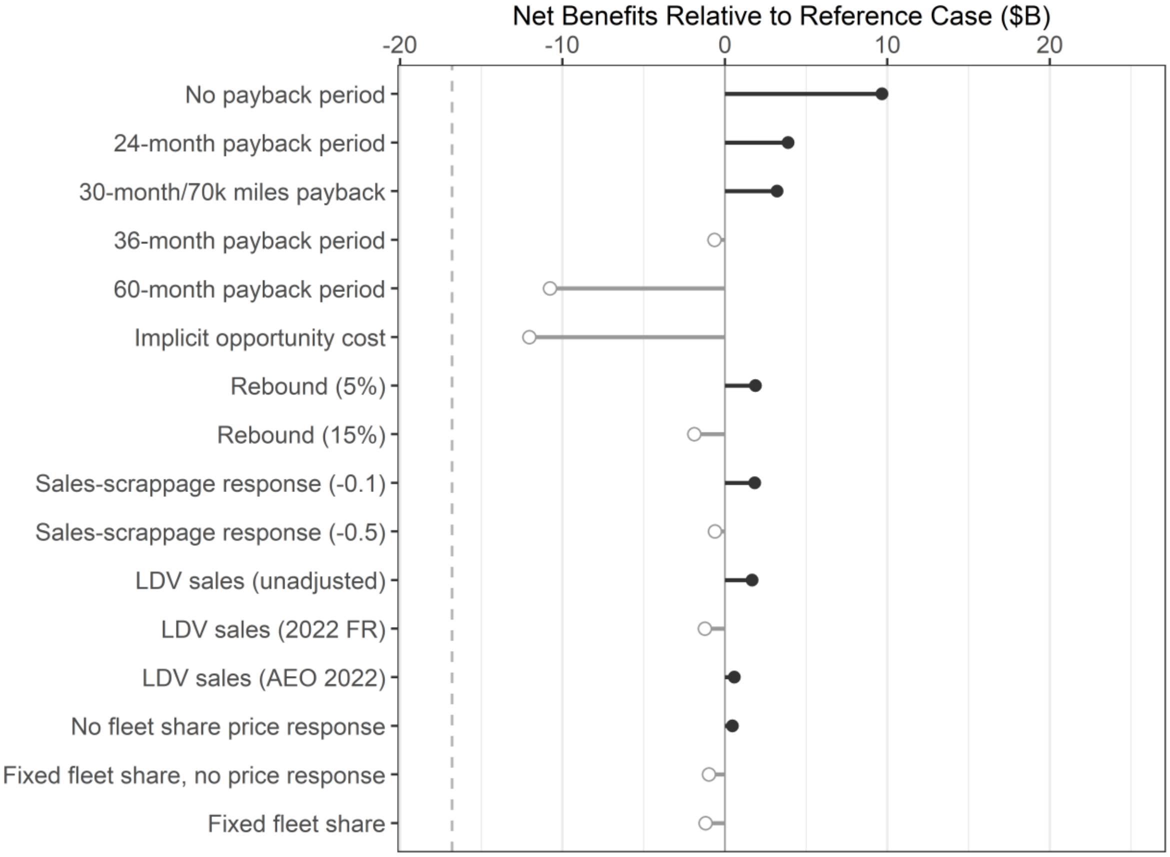
Note: All points right of the dashed line represent positive net benefits.

Figure 9-2: Net Social Benefits, Alternative PC2LT4 Relative to the Reference Case, Macroeconomic Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



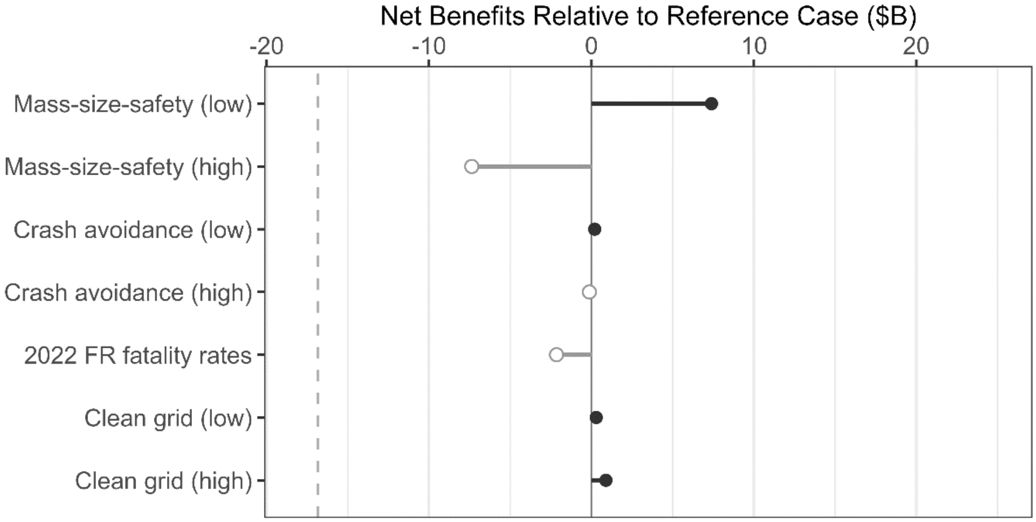
Note: All points right of the dashed line represent positive net benefits.

Figure 9-3: Net Social Benefits, Alternative PC2LT4 Relative to the Reference Case, Payback and Sales Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



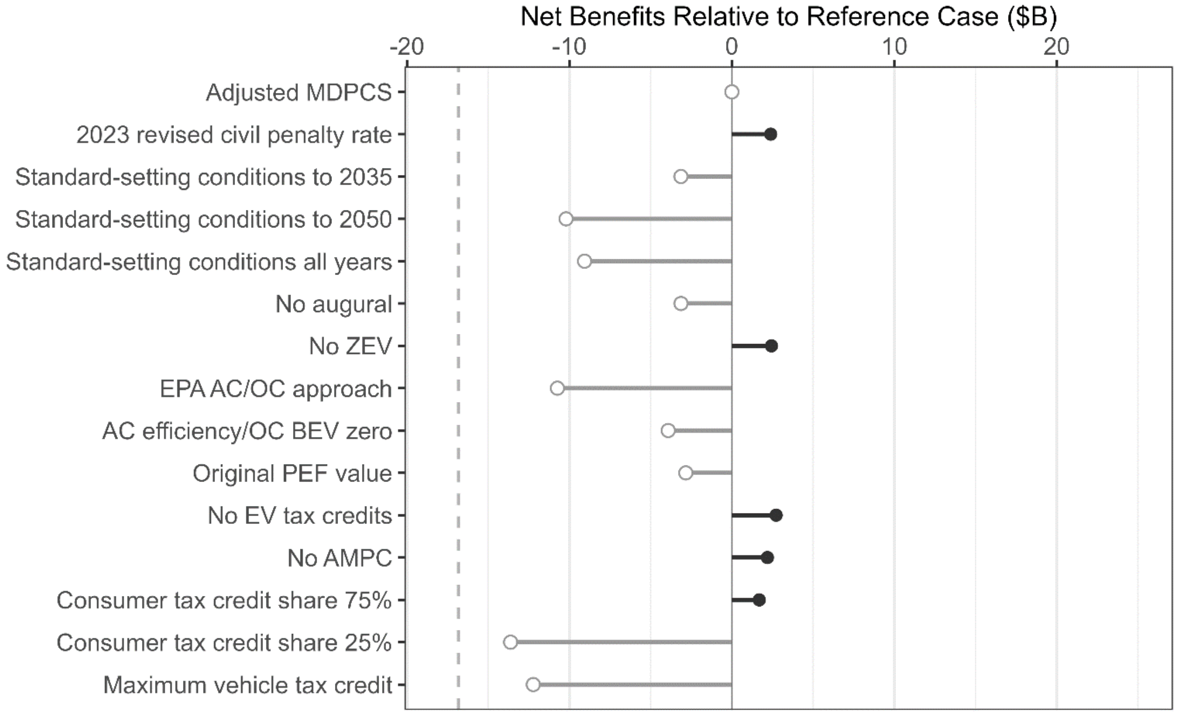
Note: All points right of the dashed line represent positive net benefits.

Figure 9-4: Net Social Benefits, Alternative PC2LT4 Relative to the Reference Case, Safety and Environmental Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



Note: All points right of the dashed line represent positive net benefits.

Figure 9-5: Net Social Benefits, Alternative PC2LT4 Relative to the Reference Case, Policy Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



Note: All points right of the dashed line represent positive net benefits.

Table 9-2: Aggregate Light-Duty Fleet Costs and Benefits Over the Lifetime of Vehicles Through MY 2032 for the Preferred Alternative (PC2LT4), by Sensitivity Case (2021$, 3 Percent DR, 3% SC-GHG DR)

Sensitivity Case	Total Social Costs ($b)	Total Social Benefits ($b)				Net Social Benefits ($b)			
		5%	3%	2.5%	3%, 95th pctile	5%	3%	2.5%	3%, 95th pctile
RC	58.6	65.0	75.5	82.9	103.9	6.3	16.8	24.3	45.2
EIS-RC	37.9	37.2	44.9	50.3	65.8	-0.7	7.0	12.5	27.9
Battery DMC +20%	58.0	65.8	76.4	83.9	105.1	7.8	18.4	26.0	47.2
Battery DMC -20%	68.6	79.3	92.4	101.7	127.9	10.7	23.8	33.1	59.3
Battery learning rate +20%	58.6	65.5	76.1	83.6	104.9	6.9	17.5	25.0	46.3
Battery learning rate -20%	53.6	59.4	68.8	75.5	94.4	5.8	15.2	21.9	40.8
BatPaC 90% cell yield	59.5	65.6	76.2	83.7	104.8	6.1	16.7	24.2	45.3
Annual vehicle redesigns	58.8	77.4	89.6	98.3	122.7	18.6	30.8	39.5	63.9
Limited HCR skips	62.3	68.4	79.4	87.2	109.2	6.1	17.1	24.9	46.8
Oil price (AEO high)	46.3	72.1	80.3	86.0	102.3	25.8	33.9	39.7	55.9
Oil price (AEO low)	57.5	51.2	62.5	70.5	93.1	-6.3	5.0	13.1	35.6
Oil price (GI reference)	55.7	56.6	67.0	74.4	95.1	0.9	11.3	18.6	39.4
High GDP + fuel (GI optimistic)	60.1	57.4	69.1	77.4	100.7	-2.7	9.0	17.3	40.6

Sensitivity Case	**Total Social Costs ($b)**	**Total Social Benefits ($b)**				**Net Social Benefits ($b)**			
		5%	**3%**	**2.5%**	**3%, 95th pctile**	**5%**	**3%**	**2.5%**	**3%, 95th pctile**
Low GDP + fuel (GI pessimistic)	55.5	63.6	73.9	81.2	101.8	8.1	18.4	25.7	46.3
High GDP + fuel (AEO high)	46.4	72.6	80.8	86.6	103.0	26.2	34.4	40.2	56.6
Low GDP + fuel (AEO low)	56.9	51.0	62.3	70.3	92.8	-5.8	5.4	13.4	35.9
High GDP (GI optimistic)	60.9	67.4	78.2	85.9	107.6	6.5	17.3	25.0	46.8
Low GDP (GI pessimistic)	55.5	63.6	73.9	81.2	101.8	8.1	18.4	25.7	46.3
Oil market externalities (low)	58.6	63.3	73.8	81.3	102.2	4.7	15.2	22.6	43.6
Oil market externalities (high)	58.6	67.1	77.6	85.0	106.0	8.4	18.9	26.4	47.3
No payback period	62.7	76.9	89.3	98.0	122.6	14.2	26.5	35.3	59.9
24-month payback period	62.3	71.5	83.1	91.3	114.3	9.2	20.7	28.9	52.0
30-month/70k miles payback	56.7	66.1	76.8	84.4	105.7	9.4	20.1	27.6	49.0
36-month payback period	62.2	67.2	78.3	86.3	108.5	5.1	16.2	24.1	46.3
60-month payback period	38.1	37.8	44.1	48.6	61.3	-0.3	6.1	10.6	23.2
Implicit opportunity cost	70.7	65.0	75.5	82.9	103.9	-5.7	4.8	12.2	33.2
Rebound (5%)	53.6	61.6	72.4	80.0	101.5	8.0	18.7	26.3	47.8
Rebound (15%)	63.6	68.4	78.6	85.8	106.3	4.7	15.0	22.2	42.7
Sales-scrappage response (-0.1)	58.1	66.1	76.8	84.4	105.7	8.0	18.7	26.2	47.6
Sales-scrappage response (-0.5)	58.8	64.6	75.0	82.4	103.2	5.8	16.2	23.6	44.5
LDV sales (unadjusted)	54.6	63.0	73.1	80.4	100.7	8.3	18.5	25.7	46.1
LDV sales (2022 FR)	60.2	65.3	75.8	83.3	104.3	5.1	15.6	23.1	44.1
LDV sales (AEO 2022)	57.7	64.7	75.1	82.5	103.3	7.0	17.4	24.8	45.6
No fleet share price response	58.4	65.2	75.7	83.2	104.3	6.8	17.3	24.8	45.8
Fixed fleet share, no price response	56.2	62.1	72.1	79.2	99.2	5.9	15.9	22.9	42.9
Fixed fleet share	56.2	61.9	71.9	79.0	98.9	5.7	15.6	22.7	42.6
Mass-size-safety (low)	50.9	64.7	75.1	82.6	103.5	13.7	24.2	31.7	52.6
Mass-size-safety (high)	66.3	65.3	75.8	83.3	104.2	-1.0	9.5	16.9	37.9
Crash avoidance (low)	58.8	65.3	75.8	83.3	104.2	6.5	17.0	24.5	45.4
Crash avoidance (high)	58.6	64.8	75.3	82.7	103.7	6.2	16.7	24.1	45.1
2022 FR fatality rates	59.4	63.6	74.1	81.5	102.5	4.2	14.7	22.1	43.1
Clean grid (low)	58.6	65.2	75.8	83.3	104.5	6.5	17.1	24.7	45.9
Clean grid (high)	58.6	65.5	76.4	84.1	105.8	6.9	17.7	25.4	47.1
Adjusted MDPCS	58.6	65.0	75.5	82.9	103.9	6.3	16.8	24.3	45.2
2023 revised civil penalty rate	57.0	65.7	76.3	83.8	105.0	8.6	19.2	26.7	47.9

Sensitivity Case	**Total Social Costs ($b)**	**Total Social Benefits ($b)**				**Net Social Benefits ($b)**			
		5%	**3%**	**2.5%**	**3%, 95th pctile**	**5%**	**3%**	**2.5%**	**3%, 95th pctile**
Standard-setting conditions to 2035	60.3	63.7	74.0	81.2	101.7	3.5	13.7	21.0	41.5
Standard-setting conditions to 2050	53.5	51.8	60.1	66.0	82.6	-1.7	6.6	12.5	29.1
Standard-setting conditions all years	44.8	45.3	52.6	57.8	72.3	0.5	7.8	12.9	27.5
No augural	56.5	60.5	70.2	77.2	96.7	4.0	13.7	20.6	40.1
No ZEV	90.7	94.7	109.9	120.8	151.3	4.0	19.3	30.1	60.6
EPA AC/OC approach	52.4	50.5	58.5	64.3	80.4	-2.0	6.1	11.8	27.9
AC efficiency/OC BEV zero	56.0	59.4	68.9	75.6	94.6	3.4	12.9	19.7	38.6
Original PEF value	39.7	46.2	53.7	59.0	74.0	6.5	14.0	19.3	34.3
No EV tax credits	53.4	62.8	73.0	80.2	100.6	9.4	19.6	26.8	47.1
No AMPC	51.9	61.0	70.9	78.0	97.8	9.1	19.0	26.1	45.9
Consumer tax credit share 75%	52.6	61.1	71.1	78.1	98.0	8.6	18.5	25.6	45.4
Consumer tax credit share 25%	38.1	35.5	41.3	45.4	57.0	-2.6	3.2	7.3	18.8
Maximum vehicle tax credit	45.8	43.2	50.4	55.6	70.1	-2.7	4.6	9.8	24.3
Oil price (AEO 2023 high)	44.8	63.6	70.8	75.9	90.1	18.9	26.0	31.1	45.3
Oil price (AEO 2023 low)	58.7	48.6	59.8	67.8	90.2	-10.1	1.1	9.1	31.5
Oil price (AEO 2023 ref)	54.3	60.5	70.4	77.5	97.4	6.1	16.1	23.2	43.1
High GDP (AEO 2023)	59.0	66.4	77.1	84.7	106.1	7.4	18.1	25.7	47.2
Low GDP (AEO 2023)	54.5	59.5	69.0	75.8	94.8	5.0	14.5	21.2	40.3
Reference GDP (AEO 2023)	58.1	63.9	74.2	81.5	102.2	5.8	16.2	23.5	44.1
Reference GDP (AEO 2022)	56.9	64.1	74.5	81.8	102.5	7.3	17.6	24.9	45.6
High GDP + fuel (AEO 2023)	56.8	65.2	75.7	83.2	104.2	8.3	18.8	26.3	47.4
Low GDP + fuel (AEO 2023)	53.9	57.5	67.3	74.3	94.0	3.6	13.4	20.4	40.1
Reference GDP + fuel (AEO 2023)	54.4	60.2	70.1	77.1	97.0	5.8	15.7	22.7	42.5
Oil Market Externalities (AEO 2023)	58.6	65.2	75.7	83.2	104.1	6.6	17.1	24.5	45.5
LD Fleet Share (AEO 2023)	55.9	61.7	71.6	78.6	98.3	5.8	15.6	22.6	42.4
Fixed fleet share (AEO 2023), no price response	55.9	62.1	72.0	79.1	98.9	6.1	16.1	23.1	43.0

Table 9-3: Selected Light-Duty Fleet Model Metrics for the Preferred Alternative (PC2LT4), by Sensitivity Case (2021$, 3 Percent DR)[221]

Sensitivity Case	Gasoline Consumption (b.gal)	Electricity Consumption (TWh)	CO_2 Emissions (MMT)	Fatalities	Criteria Emissions Deaths	MY 2032 Regulatory Cost ($/vehicle)	MY 2032 Lifetime Retail Fuel Expenditure ($/vehicle)	MY 2032 Sales	MY 2032 Jobs
RC	-88	312	-885	693	-367	932	-1,043	-81,972	6,773
EIS-RC	-42	282	-378	263	-272	298	-453	-11,599	4,188
Battery DMC +20%	-102	364	-1,059	808	-344	864	-1,105	-74,671	8,075
Battery DMC -20%	-132	738	-1,235	687	-761	1,344	-1,418	-103,570	13,151
Battery learning rate +20%	-91	381	-894	677	-417	991	-1,118	-80,941	7,151
Battery learning rate -20%	-87	249	-895	760	-385	834	-929	-80,589	6,338
BatPaC 90% cell yield	-103	344	-1,038	785	-435	909	-1,037	-83,219	6,778
Annual vehicle redesigns	-130	634	-1,253	800	-656	837	-1,122	-72,615	10,325
Limited HCR skips	-100	380	-1,002	799	-426	953	-1,092	-84,415	7,271
Oil price (AEO high)	-72	403	-681	347	-462	1,021	-1,113	-82,823	8,429
Oil price (AEO low)	-118	445	-1,181	715	-426	909	-878	-89,176	6,502
Oil price (GI reference)	-104	393	-1,040	678	-481	861	-891	-79,787	6,279
High GDP + fuel (GI optimistic)	-120	472	-1,190	705	-434	908	-911	-87,208	8,223
Low GDP + fuel (GI pessimistic)	-86	305	-862	676	-361	930	-1,102	-76,819	6,333
High GDP + fuel (AEO high)	-72	402	-677	351	-457	1,019	-1,120	-84,443	8,608
Low GDP + fuel (AEO low)	-118	446	-1,184	716	-428	909	-886	-89,775	6,555
High GDP (GI optimistic)	-92	321	-926	746	-409	914	-1,026	-83,799	7,887
Low GDP (GI pessimistic)	-86	305	-862	676	-361	930	-1,102	-76,819	6,333

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[221] Values for CY 2022-2050 unless otherwise noted.

Sensitivity Case	Gasoline Consumption (b.gal)	Electricity Consumption (TWh)	CO_2 Emissions (MMT)	Fatalities	Criteria Emissions Deaths	MY 2032 Regulatory Cost ($/vehicle)	MY 2032 Lifetime Retail Fuel Expenditure ($/vehicle)	MY 2032 Sales	MY 2032 Jobs
Oil market externalities (low)	-88	312	-885	693	-367	932	-1,043	-81,972	6,773
Oil market externalities (high)	-88	312	-885	693	-367	932	-1,043	-81,972	6,773
No payback period	-157	642	-1,553	1,144	-483	1,015	-1,392	-88,084	8,437
24-month payback period	-115	454	-1,148	832	-500	959	-1,204	-84,233	8,782
30-month/70k miles payback	-87	306	-875	665	-374	934	-1,049	-52,883	9,067
36-month payback period	-103	537	-981	636	-421	1,083	-1,187	-79,375	9,551
60-month payback period	-41	166	-404	154	-314	835	-555	-84,373	5,351
Implicit opportunity cost	-88	312	-885	693	-367	932	-1,043	-81,972	6,773
Rebound (5%)	-90	304	-904	303	-414	932	-1,072	-81,972	6,773
Rebound (15%)	-87	321	-866	1,084	-321	932	-1,015	-81,972	6,773
Sales-scrappage response (-0.1)	-88	313	-889	661	-381	930	-1,065	-20,620	10,823
Sales-scrappage response (-0.5)	-88	311	-884	704	-364	932	-1,035	-102,386	5,401
LDV sales (unadjusted)	-86	302	-862	677	-359	927	-1,117	-74,737	6,124
LDV sales (2022 FR)	-87	303	-879	711	-391	912	-990	-84,418	7,860
LDV sales (AEO 2022)	-85	277	-862	714	-377	910	-1,043	-80,921	7,883
No fleet share price response	-88	308	-887	688	-375	931	-1,038	-81,909	6,836
Fixed fleet share, no price response	-81	266	-823	721	-344	876	-977	-77,571	6,787
Fixed fleet share	-81	265	-819	720	-341	872	-983	-77,076	6,491
Mass-size-safety (low)	-88	312	-885	-601	-367	932	-1,043	-81,972	6,773

Sensitivity Case	Gasoline Consumption (b.gal)	Electricity Consumption (TWh)	CO$_2$ Emissions (MMT)	Fatalities	Criteria Emissions Deaths	MY 2032 Regulatory Cost ($/vehicle)	MY 2032 Lifetime Retail Fuel Expenditure ($/vehicle)	MY 2032 Sales	MY 2032 Jobs
Mass-size-safety (high)	-88	312	-885	1,985	-367	932	-1,043	-81,972	6,773
Crash avoidance (low)	-88	312	-885	717	-367	932	-1,043	-81,972	6,773
Crash avoidance (high)	-88	312	-885	660	-367	932	-1,043	-81,972	6,773
2022 FR fatality rates	-88	312	-885	916	-367	932	-1,043	-81,972	6,773
Clean grid (low)	-88	312	-899	693	-451	932	-1,043	-81,972	6,773
Clean grid (high)	-88	312	-929	693	-633	932	-1,043	-81,972	6,773
Adjusted MDPCS	-88	312	-885	693	-367	932	-1,043	-81,972	6,773
2023 revised civil penalty rate	-88	308	-880	683	-370	895	-1,048	-77,080	6,927
Standard-setting conditions to 2035	-92	288	-935	775	-403	925	-1,034	-82,043	6,629
Standard-setting conditions to 2050	-79	169	-824	762	-245	817	-887	-73,484	5,179
Standard-setting conditions all years	-59	159	-620	590	-172	617	-689	-51,659	4,810
No augural	-76	262	-764	601	-353	602	-804	-47,567	7,089
No ZEV	-173	706	-1,708	1,274	-838	1,894	-1,884	-174,661	14,938
EPA AC/OC approach	-92	368	-911	665	-436	1,393	-952	-154,145	7,398
AC efficiency/OC BEV zero	-87	280	-881	744	-370	1,066	-1,036	-104,255	5,238
Original PEF value	-56	160	-569	457	-212	541	-753	-40,055	6,270
No EV tax credits	-98	421	-968	697	-354	838	-1,045	-84,393	6,206
No AMPC	-92	362	-917	624	-276	831	-1,051	-73,519	6,700
Consumer tax credit share 75%	-90	348	-895	628	-237	833	-1,059	-66,797	7,346
Consumer tax credit share 25%	-52	224	-493	265	-368	790	-410	-90,123	1,774

Sensitivity Case	Gasoline Consumption (b.gal)	Electricity Consumption (TWh)	CO_2 Emissions (MMT)	Fatalities	Criteria Emissions Deaths	MY 2032 Regulatory Cost ($/vehicle)	MY 2032 Lifetime Retail Fuel Expenditure ($/vehicle)	MY 2032 Sales	MY 2032 Jobs
Maximum vehicle tax credit	-90	520	-842	436	-529	1,034	-685	-94,771	5,843
Oil price (AEO 2023 high)	-54	285	-524	291	-351	903	-838	-81,730	6,675
Oil price (AEO 2023 low)	-122	476	-1,218	692	-430	929	-823	-92,739	6,716
Oil price (AEO 2023 ref)	-92	338	-915	659	-403	850	-950	-77,161	6,116
High GDP (AEO 2023)	-91	324	-919	717	-383	932	-1,068	-81,950	6,790
Low GDP (AEO 2023)	-87	323	-867	652	-411	898	-947	-82,552	5,988
Reference GDP (AEO 2023)	-88	317	-881	685	-367	929	-1,022	-81,996	6,777
Reference GDP (AEO 2022)	-86	285	-866	710	-382	905	-1,041	-80,131	7,829
High GDP + fuel (AEO 2023)	-95	393	-932	660	-411	924	-1,073	-77,082	7,696
Low GDP + fuel (AEO 2023)	-89	303	-897	645	-390	839	-879	-79,283	5,854
Reference GDP + fuel (AEO 2023)	-91	334	-911	656	-401	856	-940	-77,575	6,233
Oil Market Externalities (AEO 2023)	-88	312	-885	693	-367	932	-1,043	-81,972	6,773
LD Fleet Share (AEO 2023)	-84	268	-848	714	-379	882	-986	-79,270	7,107
Fixed fleet share (AEO 2023), no price response	-83	260	-845	714	-375	883	-982	-79,521	7,275

Table 9-4: Light-Duty Fleet Penetration Rates of Selected Technologies for the Preferred Alternative (PC2LT4), by Sensitivity Case (Percent, MY 2032)

Sensitivity Case	HCR		SHEV		PHEV		BEV[222]	
	No Action	Change	No Action	Change	No Action	Change	No Action	Change
RC	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
EIS-RC	16.0	-0.4	10.3	-0.5	2.6	+0.5	52.8	+2.8
Battery DMC +20%	18.6	-4.9	24.3	+14.9	0.2	+3.4	32.3	0
Battery DMC -20%	17.9	-6.3	15.1	+6.5	9.1	+11.5	34.1	+0.1
Battery learning rate +20%	19.2	-6.5	21.5	+12.8	3.1	+6.6	32.3	0
Battery learning rate -20%	19.4	-6.2	21.1	+16.7	3.4	+2.3	32.3	0
BatPaC 90% cell yield	19.5	-6.2	21.2	+15.8	2.4	+3.4	32.5	0
Annual vehicle redesigns	19.6	-6.7	21.9	+17.8	3.2	+3.2	32.3	0
Limited HCR skips	28.7	-10.7	19.7	+16.3	2.7	+4.5	32.3	0
Oil price (AEO high)	11.9	-1.8	15.4	+0.9	25.6	+6.4	32.7	+0.1
Oil price (AEO low)	18.8	-6.3	23.8	+16.8	0	+3.7	32.3	0
Oil price (GI reference)	19.2	-6.4	21.2	+16.1	2.6	+3.5	32.3	0
High GDP + fuel (GI optimistic)	19.2	-6.1	23.2	+15.0	0.6	+4.4	32.3	0
Low GDP + fuel (GI pessimistic)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
High GDP + fuel (AEO high)	11.9	-1.8	15.5	+0.9	25.6	+6.4	32.7	+0.1
Low GDP + fuel (AEO low)	18.8	-6.3	23.8	+16.8	0	+3.7	32.3	0
High GDP (GI optimistic)	19.2	-6.4	21.9	+14.5	2.9	+4.6	32.3	0
Low GDP (GI pessimistic)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Oil market externalities (low)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Oil market externalities (high)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
No payback period	17.7	-5.6	22.0	+17.0	0	+3.7	32.2	0
24-month payback period	19.5	-6.4	22.0	+16.9	0.5	+4.0	32.4	0

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[222] Due to EPCA provisions, during our standard-setting years, the CAFE Model does not consider BEVs as a compliance strategy to achieve fuel economy standards. While BEV penetration values in this table fluctuate slightly, NHTSA has verified that this small variation is due to rounding associated with the vehicle sales module – the CAFE Model is not adding additional BEVs to the fleet in response to CAFE standards.

Sensitivity Case	HCR		SHEV		PHEV		BEV[222]	
	No Action	Change	No Action	Change	No Action	Change	No Action	Change
30-month/70k miles payback	19.2	-6.4	21.9	+15.0	2.9	+4.6	32.3	0
36-month payback period	19.1	-6.4	21.6	+9.2	4.1	+9.8	32.3	0
60-month payback period	5.4	-0.1	19.1	+0.8	33.9	+3.9	32.6	+0.1
Implicit opportunity cost	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Rebound (5%)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Rebound (15%)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Sales-scrappage response (-0.1)	19.2	-6.3	21.9	+15.1	2.9	+4.6	32.3	0
Sales-scrappage response (-0.5)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
LDV sales (unadjusted)	19.2	-6.3	21.9	+14.8	2.9	+4.6	32.3	0
LDV sales (2022 FR)	19.2	-6.4	21.9	+14.6	2.9	+4.5	32.3	0
LDV sales (AEO 2022)	19.6	-6.6	21.6	+15.4	2.9	+4.3	32.3	0
No fleet share price response	19.2	-6.4	21.9	+15.1	2.9	+4.6	32.3	0
Fixed fleet share, no price response	19.9	-5.9	21.7	+14.0	2.5	+4.2	32.8	0
Fixed fleet share	19.9	-5.9	21.7	+14.0	2.5	+4.2	32.8	0
Mass-size-safety (low)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Mass-size-safety (high)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Crash avoidance (low)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Crash avoidance (high)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
2022 FR fatality rates	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Clean grid (low)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Clean grid (high)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Adjusted MDPCS	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
2023 revised civil penalty rate	19.2	-6.4	21.8	+15.3	2.9	+4.5	32.3	0
Standard-setting conditions to 2035	19.2	-6.3	21.9	+15.2	2.9	+4.4	32.3	0
Standard-setting conditions to 2050	18.3	-6.4	23.6	+13.8	3.6	+3.8	32.2	0

Sensitivity Case	**HCR**		**SHEV**		**PHEV**		**BEV**[222]	
	No Action	**Change**	**No Action**	**Change**	**No Action**	**Change**	**No Action**	**Change**
Standard-setting conditions all years	15.6	-4.1	31.6	+8.8	2.2	+3.4	32.1	0
No augural	12.9	-3.8	19.1	+11.1	2.9	+3.4	45.3	0
No ZEV	24.8	-16.1	27.2	+28.5	3.8	+8.8	18.8	+0.1
EPA AC/OC approach	16.4	-7.0	31.9	+11.3	4.1	+4.4	32.3	0
AC efficiency/OC BEV zero	18.9	-6.9	24.2	+15.0	3.4	+4.0	32.4	0
Original PEF value	20.3	-4.1	18.4	+8.5	2.9	+3.6	32.3	0
No EV tax credits	18.5	-5.5	26.8	+14.1	0	+3.5	32.3	0
No AMPC	18.6	-5.4	26.0	+13.9	0.1	+3.7	32.3	0
Consumer tax credit share 75%	18.7	-5.4	25.9	+14.3	0	+3.7	32.3	0
Consumer tax credit share 25%	1.2	0	13.7	+2.0	43.3	+2.0	32.5	0
Maximum vehicle tax credit	2.5	-0.5	9.7	0	41.2	+5.7	33.8	+0.1
Oil price (AEO 2023 high)	7.1	-0.6	15.0	0	32.6	+4.4	33.1	+0.1
Oil price (AEO 2023 low)	18.9	-6.3	23.8	+16.6	0	+3.7	32.3	0
Oil price (AEO 2023 ref)	19.4	-6.6	21.2	+15.4	3.5	+3.5	32.3	0
High GDP (AEO 2023)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
Low GDP (AEO 2023)	19.1	-6.3	21.7	+14.6	3.5	+4.0	32.3	0
Reference GDP (AEO 2023)	19.2	-6.3	21.9	+14.7	2.9	+4.6	32.3	0
Reference GDP (AEO 2022)	19.6	-6.5	21.5	+15.0	2.9	+4.3	32.3	0
High GDP + fuel (AEO 2023)	19.4	-6.6	21.3	+13.3	3.8	+5.5	32.3	0
Low GDP + fuel (AEO 2023)	19.3	-6.4	21.6	+15.7	3.4	+3.2	32.3	0
Reference GDP + fuel (AEO 2023)	19.4	-6.6	21.2	+15.3	3.5	+3.6	32.3	0
Oil Market Externalities (AEO 2023)	19.2	-6.3	21.9	+15.0	2.9	+4.6	32.3	0
LD Fleet Share (AEO 2023)	19.4	-6.0	21.2	+15.1	3.1	+3.8	32.5	0
Fixed fleet share (AEO 2023), no price response	19.4	-6.0	21.2	+15.1	3.1	+3.9	32.5	0

Table 9-5: Aggregate Light-Duty Fleet Costs and Benefits Over the Lifetime of Vehicles Through MY 2032 for the Preferred Alternative (PC2LT4), by Sensitivity Case (2021$, 7 Percent Discount Rate, 3% SC-GHG DR)

Sensitivity Case	Total Social Costs ($b)	Total Social Benefits ($b)				Net Social Benefits ($b)				MY 2032 Regulatory Cost ($/vehicle)	MY 2032 Lifetime Retail Fuel Expenditure ($/vehicle)
		5%	3%	2.5%	3%, 95th pctile	5%	3%	2.5%	3%, 95th pctile		
RC	39.1	37.0	47.5	54.9	75.9	-2.1	8.4	15.8	36.8	932	-809
EIS-RC	25.3	22.0	29.7	35.1	50.6	-3.4	4.3	9.8	25.2	298	-354
Battery DMC +20%	38.3	37.3	47.9	55.5	76.7	-1.0	9.6	17.1	38.3	864	-853
Battery DMC -20%	45.1	45.0	58.1	67.4	93.5	-0.1	13.0	22.3	48.4	1,344	-1,098
Battery learning rate +20%	39.0	37.2	47.8	55.3	76.5	-1.9	8.7	16.3	37.5	991	-866
Battery learning rate -20%	35.8	33.8	43.2	49.9	68.8	-2.0	7.4	14.1	33.0	834	-721
BatPaC 90% cell yield	39.5	37.4	47.9	55.4	76.5	-2.2	8.4	15.9	37.0	909	-804
Annual vehicle redesigns	38.1	44.3	56.5	65.2	89.6	6.2	18.4	27.1	51.5	837	-869
Limited HCR skips	41.4	38.9	49.9	57.7	79.7	-2.5	8.5	16.3	38.3	953	-846
Oil price (AEO high)	31.1	40.6	48.7	54.5	70.7	9.5	17.6	23.4	39.6	1,021	-861
Oil price (AEO low)	37.8	29.5	40.8	48.9	71.4	-8.2	3.0	11.1	33.6	909	-682
Oil price (GI reference)	37.0	32.6	43.0	50.4	71.2	-4.4	6.0	13.4	34.2	861	-694
High GDP + fuel (GI optimistic)	39.7	33.1	44.8	53.0	76.3	-6.6	5.1	13.4	36.7	908	-703
Low GDP + fuel (GI pessimistic)	36.9	36.0	46.3	53.6	74.2	-0.8	9.5	16.8	37.3	930	-850
High GDP + fuel (AEO high)	31.1	40.8	49.0	54.8	71.2	9.7	17.9	23.7	40.1	1,019	-865
Low GDP + fuel (AEO low)	37.3	29.4	40.7	48.7	71.2	-7.9	3.3	11.3	33.8	909	-687
High GDP (GI optimistic)	40.7	38.4	49.3	57.0	78.7	-2.3	8.6	16.3	38.0	914	-797
Low GDP (GI pessimistic)	36.9	36.0	46.3	53.6	74.2	-0.8	9.5	16.8	37.3	930	-850
Oil market externalities (low)	39.1	36.1	46.6	54.0	75.0	-3.0	7.5	14.9	35.9	932	-809
Oil market externalities (high)	39.1	38.1	48.6	56.0	77.0	-1.0	9.5	16.9	37.9	932	-809
No payback period	41.6	43.2	55.5	64.3	88.9	1.6	13.9	22.7	47.3	1,015	-1,073
24-month payback period	41.4	40.6	52.1	60.3	83.4	-0.8	10.8	18.9	42.0	959	-931
30-month/70k miles payback	38.1	37.6	48.3	55.9	77.2	-0.5	10.2	17.8	39.1	934	-813

Sensitivity Case	Total Social Costs ($b)	Total Social Benefits ($b)				Net Social Benefits ($b)				MY 2032 Regulatory Cost ($/vehicle)	MY 2032 Lifetime Retail Fuel Expenditure ($/vehicle)
		5%	3%	2.5%	3%, 95th pctile	5%	3%	2.5%	3%, 95th pctile		
36-month payback period	41.3	38.1	49.2	57.2	79.4	-3.2	8.0	15.9	38.1	1,083	-918
60-month payback period	25.3	21.5	27.9	32.4	45.0	-3.8	2.5	7.0	19.7	835	-428
Implicit opportunity cost	46.3	37.0	47.5	54.9	75.9	-9.3	1.2	8.6	29.6	932	-809
Rebound (5%)	36.4	35.2	45.9	53.6	75.1	-1.2	9.6	17.2	38.7	932	-832
Rebound (15%)	41.8	38.8	49.0	56.3	76.7	-3.1	7.2	14.4	34.9	932	-786
Sales-scrappage response (-0.1)	38.7	37.7	48.4	55.9	77.3	-1.0	9.7	17.2	38.6	930	-825
Sales-scrappage response (-0.5)	39.2	36.7	47.2	54.5	75.4	-2.5	7.9	15.3	36.2	932	-803
LDV sales (unadjusted)	36.3	35.7	45.9	53.1	73.5	-0.5	9.6	16.9	37.2	927	-864
LDV sales (2022 FR)	40.3	37.2	47.7	55.2	76.2	-3.1	7.4	14.9	35.9	912	-768
LDV sales (AEO 2022)	38.4	36.7	47.1	54.5	75.3	-1.7	8.7	16.1	36.9	910	-808
No fleet share price response	39.0	37.1	47.6	55.1	76.2	-1.9	8.7	16.1	37.2	931	-805
Fixed fleet share, no price response	37.5	35.4	45.3	52.4	72.4	-2.1	7.8	14.9	34.9	876	-757
Fixed fleet share	37.5	35.2	45.2	52.3	72.2	-2.3	7.7	14.8	34.7	872	-762
Mass-size-safety (low)	35.0	36.8	47.3	54.7	75.7	1.8	12.3	19.7	40.7	932	-809
Mass-size-safety (high)	43.2	37.2	47.7	55.1	76.1	-6.0	4.4	11.9	32.9	932	-809
Crash avoidance (low)	39.2	37.2	47.7	55.1	76.1	-2.0	8.5	15.9	36.9	932	-809
Crash avoidance (high)	39.1	36.9	47.4	54.8	75.8	-2.2	8.3	15.7	36.7	932	-809
2022 FR fatality rates	39.6	36.2	46.6	54.1	75.1	-3.4	7.1	14.5	35.5	932	-809
Clean grid (low)	39.1	37.1	47.7	55.2	76.4	-2.0	8.6	16.1	37.3	932	-809
Clean grid (high)	39.1	37.3	48.1	55.8	77.5	-1.8	9.0	16.7	38.4	932	-809
Adjusted MDPCS	39.1	37.0	47.5	54.9	75.9	-2.1	8.4	15.8	36.8	932	-809
2023 revised civil penalty rate	38.0	37.4	48.0	55.5	76.7	-0.6	10.0	17.5	38.7	895	-812
Standard-setting conditions to 2035	39.8	36.3	46.5	53.8	74.3	-3.6	6.7	14.0	34.4	925	-802
Standard-setting conditions to 2050	34.6	29.6	37.8	43.7	60.3	-5.1	3.2	9.1	25.7	817	-689

Sensitivity Case	**Total Social Costs ($b)**	**Total Social Benefits ($b)**				**Net Social Benefits ($b)**				**MY 2032 Regulatory Cost ($/vehicle)**	**MY 2032 Lifetime Retail Fuel Expenditure ($/vehicle)**
		5%	**3%**	**2.5%**	**3%, 95th pctile**	**5%**	**3%**	**2.5%**	**3%, 95th pctile**		
Standard-setting conditions all years	29.3	26.1	33.4	38.5	53.1	-3.2	4.1	9.3	23.9	617	-536
No augural	37.7	34.6	44.3	51.3	70.8	-3.1	6.6	13.5	33.0	602	-623
No ZEV	59.4	53.4	68.7	79.5	110.0	-6.0	9.3	20.1	50.6	1,894	-1,461
EPA AC/OC approach	34.3	28.4	36.5	42.2	58.3	-5.8	2.2	7.9	24.0	1,393	-739
AC efficiency/OC BEV zero	37.0	33.7	43.2	49.9	68.9	-3.4	6.1	12.9	31.9	1,066	-804
Original PEF value	26.0	26.3	33.8	39.1	54.1	0.3	7.8	13.1	28.1	541	-584
No EV tax credits	35.8	35.6	45.8	53.0	73.4	-0.2	10.0	17.2	37.6	838	-807
No AMPC	34.5	34.6	44.5	51.5	71.4	0.1	10.0	17.0	36.9	831	-812
Consumer tax credit share 75%	34.7	34.7	44.6	51.7	71.5	-0.1	9.9	16.9	36.8	833	-818
Consumer tax credit share 25%	25.9	20.4	26.2	30.3	41.8	-5.5	0.3	4.4	15.9	790	-318
Maximum vehicle tax credit	30.6	24.5	31.8	36.9	51.4	-6.1	1.2	6.3	20.8	1,034	-528
Oil price (AEO 2023 high)	30.0	36.3	43.5	48.5	62.8	6.3	13.4	18.5	32.8	903	-650
Oil price (AEO 2023 low)	38.7	28.1	39.4	47.3	69.8	-10.6	0.7	8.6	31.1	929	-638
Oil price (AEO 2023 ref)	36.3	34.5	44.5	51.6	71.5	-1.8	8.2	15.3	35.2	850	-737
High GDP (AEO 2023)	39.3	37.8	48.5	56.1	77.5	-1.5	9.2	16.8	38.3	932	-828
Low GDP (AEO 2023)	36.5	33.9	43.4	50.2	69.2	-2.6	6.9	13.7	32.7	898	-736
Reference GDP (AEO 2023)	38.8	36.4	46.8	54.1	74.7	-2.3	8.0	15.3	35.9	929	-794
Reference GDP (AEO 2022)	37.9	36.4	46.7	54.1	74.7	-1.5	8.8	16.2	36.8	905	-805
High GDP + fuel (AEO 2023)	37.9	37.1	47.6	55.1	76.1	-0.8	9.7	17.2	38.2	924	-832
Low GDP + fuel (AEO 2023)	36.0	33.0	42.9	49.9	69.6	-3.0	6.9	13.9	33.6	839	-686
Reference GDP + fuel (AEO 2023)	36.4	34.4	44.3	51.4	71.2	-1.9	8.0	15.0	34.8	856	-731
Oil Market Externalities (AEO 2023)	39.1	37.1	47.6	55.0	76.0	-2.0	8.5	15.9	36.9	932	-809
LD Fleet Share (AEO 2023)	37.4	35.1	45.0	52.0	71.7	-2.3	7.6	14.6	34.3	882	-765
Fixed fleet share (AEO 2023), no price response	37.4	35.3	45.2	52.3	72.2	-2.1	7.9	14.9	34.8	883	-761

9.2.1.2. HDPUV

As in the chapter immediately below, Figure 9-6 through Figure 9-10 illustrate the effect of varying an array of model input assumptions. The axis measuring net benefits is fixed across figures to ease comparison. In the HDPUV context, input assumptions broadly fall into two groupings: those that produce large effects on net benefit estimates and those that result in rather muted outcomes. This differs from the sensitivity analysis outcomes in the LD fleet. Most of the bimodal nature of these sensitivity case outcomes is the result of the smaller size of the HDPUV fleet and fact that large portions of the fleet respond together. As expected, the scenarios that produce the largest change in net benefits are those that alter the costs of electrification (e.g., battery costs, tax credits) or those that affect electrification benefits (e.g., oil price forecasts).

The remaining tables in this chapter mirror those included in the LD chapter above. Table 9-6 and Table 9-7 present the full suite of sensitivity case results and summarize key output measures including fuel consumption and associated emissions, consumer costs and benefits, and aggregate social benefits, costs, and net benefits. Table 9-8 includes baseline technology penetration rates for a set of modeled technologies alongside the change in technology penetration rates under the preferred alternative. The table includes some technologies that are more prevalent in the HDPUV fleet and were therefore not included in the LD sensitivity summary. In this table, note that the technology penetration rates for MY 2038 vehicles in the No-Action Alternative are not identical across sensitivity cases because the assumptions in the sensitivity case affects behavior both in the No-Action Alternative and action alternatives, so comparing across scenarios must account for these differences *and* the changes produced by the preferred alternative. Table 9-9 concludes the chapter and presents a subset of the columns of the three preceding tables, but with a social DR of seven percent.

Figure 9-6: Net Social Benefits, Alternative HDPUV10 Relative to the Reference Case, Technology Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)

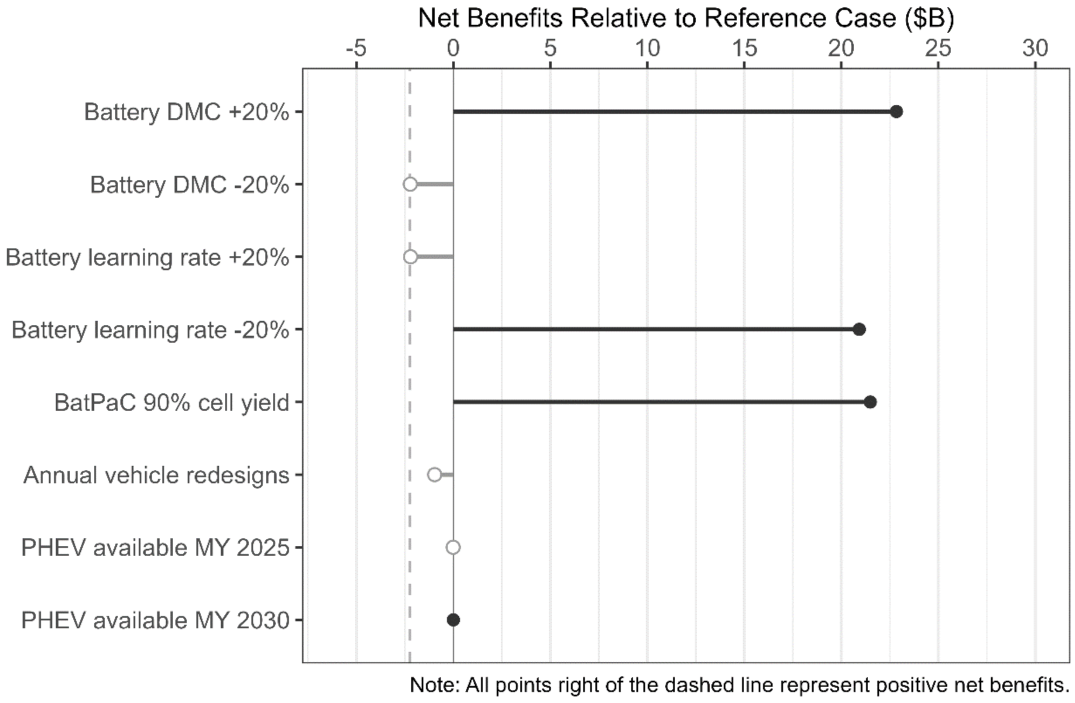
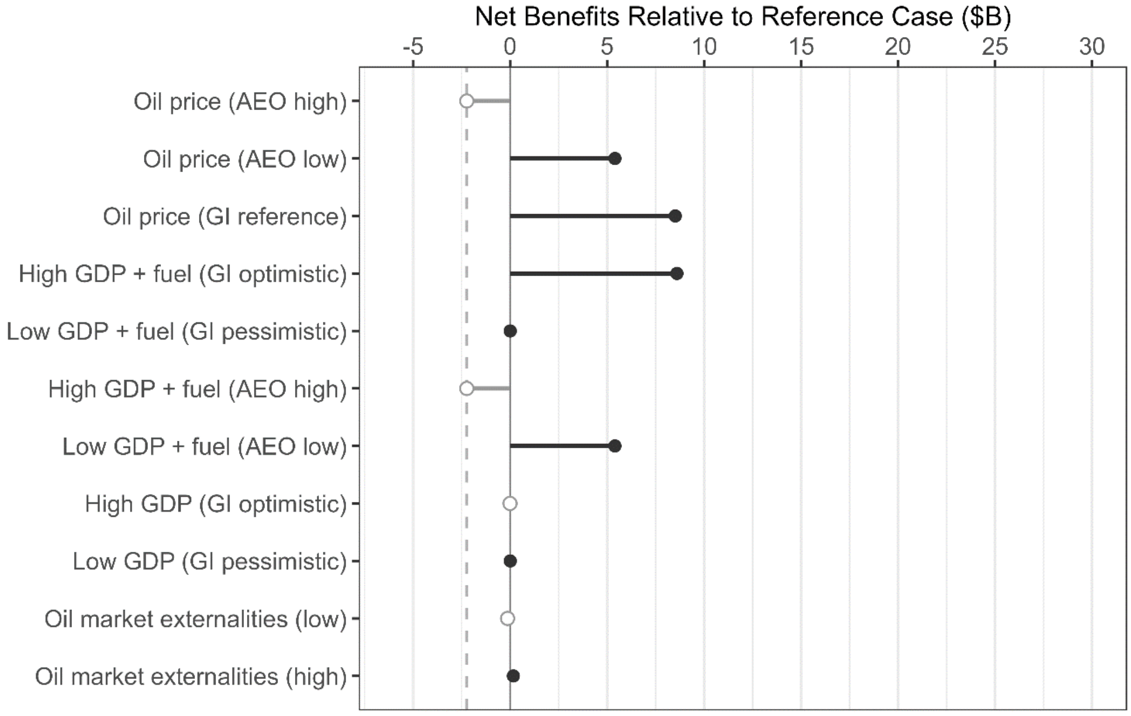
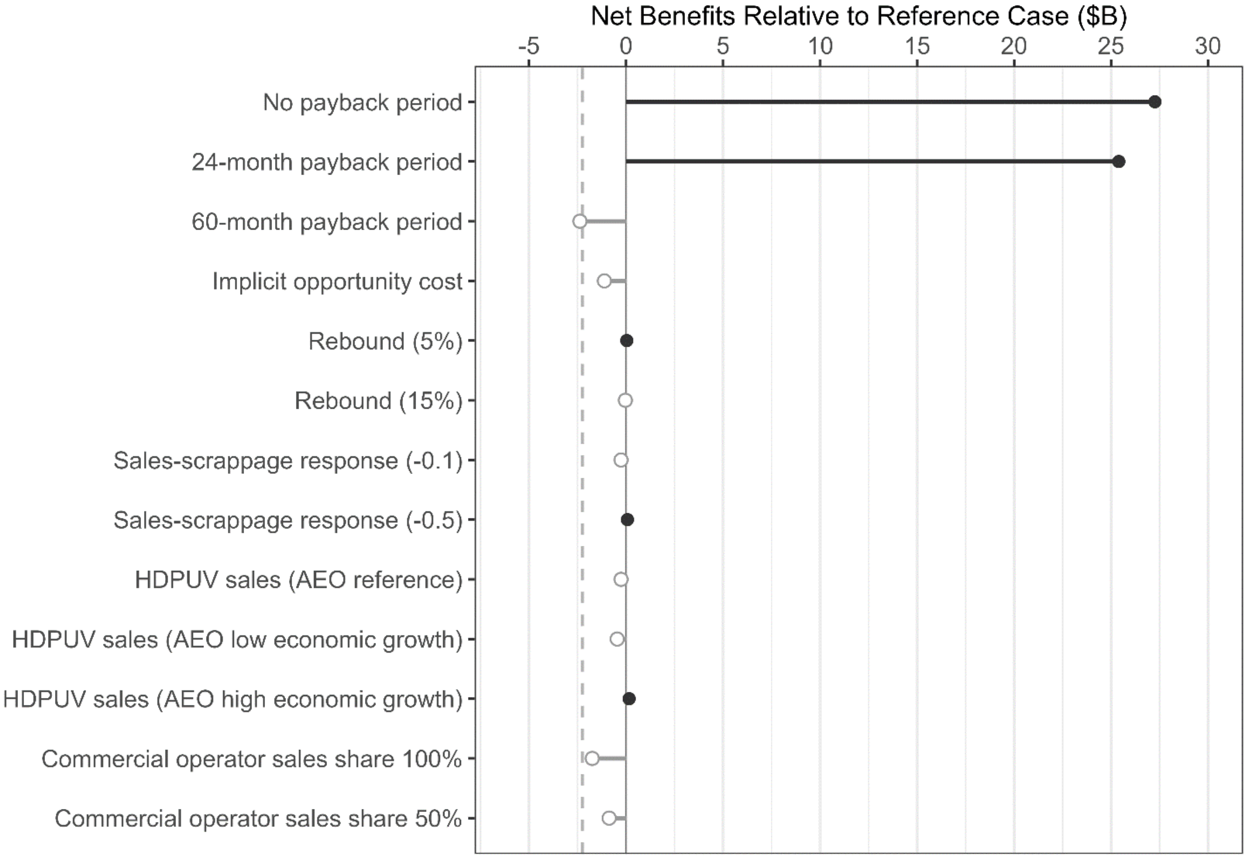


Figure 9-7: Net Social Benefits, Alternative HDPUV10 Relative to the Reference Case, Macroeconomic Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



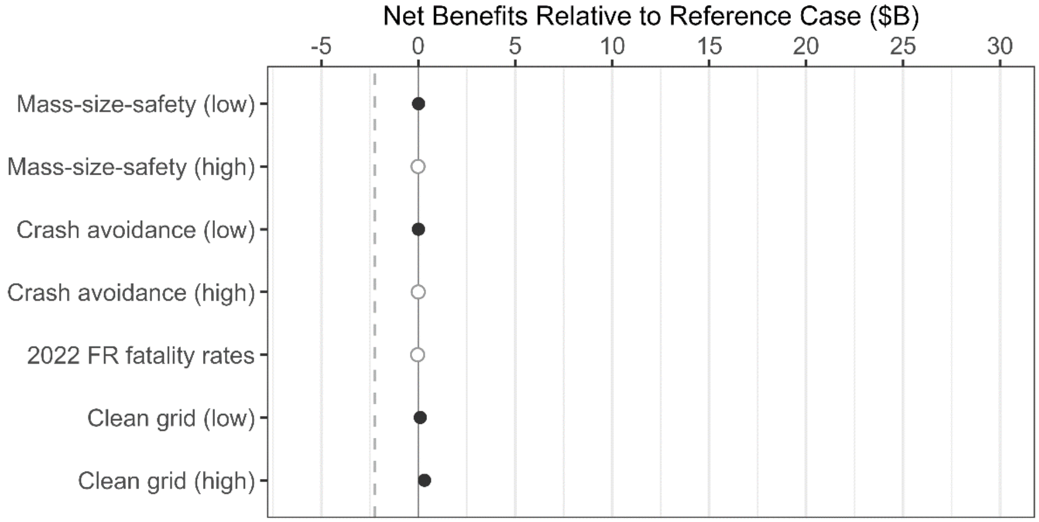
Note: All points right of the dashed line represent positive net benefits.

Figure 9-8: Net Social Benefits, Alternative HDPUV10 Relative to the Reference Case, Sales and Payback Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



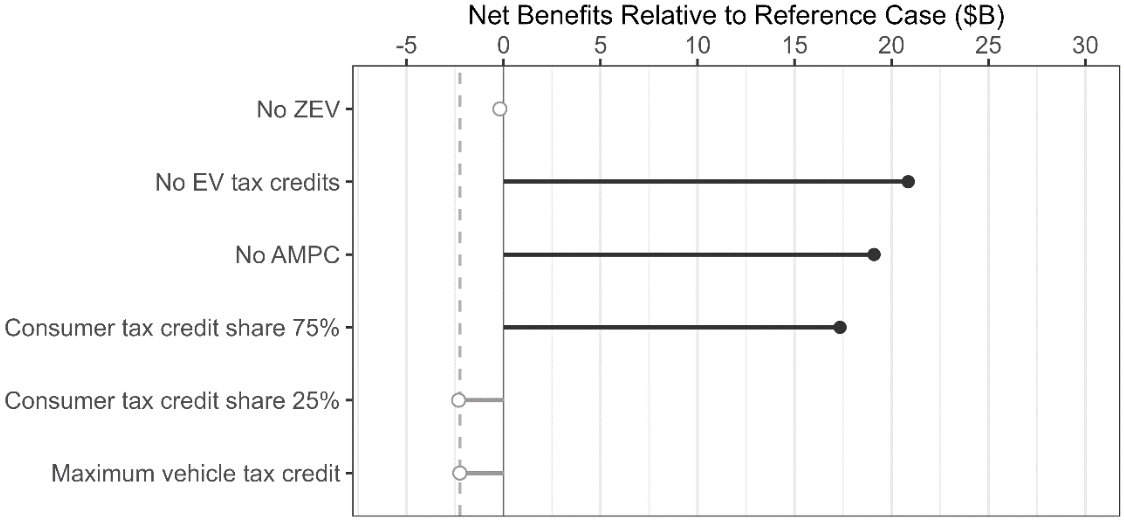
Note: All points right of the dashed line represent positive net benefits.

Figure 9-9: Net Social Benefits, Alternative HDPUV10 Relative to the Reference Case, Social and Environmental Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



Note: All points right of the dashed line represent positive net benefits.

Figure 9-10: Net Social Benefits, Alternative HDPUV10 Relative to the Reference Case, Policy Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



Note: All points right of the dashed line represent positive net benefits.

Table 9-6: Aggregate HDPUV Fleet Costs and Benefits in CY 2022-2050 for the Preferred Alternative (HDPUV10), by Sensitivity Case (2021$, 3 Percent DR, 3% SC-GHG DR)

Sensitivity Case	Total Social Costs ($b)	Total Social Benefits ($b)				Net Social Benefits ($b)			
		5%	3%	2.5%	3%, 95th pctile	5%	3%	2.5%	3%, 95th pctile
RC	2.07	3.58	4.32	4.85	6.31	1.50	2.25	2.78	4.24
Battery DMC +20%	41.50	51.91	66.58	77.13	105.88	10.41	25.08	35.63	64.37
Battery DMC -20%	0.06	0.07	0.09	0.11	0.15	0.00	0.03	0.04	0.09
Battery learning rate +20%	0.06	0.07	0.10	0.11	0.16	0.02	0.04	0.06	0.10
Battery learning rate -20%	35.33	45.30	58.50	67.97	93.88	9.97	23.17	32.64	58.55
BatPaC 90% cell yield	40.37	49.78	64.11	74.41	102.47	9.41	23.74	34.03	62.09
Annual vehicle redesigns	1.07	1.96	2.35	2.63	3.40	0.89	1.28	1.56	2.33
PHEV available MY 2025	2.08	3.57	4.31	4.85	6.30	1.49	2.23	2.77	4.22
PHEV available MY 2030	2.07	3.58	4.32	4.85	6.31	1.50	2.25	2.78	4.24
Oil price (AEO high)	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Oil price (AEO low)	37.59	28.22	45.24	57.48	90.80	-9.38	7.65	19.88	53.20
Oil price (GI reference)	13.94	19.17	24.69	28.66	39.46	5.23	10.76	14.73	25.52
High GDP + fuel (GI optimistic)	37.28	31.48	48.12	60.08	92.65	-5.80	10.84	22.80	55.38
Low GDP + fuel (GI pessimistic)	2.07	3.58	4.33	4.86	6.32	1.51	2.25	2.79	4.24
High GDP + fuel (AEO high)	0.00	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Low GDP + fuel (AEO low)	37.60	28.22	45.25	57.49	90.82	-9.38	7.65	19.89	53.21
High GDP (GI optimistic)	2.07	3.57	4.31	4.85	6.30	1.50	2.24	2.77	4.23
Low GDP (GI pessimistic)	2.07	3.58	4.33	4.86	6.32	1.51	2.25	2.79	4.24
Oil market externalities (low)	2.07	3.44	4.19	4.72	6.18	1.37	2.11	2.65	4.10
Oil market externalities (high)	2.07	3.74	4.49	5.02	6.48	1.67	2.41	2.95	4.40
No payback period	42.96	55.46	72.47	84.69	118.00	12.49	29.50	41.73	75.04
24-month payback period	36.68	50.07	64.32	74.55	102.54	13.38	27.64	37.87	65.86
60-month payback period	0.04	-0.11	-0.09	-0.07	-0.03	-0.15	-0.13	-0.12	-0.08
Implicit opportunity cost	3.19	3.58	4.32	4.85	6.31	0.38	1.13	1.66	3.12

Sensitivity Case	Total Social Costs ($b)	Total Social Benefits ($b)				Net Social Benefits ($b)			
		5%	3%	2.5%	3%, 95th pctile	5%	3%	2.5%	3%, 95th pctile
Rebound (5%)	1.97	3.50	4.25	4.80	6.27	1.53	2.28	2.82	4.30
Rebound (15%)	2.18	3.65	4.38	4.91	6.35	1.47	2.21	2.74	4.18
Sales-scrappage response (-0.1)	2.22	3.48	4.21	4.73	6.16	1.26	1.99	2.51	3.94
Sales-scrappage response (-0.5)	1.95	3.54	4.26	4.78	6.18	1.60	2.32	2.83	4.24
HDPUV sales (AEO reference)	1.70	3.08	3.68	4.12	5.30	1.38	1.99	2.42	3.60
HDPUV sales (AEO low economic growth)	1.51	2.76	3.29	3.68	4.73	1.25	1.79	2.18	3.23
HDPUV sales (AEO high economic growth)	2.14	3.78	4.54	5.09	6.57	1.64	2.40	2.95	4.44
Commercial operator sales share 100%	3.82	3.58	4.32	4.85	6.31	-0.24	0.50	1.04	2.49
Commercial operator sales share 50%	2.95	3.58	4.32	4.85	6.31	0.63	1.37	1.91	3.36
Mass-size-safety (low)	2.07	3.59	4.33	4.87	6.32	1.52	2.26	2.80	4.25
Mass-size-safety (high)	2.07	3.56	4.31	4.84	6.29	1.49	2.23	2.77	4.22
Crash avoidance (low)	2.07	3.58	4.33	4.86	6.32	1.51	2.25	2.79	4.24
Crash avoidance (high)	2.07	3.57	4.31	4.85	6.30	1.50	2.24	2.78	4.23
2022 FR fatality rates	2.07	3.54	4.28	4.82	6.27	1.47	2.21	2.75	4.20
Clean grid (low)	2.07	3.63	4.42	4.99	6.53	1.56	2.35	2.91	4.46
Clean grid (high)	2.07	3.75	4.64	5.28	7.01	1.68	2.56	3.20	4.94
No ZEV	2.38	3.57	4.44	5.06	6.77	1.19	2.06	2.68	4.39
No EV tax credits	28.48	40.37	51.59	59.63	81.75	11.89	23.11	31.15	53.27
No AMPC	28.13	38.61	49.48	57.26	78.67	10.48	21.35	29.13	50.55
Consumer tax credit share 75%	29.07	37.79	48.66	56.44	77.86	8.73	19.59	27.38	48.80
Consumer tax credit share 25%	-0.16	-0.18	-0.23	-0.26	-0.37	-0.02	-0.07	-0.11	-0.21
Maximum vehicle tax credit	-0.02	-0.02	-0.03	-0.03	-0.05	0.00	-0.01	-0.01	-0.03
Oil price (AEO 2023 high)	0.03	-0.01	0.00	0.00	0.02	-0.04	-0.03	-0.03	-0.01

Sensitivity Case	Total Social Costs ($b)	Total Social Benefits ($b)				Net Social Benefits ($b)			
		5%	3%	2.5%	3%, 95th pctile	5%	3%	2.5%	3%, 95th pctile
Oil price (AEO 2023 low)	36.77	25.88	42.91	55.15	88.49	-10.89	6.14	18.38	51.72
Oil price (AEO 2023 ref)	10.71	15.35	19.41	22.33	30.30	4.63	8.70	11.62	19.58
High GDP (AEO 2023)	2.07	3.57	4.31	4.85	6.30	1.50	2.24	2.78	4.23
Low GDP (AEO 2023)	2.07	3.58	4.32	4.86	6.32	1.51	2.25	2.79	4.24
Reference GDP (AEO 2023)	2.07	3.57	4.32	4.85	6.31	1.50	2.25	2.78	4.23
Reference GDP (AEO 2022)	2.07	3.58	4.32	4.85	6.31	1.50	2.25	2.78	4.24
High GDP + fuel (AEO 2023)	-0.09	-0.10	-0.13	-0.15	-0.21	-0.01	-0.04	-0.06	-0.12
Low GDP + fuel (AEO 2023)	11.15	15.10	19.45	22.57	31.09	3.95	8.30	11.42	19.94
Reference GDP + fuel (AEO 2023)	10.71	15.34	19.41	22.33	30.29	4.63	8.70	11.62	19.58
Oil Market Externalities (AEO 2023)	2.07	3.60	4.34	4.88	6.33	1.52	2.27	2.80	4.26
HDPUV sales (AEO 2023)	2.15	3.76	4.53	5.08	6.59	1.61	2.38	2.94	4.44
HDPUV sales (AEO 2023 reference)	1.74	3.24	3.85	4.29	5.49	1.50	2.11	2.56	3.76
HDPUV sales (AEO 2023 low economic growth)	1.98	3.44	4.15	4.66	6.04	1.46	2.16	2.67	4.05
HDPUV sales (AEO 2023 high economic growth)	2.27	4.07	4.88	5.47	7.06	1.80	2.61	3.20	4.79

Table 9-7: Selected HDPUV Fleet Model Metrics for the Preferred Alternative (HDPUV10), by Sensitivity Case (2021$, 3 Percent DR)[223]

Sensitivity Case	Gasoline Consumption (b.gal)	Electricity Consumption (TWh)	CO_2 Emissions (MMT)	Fatalities	Criteria Emissions Deaths	MY 2038 Regulatory Cost ($/vehicle)	MY 2038 Lifetime Retail Fuel Expenditure ($/vehicle)	MY 2038 Sales	MY 2038 Jobs
RC	-3	24	-22	1	-11	131	-439	-576	-34
Battery DMC +20%	-53	499	-437	-32	-242	2,483	-7,422	-13,335	-813
Battery DMC -20%	0	1	-1	0	0	0	10	0	0

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[223] Values for CY 2022-2050 unless otherwise noted.

Sensitivity Case	Gasoline Consumption (b.gal)	Electricity Consumption (TWh)	CO_2 Emissions (MMT)	Fatalities	Criteria Emissions Deaths	MY 2038 Regulatory Cost ($/vehicle)	MY 2038 Lifetime Retail Fuel Expenditure ($/vehicle)	MY 2038 Sales	MY 2038 Jobs
Battery learning rate +20%	0	1	-1	0	0	2	-7	-11	0
Battery learning rate -20%	-47	453	-391	-3	-221	2,168	-7,230	-10,422	-635
BatPaC 90% cell yield	-51	487	-427	-9	-232	2,345	-7,248	-12,125	-740
Annual vehicle redesigns	-1	4	-12	3	-5	109	-392	-415	-26
PHEV available MY 2025	-3	24	-22	1	-11	132	-439	-572	-34
PHEV available MY 2030	-3	24	-22	1	-11	131	-439	-576	-34
Oil price (AEO high)	0	0	0	0	0	1	-2	-10	-1
Oil price (AEO low)	-60	528	-508	-122	-288	2,092	-5,037	-13,266	-807
Oil price (GI reference)	-20	179	-165	-20	-90	832	-2,217	-4,804	-292
High GDP + fuel (GI optimistic)	-58	519	-496	-106	-278	2,086	-5,979	-12,757	-777
Low GDP + fuel (GI pessimistic)	-3	24	-22	1	-11	131	-440	-576	-34
High GDP + fuel (AEO high)	0	0	0	0	0	1	-2	-10	-1
Low GDP + fuel (AEO low)	-60	528	-508	-122	-288	2,092	-5,041	-13,266	-807
High GDP (GI optimistic)	-3	24	-22	1	-11	131	-438	-576	-34
Low GDP (GI pessimistic)	-3	24	-22	1	-11	131	-440	-576	-34
Oil market externalities (low)	-3	24	-22	1	-11	131	-439	-576	-34
Oil market externalities (high)	-3	24	-22	1	-11	131	-439	-576	-34
No payback period	-61	558	-508	74	-264	1,970	-8,116	-6,930	-423
24-month payback period	-50	462	-423	20	-225	2,062	-7,864	-8,314	-507
60-month payback period	0	1	-1	0	-1	0	-9	10	1
Implicit opportunity cost	-3	24	-22	1	-11	131	-439	-576	-34
Rebound (5%)	-3	24	-23	-2	-12	131	-447	-576	-34
Rebound (15%)	-3	25	-22	4	-10	131	-431	-576	-34
Sales-scrappage response (-0.1)	-3	25	-22	6	-10	131	-438	-145	-8

Sensitivity Case	Gasoline Consumption (b.gal)	Electricity Consumption (TWh)	CO_2 Emissions (MMT)	Fatalities	Criteria Emissions Deaths	MY 2038 Regulatory Cost ($/vehicle)	MY 2038 Lifetime Retail Fuel Expenditure ($/vehicle)	MY 2038 Sales	MY 2038 Jobs
Sales-scrappage response (-0.5)	-3	23	-22	-1	-11	127	-421	-702	-42
HDPUV sales (AEO reference)	-2	19	-18	1	-9	126	-417	-485	-29
HDPUV sales (AEO low economic growth)	-2	17	-16	0	-8	125	-410	-466	-29
HDPUV sales (AEO high economic growth)	-3	25	-23	1	-11	126	-416	-599	-37
Commercial operator sales share 100%	-3	24	-22	1	-11	131	-439	-576	-34
Commercial operator sales share 50%	-3	24	-22	1	-11	131	-439	-576	-34
Mass-size-safety (low)	-3	24	-22	1	-11	131	-439	-576	-34
Mass-size-safety (high)	-3	24	-22	1	-11	131	-439	-576	-34
Crash avoidance (low)	-3	24	-22	1	-11	131	-439	-576	-34
Crash avoidance (high)	-3	24	-22	1	-11	131	-439	-576	-34
2022 FR fatality rates	-3	24	-22	2	-11	131	-439	-576	-34
Clean grid (low)	-3	24	-24	1	-19	131	-439	-576	-34
Clean grid (high)	-3	24	-27	1	-35	131	-439	-576	-34
No ZEV	-3	17	-26	5	-13	153	-556	-584	-35
No EV tax credits	-39	358	-330	-8	-176	1,945	-7,377	-7,779	-473
No AMPC	-39	369	-320	0	-180	1,961	-7,422	-8,019	-490
Consumer tax credit share 75%	-39	366	-320	31	-174	1,926	-7,464	-7,543	-458
Consumer tax credit share 25%	0	-2	1	0	1	-10	42	-2	0
Maximum vehicle tax credit	0	0	0	0	0	1	1	-27	-2
Oil price (AEO 2023 high)	0	0	0	0	0	1	-9	9	0
Oil price (AEO 2023 low)	-60	519	-508	-139	-290	2,095	-4,722	-14,180	-864
Oil price (AEO 2023 ref)	-15	159	-121	-9	-72	644	-2,099	-3,092	-188

Sensitivity Case	Gasoline Consumption (b.gal)	Electricity Consumption (TWh)	CO_2 Emissions (MMT)	Fatalities	Criteria Emissions Deaths	MY 2038 Regulatory Cost ($/vehicle)	MY 2038 Lifetime Retail Fuel Expenditure ($/vehicle)	MY 2038 Sales	MY 2038 Jobs
High GDP (AEO 2023)	-3	24	-22	1	-11	131	-438	-576	-34
Low GDP (AEO 2023)	-3	24	-22	1	-11	131	-440	-576	-34
Reference GDP (AEO 2023)	-3	24	-22	1	-11	131	-439	-576	-34
Reference GDP (AEO 2022)	-3	24	-22	1	-11	131	-439	-576	-34
High GDP + fuel (AEO 2023)	0	-1	1	0	1	-7	26	-3	0
Low GDP + fuel (AEO 2023)	-16	165	-130	-16	-78	695	-2,079	-3,667	-223
Reference GDP + fuel (AEO 2023)	-15	159	-121	-9	-72	644	-2,098	-3,092	-188
Oil Market Externalities (AEO 2023)	-3	24	-22	1	-11	131	-439	-576	-34
HDPUV sales (AEO 2023)	-3	25	-23	1	-12	130	-434	-621	-38
HDPUV sales (AEO 2023 reference)	-2	19	-18	1	-9	124	-407	-524	-32
HDPUV sales (AEO 2023 low economic growth)	-3	23	-21	1	-11	131	-434	-542	-33
HDPUV sales (AEO 2023 high economic growth)	-3	26	-24	1	-12	125	-415	-660	-40

Table 9-8: HDPUV Fleet Penetration Rates of Selected Technologies for the Preferred Alternative (HDPUV10), by Sensitivity Case (Percent, MY 2038)

Sensitivity Case	Advanced Transmissions		Advanced Gas Engines		Mild Hybrid		SHEV		PHEV		BEV	
	No Action	Change	No Action	Change	No Action	Change	No Action	Change	No Action	Change	No Action	Change
RC	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Battery DMC +20%	47.2	-27.3	27.2	-7.3	24.4	-6.9	36.7	0	0.2	+13.3	15.9	+14.0
Battery DMC -20%	0.1	0	0.1	+0.1	0	0	4.0	0	45.3	0	50.5	0
Battery learning rate +20%	18.4	0	1.6	0	16.8	0	26.0	0	9.1	0	46.5	0

Sensitivity Case	**Advanced Transmissions**		**Advanced Gas Engines**		**Mild Hybrid**		**SHEV**		**PHEV**		**BEV**	
	No Action	**Change**	**No Action**	**Change**	**No Action**	**Change**	**No Action**	**Change**	**No Action**	**Change**	**No Action**	**Change**
Battery learning rate -20%	47.1	-25.8	27.6	-6.2	23.9	-4.9	35.8	-0.9	0.2	+11.1	16.8	+15.5
BatPaC 90% cell yield	47.3	-27.7	27.7	-8.1	23.9	-6.8	35.9	+1.6	0.2	+11.6	16.6	+14.5
Annual vehicle redesigns	20.5	-1.7	5.9	+5.4	16.6	-1.2	25.8	+1.2	9.1	0	44.6	+0.5
PHEV available MY 2025	20.3	-1.6	3.5	+1.6	16.8	-1.5	15.6	0	19.6	+1.5	44.6	+0.2
PHEV available MY 2030	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Oil price (AEO high)	0	0	0	0	0	0	0	0	49.7	0	50.2	0
Oil price (AEO low)	47.1	-28.6	11.4	+7.0	18.3	-2.3	36.8	+2.0	0	+10.4	16.1	+16.2
Oil price (GI reference)	30.4	-11.5	20.2	-1.3	22.7	-11.5	36.0	+0.2	0.2	+9.5	33.4	+1.7
High GDP + fuel (GI optimistic)	47.3	-27.8	12.5	+7.0	16.6	-3.3	36.5	+1.0	0	+9.9	16.1	+16.9
Low GDP + fuel (GI pessimistic)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
High GDP + fuel (AEO high)	0	0	0	0	0	0	0	0	49.7	0	50.2	0
Low GDP + fuel (AEO low)	47.1	-28.6	11.4	+7.0	18.3	-2.3	36.8	+2.0	0	+10.4	16.1	+16.2
High GDP (GI optimistic)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Low GDP (GI pessimistic)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Oil market externalities (low)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Oil market externalities (high)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
No payback period	28.6	-3.7	11.7	-4.8	23.7	-2.7	37.6	-9.0	0.1	+13.0	15.7	+17.0
24-month payback period	47.3	-27.3	11.5	+8.4	19.2	-5.9	35.8	+1.1	0.2	+10.0	16.7	+16.2
60-month payback period	0	0	0	0	0	0	0	0	49.8	-0.1	50.2	+0.1
Implicit opportunity cost	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Rebound (5%)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Rebound (15%)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Sales-scrappage response (-0.1)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2

Sensitivity Case	Advanced Transmissions		Advanced Gas Engines		Mild Hybrid		SHEV		PHEV		BEV	
	No Action	Change	No Action	Change	No Action	Change	No Action	Change	No Action	Change	No Action	Change
Sales-scrappage response (-0.5)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.1
HDPUV sales (AEO reference)	20.2	-1.5	3.4	+1.7	17.1	-1.5	26.0	0	9.1	+1.5	44.7	0
HDPUV sales (AEO low economic growth)	20.2	-1.5	3.4	+1.7	17.1	-1.5	26.0	0	9.1	+1.5	44.7	+0.1
HDPUV sales (AEO high economic growth)	20.2	-1.5	3.5	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.1
Commercial operator sales share 100%	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Commercial operator sales share 50%	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Mass-size-safety (low)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Mass-size-safety (high)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Crash avoidance (low)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Crash avoidance (high)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
2022 FR fatality rates	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Clean grid (low)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Clean grid (high)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
No ZEV	21.3	-1.7	3.6	+8.2	18.0	-0.9	26.2	+0.6	9.1	+0.1	43.5	+0.9
No EV tax credits	46.9	-31.8	26.9	-11.8	24.2	-10.9	36.0	+7.0	0.2	+8.3	16.9	+16.4
No AMPC	47.1	-26.0	27.6	-6.4	23.9	-9.3	36.0	-1.0	0.2	+9.3	16.6	+17.6
Consumer tax credit share 75%	47.0	-27.1	27.0	-7.1	24.3	-11.1	36.0	+0.9	0.2	+8.0	16.9	+18.2
Consumer tax credit share 25%	1.1	+0.2	1.1	+0.2	0	0	0.6	0	50.3	0	48.1	-0.2
Maximum vehicle tax credit	3.6	0	3.6	0	2.5	0	4.9	0	44.8	0	46.7	0
Oil price (AEO 2023 high)	0	0	0	0	0	0	0	0	49.7	-0.1	50.3	+0.1
Oil price (AEO 2023 low)	47.1	-28.7	11.5	+7.0	15.0	-3.0	36.7	+2.0	0	+10.5	16.1	+16.2

Sensitivity Case	Advanced Transmissions		Advanced Gas Engines		Mild Hybrid		SHEV		PHEV		BEV	
	No Action	Change	No Action	Change	No Action	Change	No Action	Change	No Action	Change	No Action	Change
Oil price (AEO 2023 ref)	22.7	-6.2	22.7	-6.2	16.1	-3.6	34.7	-4.4	0.3	+7.8	42.3	+2.7
High GDP (AEO 2023)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Low GDP (AEO 2023)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Reference GDP (AEO 2023)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
Reference GDP (AEO 2022)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
High GDP + fuel (AEO 2023)	18.2	+0.1	18.2	+0.1	16.3	0	25.8	0	9.1	0	46.9	-0.1
Low GDP + fuel (AEO 2023)	26.2	-7.8	26.2	-7.8	16.0	-5.0	34.7	-3.1	0.3	+8.1	38.8	+2.8
Reference GDP + fuel (AEO 2023)	22.7	-6.2	22.7	-6.2	16.1	-3.6	34.7	-4.4	0.3	+7.8	42.3	+2.7
Oil Market Externalities (AEO 2023)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
HDPUV sales (AEO 2023)	20.2	-1.6	3.4	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
HDPUV sales (AEO 2023 reference)	20.3	-1.5	3.5	+1.7	17.1	-1.5	26.0	0	9.1	+1.5	44.6	0
HDPUV sales (AEO 2023 low economic growth)	20.3	-1.6	3.5	+1.6	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.2
HDPUV sales (AEO 2023 high economic growth)	20.2	-1.5	3.4	+1.7	17.1	-1.5	26.0	0	9.1	+1.5	44.6	+0.1

Table 9-9: Aggregate HDPUV Fleet Costs and Benefits in CY 2022-2050 for the Preferred Alternative (HDPUV10), by Sensitivity Case (2021$, 7 Percent DR, 3% SC-GHG DR)

Sensitivity Case	Total Social Costs ($b)	Total Social Benefits ($b)				Net Social Benefits ($b)				MY 2038 Regulatory Cost ($/vehicle)	MY 2038 Lifetime Retail Fuel Expenditure ($/vehicle)
		5%	3%	2.5%	3%, 95th pctile	5%	3%	2.5%	3%, 95th pctile		
RC	0.99	1.69	2.43	2.97	4.42	0.69	1.44	1.97	3.43	131	-339
Battery DMC +20%	20.88	25.45	40.12	50.67	79.41	4.56	19.24	29.78	58.53	2,483	-5,722

Sensitivity Case	Total Social Costs ($b)	Total Social Benefits ($b)				Net Social Benefits ($b)				MY 2038 Regulatory Cost ($/vehicle)	MY 2038 Lifetime Retail Fuel Expenditure ($/vehicle)
		5%	3%	2.5%	3%, 95th pctile	5%	3%	2.5%	3%, 95th pctile		
Battery DMC -20%	0.03	0.03	0.06	0.07	0.12	0.00	0.02	0.04	0.08	0	7
Battery learning rate +20%	0.03	0.04	0.06	0.08	0.12	0.01	0.03	0.05	0.09	2	-6
Battery learning rate -20%	18.03	22.47	35.67	45.14	71.05	4.44	17.63	27.11	53.01	2,168	-5,576
BatPaC 90% cell yield	20.08	24.39	38.72	49.01	77.08	4.31	18.64	28.94	57.00	2,345	-5,588
Annual vehicle redesigns	0.51	0.91	1.30	1.59	2.36	0.40	0.79	1.07	1.84	109	-302
PHEV available MY 2025	0.99	1.68	2.43	2.96	4.42	0.69	1.43	1.97	3.42	132	-339
PHEV available MY 2030	0.99	1.69	2.43	2.97	4.42	0.69	1.44	1.97	3.43	131	-339
Oil price (AEO high)	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	1	-1
Oil price (AEO low)	18.72	15.22	32.25	44.49	77.81	-3.50	13.53	25.76	59.08	2,092	-3,900
Oil price (GI reference)	6.77	9.32	14.84	18.82	29.61	2.56	8.08	12.05	22.84	832	-1,713
High GDP + fuel (GI optimistic)	18.63	16.63	33.27	45.23	77.81	-2.00	14.64	26.60	59.18	2,086	-4,457
Low GDP + fuel (GI pessimistic)	0.99	1.69	2.43	2.97	4.43	0.69	1.44	1.98	3.43	131	-339
High GDP + fuel (AEO high)	0.00	0.00	0.01	0.01	0.01	0.00	0.01	0.01	0.01	1	-1
Low GDP + fuel (AEO low)	18.73	15.22	32.26	44.49	77.82	-3.50	13.53	25.77	59.10	2,092	-3,902
High GDP (GI optimistic)	0.99	1.68	2.43	2.96	4.41	0.69	1.43	1.97	3.42	131	-338
Low GDP (GI pessimistic)	0.99	1.69	2.43	2.97	4.43	0.69	1.44	1.98	3.43	131	-339
Oil market externalities (low)	0.99	1.63	2.37	2.91	4.36	0.63	1.38	1.91	3.37	131	-339
Oil market externalities (high)	0.99	1.76	2.50	3.04	4.49	0.77	1.51	2.04	3.50	131	-339
No payback period	21.05	27.33	44.34	56.57	89.87	6.28	23.29	35.51	68.82	1,970	-6,260
24-month payback period	18.56	24.76	39.02	49.25	77.24	6.20	20.46	30.69	58.68	2,062	-6,068
60-month payback period	0.02	-0.05	-0.03	-0.01	0.03	-0.07	-0.05	-0.03	0.01	0	-7
Implicit opportunity cost	1.45	1.69	2.43	2.97	4.42	0.24	0.98	1.52	2.97	131	-339
Rebound (5%)	0.95	1.66	2.41	2.95	4.42	0.71	1.46	2.00	3.47	131	-345
Rebound (15%)	1.04	1.72	2.45	2.98	4.42	0.68	1.41	1.94	3.38	131	-333

Sensitivity Case	Total Social Costs ($b)	Total Social Benefits ($b)				Net Social Benefits ($b)				MY 2038 Regulatory Cost ($/vehicle)	MY 2038 Lifetime Retail Fuel Expenditure ($/vehicle)
		5%	3%	2.5%	3%, 95th pctile	5%	3%	2.5%	3%, 95th pctile		
Sales-scrappage response (-0.1)	1.06	1.64	2.37	2.89	4.32	0.58	1.31	1.84	3.26	131	-338
Sales-scrappage response (-0.5)	0.93	1.67	2.38	2.90	4.30	0.74	1.46	1.97	3.38	127	-325
HDPUV sales (AEO reference)	0.81	1.44	2.05	2.48	3.66	0.64	1.24	1.68	2.85	126	-322
HDPUV sales (AEO low economic growth)	0.72	1.30	1.83	2.22	3.27	0.57	1.11	1.50	2.55	125	-317
HDPUV sales (AEO high economic growth)	1.01	1.77	2.53	3.08	4.56	0.76	1.52	2.07	3.55	126	-321
Commercial operator sales share 100%	1.68	1.69	2.43	2.97	4.42	0.01	0.75	1.29	2.74	131	-339
Commercial operator sales share 50%	1.34	1.69	2.43	2.97	4.42	0.35	1.10	1.63	3.09	131	-339
Mass-size-safety (low)	0.99	1.69	2.44	2.97	4.43	0.70	1.44	1.98	3.43	131	-339
Mass-size-safety (high)	0.99	1.68	2.42	2.96	4.41	0.69	1.43	1.97	3.42	131	-339
Crash avoidance (low)	0.99	1.69	2.43	2.97	4.42	0.70	1.44	1.97	3.43	131	-339
Crash avoidance (high)	0.99	1.68	2.43	2.96	4.42	0.69	1.43	1.97	3.42	131	-339
2022 FR fatality rates	0.99	1.67	2.41	2.95	4.40	0.68	1.42	1.96	3.41	131	-339
Clean grid (low)	0.99	1.72	2.51	3.07	4.62	0.72	1.51	2.08	3.62	131	-339
Clean grid (high)	0.99	1.78	2.67	3.31	5.04	0.79	1.68	2.31	4.05	131	-339
No ZEV	1.20	1.74	2.61	3.23	4.94	0.54	1.41	2.03	3.74	153	-429
No EV tax credits	14.98	20.31	31.53	39.57	61.69	5.33	16.56	24.59	46.71	1,945	-5,692
No AMPC	14.83	19.46	30.32	38.10	59.52	4.63	15.49	23.27	44.69	1,961	-5,726
Consumer tax credit share 75%	15.30	19.08	29.95	37.73	59.15	3.78	14.64	22.42	43.84	1,926	-5,759
Consumer tax credit share 25%	-0.09	-0.09	-0.14	-0.18	-0.28	0.00	-0.05	-0.09	-0.19	-10	33
Maximum vehicle tax credit	-0.01	-0.01	-0.02	-0.03	-0.05	0.00	-0.01	-0.02	-0.04	1	1
Oil price (AEO 2023 high)	0.01	-0.01	0.00	0.01	0.03	-0.02	-0.01	0.00	0.01	1	-7
Oil price (AEO 2023 low)	18.37	14.14	31.17	43.41	76.75	-4.23	12.80	25.04	58.38	2,095	-3,631

Sensitivity Case	**Total Social Costs ($b)**	**Total Social Benefits ($b)**				**Net Social Benefits ($b)**				**MY 2038 Regulatory Cost ($/vehicle)**	**MY 2038 Lifetime Retail Fuel Expenditure ($/vehicle)**
		5%	**3%**	**2.5%**	**3%, 95th pctile**	**5%**	**3%**	**2.5%**	**3%, 95th pctile**		
Oil price (AEO 2023 ref)	5.33	7.42	11.49	14.41	22.37	2.09	6.15	9.07	17.04	644	-1,616
High GDP (AEO 2023)	0.99	1.68	2.43	2.96	4.41	0.69	1.43	1.97	3.42	131	-338
Low GDP (AEO 2023)	0.99	1.69	2.43	2.97	4.43	0.69	1.44	1.98	3.43	131	-339
Reference GDP (AEO 2023)	0.99	1.69	2.43	2.97	4.42	0.69	1.44	1.97	3.43	131	-339
Reference GDP (AEO 2022)	0.99	1.69	2.43	2.97	4.42	0.69	1.44	1.97	3.43	131	-339
High GDP + fuel (AEO 2023)	-0.06	-0.06	-0.09	-0.11	-0.17	0.00	-0.03	-0.05	-0.11	-7	20
Low GDP + fuel (AEO 2023)	5.54	7.36	11.71	14.83	23.35	1.81	6.16	9.29	17.81	695	-1,608
Reference GDP + fuel (AEO 2023)	5.33	7.42	11.48	14.40	22.37	2.09	6.15	9.07	17.03	644	-1,615
Oil Market Externalities (AEO 2023)	0.99	1.70	2.44	2.98	4.43	0.70	1.45	1.98	3.44	131	-339
HDPUV sales (AEO 2023)	1.03	1.77	2.54	3.09	4.60	0.74	1.51	2.06	3.57	130	-335
HDPUV sales (AEO 2023 reference)	0.82	1.51	2.13	2.57	3.77	0.69	1.30	1.75	2.95	124	-314
HDPUV sales (AEO 2023 low economic growth)	0.95	1.62	2.33	2.84	4.22	0.67	1.38	1.88	3.27	131	-335
HDPUV sales (AEO 2023 high economic growth)	1.08	1.91	2.72	3.31	4.90	0.83	1.65	2.23	3.82	125	-320

9.2.2. Effect of Technology-Related Parameters

9.2.2.1. Redesign Schedules

Vehicle manufacturers establish redesign schedules for their vehicles by considering the availability of capital and other resources, competitive position in certain market segments, the sales volume for each of the manufacturer's vehicle models, and the influence of regulatory requirements. As discussed in Preamble Section II.C and in Chapter 9.1 in this PRIA, NHTSA used an informed, historical review of redesign and refresh intervals to estimate future redesign and refresh intervals. However, the nature of automotive refresh and redesign cycles is not always consistent and can vary by model type, segment competitiveness, new entrants, or a manufacturer's capital availability, among other factors. To test an extreme case of redesign flexibility, one sensitivity allowed for annual vehicle redesigns. In this setting, the pool of available vehicle and technology combinations appears significantly greater for each manufacturer because there are more opportunities for vehicle redesigns. This increases the likelihood of more optimal technology solutions for the given set of parameters being selected by the CAFE Model in each model year. This could lead to a more optimal overall solution with an expanded set of parameters, producing higher overall consumer and social benefits, while at the same time lowering technology costs if there were no additional costs associated with a redesign cadence this rapid, which the agency believes is unlikely in such an extreme case. Since we anticipate that an annual redesign cadence would carry higher costs, the expanded set of parameters is unrealistic. Table 9-2 shows the social benefits increase by about 19 percent over the RC with only a slight increase in costs for light duty. Table 9-3 shows other metrics for light duty vehicles with an annual redesign schedule that has increased benefits and decreased costs. For example, there is a 47 percent decrease in fuel consumption and an average of $95 per-vehicle regulatory cost decrease for light duty vehicles compared to RC. While this demonstrates the value of nimble manufacturer response to fuel efficiency requirements, we believe it is an unrealistic representation of manufacturers' ability to modify their vehicle portfolios. This case does not account for the costs of stranded capital from such high frequency redesigns, nor scaling up of the facilities and development and design teams required to implement annual redesign schedules across the portfolio. These costs would likely be significant, and the CAFE Model does not currently estimate or incorporate these into overall program cost estimates. We did not test less extreme examples, because we think that those redesign/reschedule wouldn't show significant benefits.

For the HDPUV fleet, Table 9-6 shows a SC and benefit decrease of $1 and $1.9 billion dollars, respectively, in an annual redesign schedule compared to the reference case. This translates to a net social benefit decrease of just under $1 billion when allowing for annual vehicle redesigns in the analysis. Since the HDPUV fleet has a different sales volume and lower amount of vehicle nameplates, redesign cycles impact the HDPUV fleet differently. Table 9-7 also shows the regulatory cost per vehicle for HDPUV decreases by 22 dollars. This reflects the immediate adoption of fuel saving technology for manufacturers in unrealistic year-over-year redesigns for each vehicle and avoids adoption of costly technologies in the future years. As indicated above, the significant costs associated with an annual redesign cadence are not currently estimated or incorporated in the model.

9.2.2.2. Battery Costs

Sensitivity results in Table 9-1 and Table 9-2 include several cases for two aspects of electrification technology costs: direct costs of batteries and battery learning rates. For more information on how this sensitivity information relates to NHTSA's tentative determination of which regulatory alternatives would be maximum feasible, please see Preamble Section V.D. The sensitivity analysis includes versions of the model related to battery cost – with battery DMCs 20 percent higher and lower than their RC levels; additionally, we analyze a separate sensitivity case that utilizes the BatPaC model to make predictive battery costs into the future.[224] Lastly, we analyze scenarios where the rate of battery learning is 20 percent higher and lower than its RC level. Figure 9-11 below includes indexed cost values for battery cost trajectories under all five scenarios along with the RC for a BEV3 with a 70.1kWh battery-pack. As discussed in Draft TSD Chapter 3.3.5.3, we compared our projected battery pack costs to the projected pack costs from other sources to assess the learning rate applied in the central analysis. The survey of other sources' projected pack costs showed that most projected costs, taking into account raw material cost increases. Therefore, we determined

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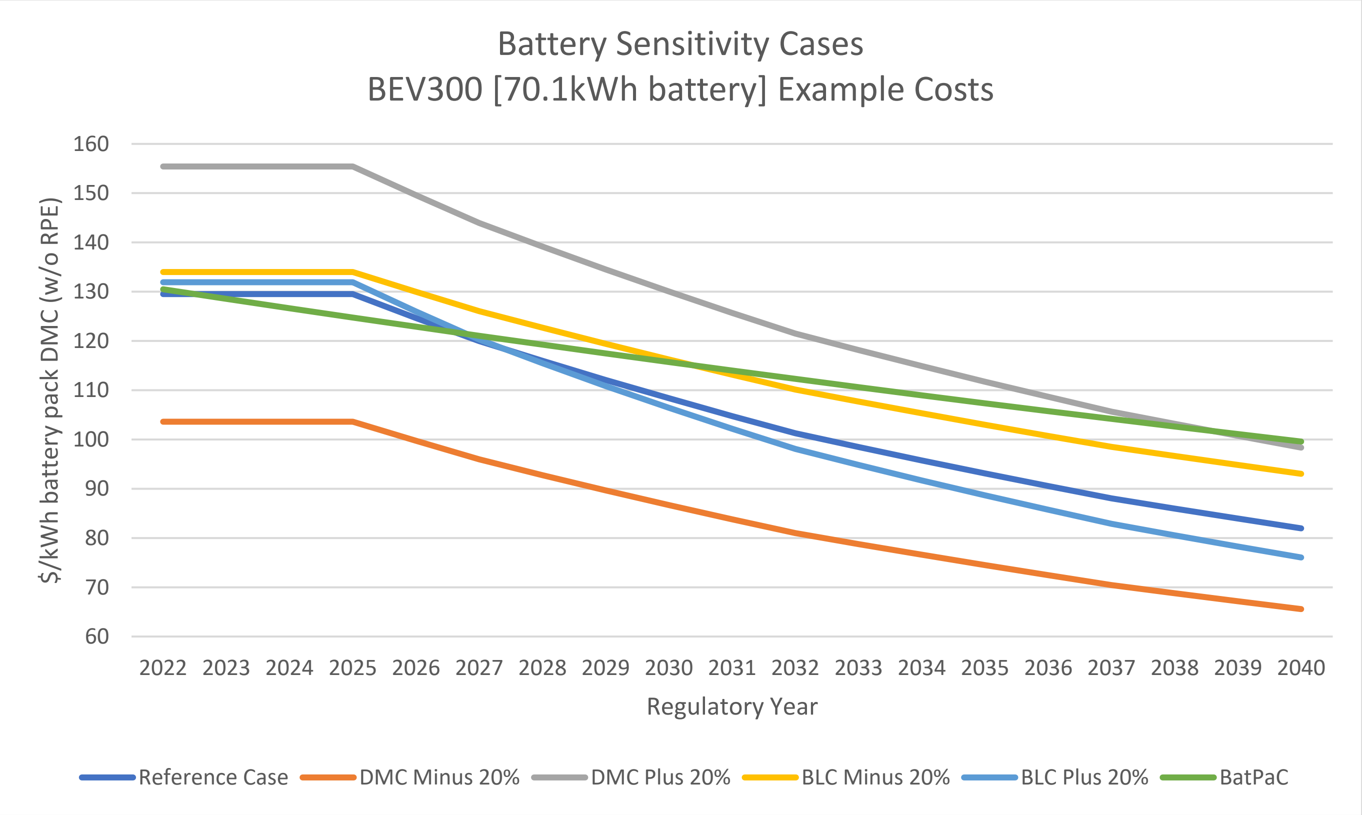
[224] See docket memo for further details.

that limiting sensitivity cases to examining the impacts of increasing and decreasing the direct manufacturing cost (DMC) of batteries and battery learning costs (BLC) by 20 percent from their RC levels was reasonable. The measure presented in the figure is BEV3 battery cost to equivalent to the MY 2022 battery pack cost (produced in CY 2021). The curves in the graph illustrate the differences in the battery cases over time. Battery direct costs (±20 percent and the BatPaC case) are a fixed ratio of the reference cost values. Learning cost scenarios, however, gradually deviate from the reference level. This is especially important to note when coupled with the timing of most electrification technology applications. Model runs with greater levels of electrification earlier will see a smaller effect from accelerated learning cost changes.

Figure 9-11: Battery Cost Sensitivity Cases



Across battery sensitivity cases (and the RC), the (20)% DMC case resulted in highest PHEV penetration – 9.1% of the fleet under No Action and 20.6% under the Preferred Alternative. In contrast, the +20% DMC case reduced PHEVs to 0.2% of the LD fleet under No Action and 3.6% of the LD fleet under the Preferred Alternative. The resulting PHEV penetration in remaining battery sensitivity cases fell near the RC (2.9% under No Action and 7.5% under the Preferred Alternative); the +20 Battery Learning Curve case, the (20)% BLC case, and BatPaC case resulted in 3.1%, 3.4%, and 2.4% PHEV penetration under No Action and 9.7%, 5.7%, and 5.8% under the Preferred Alternative, respectively.

The (20)% DMC case resulted in the least SHEV technology penetration – 15.1% under the No-Action Alternative and 21.6% under the Preferred Alternative. Conversely, the only sensitivity case with SHEV penetration higher than the RC (21.9% No-Action Alternative, 36.9% Preferred Alternative) was in the +20% DMC case – 24.3% of the LD fleet under No Action and 39.2% under the Preferred Alternative. The remaining battery sensitivity cases (+20% BLC, (20)% BLC, BatPaC) resulted in SHEV penetration that did not deviate greatly from the RC – 21.5%, 21.1%, and 21.2% under No Action and 34.3%, 37.8%, and 37.0% under the Preferred Alternative, respectively.

With minor variances, the battery sensitivities had approximately the levels of penetration of HCR technologies as the RC (19.2% under No-Action Alternative, 12.9% under the Preferred Alternative); the (20)% DMC case yielded a 17.9% penetration under No-Action Alternative and 11.6% under the Preferred

Alternative. The largest HCR technology penetration under No-Action Alternative – 19.5% – resulted from the BatPaC sensitivity case, and the largest under the Preferred Alternative – 13.7% of the LD fleet – resulted from the +20% DMC sensitivity case.

For the HDPUV fleet, electrification technology application greatly varied between battery sensitivity cases; this is due to the HDPUV fleet having greater diversity of vehicle use-cases as well as having a smaller fleet, compared to LD. For instance, HD vans that are used on specific delivery routes maybe easier to electrify compared to HD pickup trucks, whose applications and routes are more sporadic. Compared to the LD fleet, HDPUVs are allowed to consider BEVs in the standard setting years, and so any significant change in electrification costs will have larger effects on the technology penetration rates. For instance, for the RC, BEVs make up 44.6% of the fleet under No Action and 44.8% under the Preferred Alternative; BEV penetration was lower, in contrast, under the +20% DMC case, (20)% BLC case, and the BatPaC cases – resulting in 15.9%, 16.8%, and 16.6% BEV penetration in the HDPUV under No Action and 29.9%, 32.3%, and 31.1% of the HDPUV fleet under the Preferred Alternative, respectively. The +20% BLC case yielded similar BEV penetration compared to the RC, with BEVs making up 46.5% of the fleet under both No Action and the Preferred Alternative. The (20)% DMC case yielded the highest BEV penetration – 50.5% BEV penetration of the fleet under No Action and 50.% under the Preferred Alternative. FCEVs are not present in the HDPUV fleet in either the RC or any of the battery sensitivity cases.

Under both the RC and +20% BLC case, 9.1% of the fleet is comprised of PHEVs under No Action; under the Preferred Alternative, the RC HDPUV fleet resulted in 10.6% PHEVs and the +20% BLC case resulted in the same fleet penetration as No Action (9.1%). The (20)% DMC case resulted in the highest PHEV penetrations across all battery sensitivity cases – 45.3% of the fleet for the (20)% DMC case under No Action and 45.3% penetration under the Preferred Alternative. In the remaining cases, PHEVs made up 0.2% of the HDPUV fleet under No Action; under the Preferred Alternative, the remaining cases (+20% DMC, -20% BLC, and BatPaC cases) resulted in 13.5%, 11.3%, and 11.8% PHEVs, respectively.

The (20)% DMC case resulted in the lowest SHEV penetration – 4% in the HDPUV fleet, under both No Action and the Preferred Alternative. Both the RC and +20% BLC case resulted in 26% SHEVs making up the fleet under both No-Action Alternative and the Preferred Alternative. The remaining cases had elevated SHEV penetration levels; the +20% DMC case resulted in 36.7% under both No-Action Alternative and the Preferred Alternative, the (20)% BLC case resulted in 35.8% under No Action and 34.9% under the Preferred Alternative, and the BatPaC case resulted in 35.9% SHEV penetration in the HDPUV fleet under No-Action Alternative and 37.5% under the Preferred Alternative.

The (20)% DMC case resulted in the lowest belt-integrated starter-generator (BISG) (mild hybrid) penetration 0% under both No-Action Alternative and the Preferred Alternative. The RC resulted in 17.1% BISG penetration under No-Action Alternative and 15.6% under the Preferred Alternative; similarly, the +20% BLC case resulted in BISG penetration of 16.8% under both No-Action Alternative and under the Preferred Alternative. The +20% DMC case resulted in the greatest BISG penetration – 24.4% under No-Action Alternative and 17.5% under the Preferred Alternative. The (20)% BLC case and the BatPaC case resulted in significant BISG penetration, as well – both yielding 23.9% BISG penetration under the No Action alternative. Under the Preferred Alternative, the (20)% BLC case yielded 19% BISG penetration, and the BatPaC case yielded 17.1% BISG penetration.

For the HDPUV fleet, outside of electrified powertrain technology, the conventional technology application for advanced engine technology was also analyzed under the battery sensitivities. The (20)% DMC case resulted in the least advanced engine technology penetration – 0.1% and 0.2% penetration for No-Action Alternative and the Preferred Alternative, respectively. The +20% BLC case and the RC also resulted in relatively low advanced engine technology. The RC yielded 3.4% penetration under No-Action Alternative and 5% under the preferred alternative while the +20% BLC case yielded 1.6% penetration under both the No Action and the preferred alternative. The remaining battery sensitivity cases yielded higher advanced engine technology penetration in the HDPUV fleet. The +20% DMC case yielded 27.2% and 19.9% penetration under No-Action Alternative and under the preferred alternative, respectively. The (20)% BLC case resulted in 27.6% and 21.4% under No Action and under the preferred alternative, respectively. Lastly, the BatPaC case resulted in 27.7% and 19.6% under No-Action Alternative and under the preferred alternative, respectively.

See Table 9-4 and Table 9-8 for changes in technology penetrations for all sensitivity cases (light duty and HDPUV, respectively) and further discussion of the results in Chapter 9.2.1.

In the LD fleet, there was a great variance in net social benefits (the difference between total SCs and total social benefits) across all battery cost scenarios[225]; compared to the RC ($16.8B benefit over No-Action Alternative), the (20)% DMC case increased net benefits $23.8B. While not as drastic, the +20% DMC case increased net benefits $18.4B and the (20)% BLC case decreased benefits by $15.2B compared to the RC.

The impact on consumers (the difference between regulatory cost and retail fuel expenditure) between the RC and all battery sensitivity cases ranged as low as $75 savings per-vehicle under the Preferred Alternative (over No-Action Alternative, $37 more than RC – with the RC saving $112 per vehicle) with the (20)% DMC case and as high as $241 savings per-vehicle (saving $129 over the RC) with the +20% DMC case. The battery learning curve (BLC) cases and BatPaC cases proved to have very similar consumer effects as the RC – indicating they had less of an impact on the consumer effects compared to DMC; the +20% BLC case yielded $126 savings, the (20)% BLC case yielded $95 savings, and the BatPaC case yielded $129 savings per-vehicle.

The HDPUV fleet, which is much smaller than the LD fleet, still shows variance in net social benefits between battery cost cases. Under the Preferred Alternative, the RC results in a $2.25B benefit over No Action. The -20% DMC and +20% BLC cases show only a minimal benefit under the Preferred Alternative, compared to No Action minus a $0.03B benefit and a $0.04B benefit, respectively. The remaining battery sensitivity cases, however, show significant improvements over No Action; the +20% DMC case results in a $18.15B benefit, the (20)% BLC case results in a $23.17B benefit, and the BatPaC case yields a $25.08B benefit – all under the Preferred Alternative over No Action. The increased benefits in action alternatives results from technologies getting applied in the standard setting years instead of baseline years (again, because the EPCA restrictions do not apply in the HDPUV context).

There is a stark contrast in consumer effects in the HDPUV fleet between battery sensitivity cases. The RC yields a $308/vehicle savings under the Preferred Alternative, compared to No-Action Alternative. The +20% BLC case yields in a $5/vehicle savings, and the (20)% DMC results in a $9 increase per-vehicle under the Preferred Alternative, compared to No-Action Alternative. The remaining cases yield a significant savings over No-Action Alternative; the +20% DMC case results in a $4,939 savings, the -20% BLC case results in a $5,062 savings, and the BatPaC case yields a $4,903 savings per-vehicle. As discussed before, any change in battery costs has a significant impact on sensitivities results considered for this analysis. If battery technology is less expensive than NHTSA currently forecasts, the benefits in the HDPUV are observed in the baseline alternative as it is quickly adopted, regardless of new standards. Alternatively, if the battery technology is more expensive, the benefits are observed to occur in the standard setting years that would adopt electrification to meet standards.

In the LD fleet, between battery sensitivity cases, there are notable differences in additional metrics, such as gasoline and electricity consumption as well as CO_2 emissions prevented. The (20)% DMC case saved 132 billion gallons of gasoline under the Preferred Alternative (compared to No Action) while the RC and (20)% BLC case only saved 88 billion gallons and 87 billion gallons under the Preferred Alternative (compared to No-Action Alternative), respectively. The +20% BLC case similarly saved 91 billion gallons of gasoline over the No Action alternative. The +20% DMC case and the BatPaC case saved approximately the same amount of gasoline – 102 billion gallons and 103 billion gallons over the No Action alternative, respectively.

Among all battery sensitivity cases, the (20)% DMC contributed to the largest difference in electricity consumption between the preferred alternative and No-Action Alternative – consuming 738 TWh more energy (over double the energy difference in most other cases, including the RC at 312 TWh under the Preferred Alternative compared to No-Action Alternative). Observed in the +20% BLC case, 381 TWh more electricity was consumed with the Preferred Alternative over No-Action Alternative. In the -20% BLC case, 249 TWh more electricity was consumed under the Preferred Alternative over No-Action Alternative.

Carbon dioxide prevention is an additional, measurable metric used to compare sensitivity studies. In the RC, we estimate 885 million metric tons (MMT) less CO_2 compared to the No-Action Alternative; similarly, the

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[225] 3% discount rate was used.

Preferred Alternative under the +20% BLC case results in 894 MMT CO_2 less than No Action, and the (20)% BLC case results in 895 MMT CO_2 less than the No-Action Alternative. The remaining battery sensitivity cases yield greater differences between the Preferred Alternative and No-Action Alternative – the greatest difference being under the (20)% DMC case with 1,235 MMT CO_2 less with the Preferred Alternative compared to No-Action Alternative. The +20% DMC case Preferred Alternative yields 1,059 MMT CO_2 less than No-Action Alternative; similarly, the BatPaC case yields 1,038 MMT CO_2 less under the Preferred Alternative compared to No-Action Alternative.

In the HDPUV fleet, additional metrics were also analyzed between battery sensitivity cases. Gasoline consumption did not change between the No-Action Alternative and Preferred Alternative for the (20)% DMC case and the +20% BLC case. There was minimal change between No-Action Alternative and the Preferred Alternative under the RC minus 3 billion gallons were saved under the Preferred Alternative over No-Action Alternative. The greatest contrast under regulatory action is shown under the remaining cases. The +20% DMC case saved 53 billion gallons of gasoline under the Preferred Alternative over No-Action Alternative. Similarly, the BatPaC case saved 51 billion gallons of gasoline under the Preferred Alternative over No-Action Alternative and the (20)% BLC case saved 47 billion gallons of gasoline under the Preferred Alternative over No-Action Alternative.

There was a small difference in electricity consumption between the Preferred Alternative and No-Action Alternative with the (20)% DMC case and the +20% BLC case – each of the cases consuming 1 TWh of electricity more under the Preferred Alternative over the No-Action Alternative. The largest difference in electricity consumption was displayed under the remaining battery sensitivity cases. The +20% DMC case consumed 499 TWh more under the Preferred Alternative over No-Action Alternative. Similarly, the (20)% BLC case resulted in an additional 453 TWh of electricity consumption under the Preferred Alternative over No-Action Alternative, and 487 TWh additional consumption with the BatPaC case.

The +20% DMC case resulted in the largest difference between the Preferred Alternative and No-Action Alternative a minus 437 MMT CO_2 less under regulatory action. Similarly, the BatPaC case yielded 427 MMT CO_2 less under the Preferred Alternative compared to No-Action Alternative. The -20% BLC case resulted in a slightly less difference under regulatory action compared to No Action – a 391 MMT CO_2 difference. The remaining battery sensitivity cases yielded in less drastic changes; under regulatory action of the Preferred Alternative, the RC resulted in 22 MMT CO_2 less than No-Action Alternative. Both the -20% DMC case and the +20% BLC case resulted in 1 MMT CO_2 less under the Preferred Alternative compared to No-Action Alternative.

These results are expected as increases and decreases in electrification costs forced manufactures to adopt other types of technologies. See Chapter 9.2.1 for these cost metrics.

9.2.2.3. Off-Cycle and AC Efficiency

AC and OC efficiency technologies can provide fuel economy benefits in real-world vehicle operation. NHTSA accounts for these benefits by adding fuel consumption improvement values (FCIVs) to a vehicle's fuel economy value. As discussed in Draft TSD Chapter 3.7, our analysis considers manufacturers adopting AC and OC technologies as a part of their compliance strategies. AC and OC FCIVs are based on an ICEs fuel economy difference not captured on the two-cycle regulatory compliance cycle and a test cycle that can capture those benefits. Existing AC and OC FCIVs – based on ICE technologies – do not appropriately represent improvements in BEV fuel efficiency because BEVs have no ICE or transmission, and so cannot take advantage of engine or transmission-specific technology improvements. We represent this in the RC modeling by limiting the amount of AC and OC technologies that BEVs can adopt. We performed two additional AC/OC sensitivity cases, one assuming no AC and OC FCIVs are available for BEVs in 2027-2050 (as opposed to the limited application of AC/OC FCIVs to BEVs in the RC), and the other mimicking EPA's proposal for ramping down AC/OC "credits" in the Clean Air Act CO_2 program.[226] Each of these is discussed further below.

AC efficiency/OC BEV zero – For this sensitivity case we looked at removing all AC and OC FCIV for BEVs in MY 2027-2050. This sensitivity case was run to better understand the impact and effectiveness of BEVs no

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[226] 88 FR 29184

longer being part of the AC and OC program. The results show a $3.9B reduction in net social benefits at the 3% DR when compared to the RC. There is also a $114 increase in regulatory cost per vehicle as manufacturers need to add more technology to traditional ICE vehicles to meet the standards. There is also a slight increase in fuel used when compared to the RC, but compared to the total amount of fuel used, it is extremely small. There is a 2.3% increase in SHEV penetration over the RC. The impact of this sensitivity is overall smaller as compared to the approach that phases out AC and OC FCIVs completely. AC and OC technologies are cost effective for conventional technologies and as such are showing minimal impacts by removing them from BEVs.

EPA AC/OC approach – This sensitivity case mimics the EPA proposal to remove AC and OC FCIVs to help us understand what the impacts may be from a CAFE perspective. For MY 2027-2050 we forced AC Leakage credits to go to zero for all vehicles, AC and OC FCIVs for BEVs goes to zero, and AC efficiency FCIVs for BEVs goes to zero. For all non-BEV vehicles, AC and OC FCIVs gradually go to zero, as shown below:

- Maximum AC/OC credits are 10 for MY 2027
- Maximum AC/OC credits are 8 in MY 2028
- Maximum AC/OC credits are 6 in MY 2029
- Maximum AC/OC credits are 3 in MY 2030
- Zero AC/OC credits in MY 2031-2050

As seen in Chapter 9.2.1, this sensitivity case showed a $10.7B reduction in net social benefits when compared to the RC. This is in large part because of the increased technology costs from additional technologies: there are approximately 6% more SHEVs and 1% more PHEVs in this sensitivity case when compared to the RC in MY2032. As expected, the regulatory per vehicle cost increased from $932 to $1,393 between the RC and the sensitivity case, though we also see 4 billion gallons of gasoline saved.

9.2.2.4. Engine Technologies

We ran one sensitivity case to further inform our decisions concerning constraints we apply to the application of HCR engine technologies (HCR, HCRE, and HCRD) in the standard setting analysis. Preamble Section II.D and Draft TSD Chapter 3 discuss the constraints we apply to the application of HCR engine technologies, in particular to proxy capital that a manufacturer would lose by switching from manufacturing one type of engine technology to HCR engine technology (i.e., “stranded capital”), and to represent what we believe is an appropriate restriction of the technology to vehicles that have higher load requirements, based on feedback from the automotive industry and our engineering judgment. A discussion of these engine technologies and a discussion of the SKIPs we applied in the RC is located in Chapter 3.1 of the Draft TSD and the application of SKIPs in the RC is located in the Market Data Input File.

Limited HCR skips – We removed all adoption constraints for the HCR, HCRE, and HCRD engine technologies.

When we removed the constraints on application of HCR technology, HCR technology penetration increased by approximately 9.5%, to 28.7% in the no action alternative, but was reduced by 10.7% between the no action and preferred alternative. Initial HCR technology penetration increased between the RC no-action alternative and the sensitivity case no-action alternative because more vehicles can adopt this technology. From a technology perspective, more of the basic engines can and do select the HCR technology along the way; in fact, there are 5.2% more HCR engines in MY2032 in this sensitivity than in the RC. Fines are also lower because more vehicles like the Camaro, Ram 1500, F-150, Silverado, Mustang, etc. are able to adopt HCR. However, while these results look positive, they can be misleading as we do not believe that HCR technology could be applied to these vehicles and the vehicles maintain important performance metrics like towing in the case of the pickup trucks. In addition, as discussed below, the CAFE Model does not account for the cost of stranded capital that a manufacturer would incur from switching from one engine technology to an HCR engine technology.

The regulatory cost on a per vehicle basis increased compared to the RC from $932 in MY 2032, to $953. The net social benefits also slightly increased between the no-action alternative and the preferred alternative, by $0.3 billion. This small increase in net social benefits is in part due to the 12-billion-gallon reduction in gasoline consumed and a negligible increase in regulatory costs. However, we believe that in the real world, manufacturers would incur significantly more costs from switching to HCR technology that would vastly outweigh the additional slight increase in societal benefit. As discussed in the Preamble III.C.3 and Draft TSD Chapter 3, it costs approximately $1 billion for a manufacturer to design, build, and deploy a new engine. Just one manufacturer that incurs the costs to switch to HCR technology under the limited HCR SKIP case would incur costs that significantly outweigh the limited increased social benefits.

The data shown in more detail in Chapter 9.2.1 shows the minimal impact of the HCR adoption constraint for this rule.

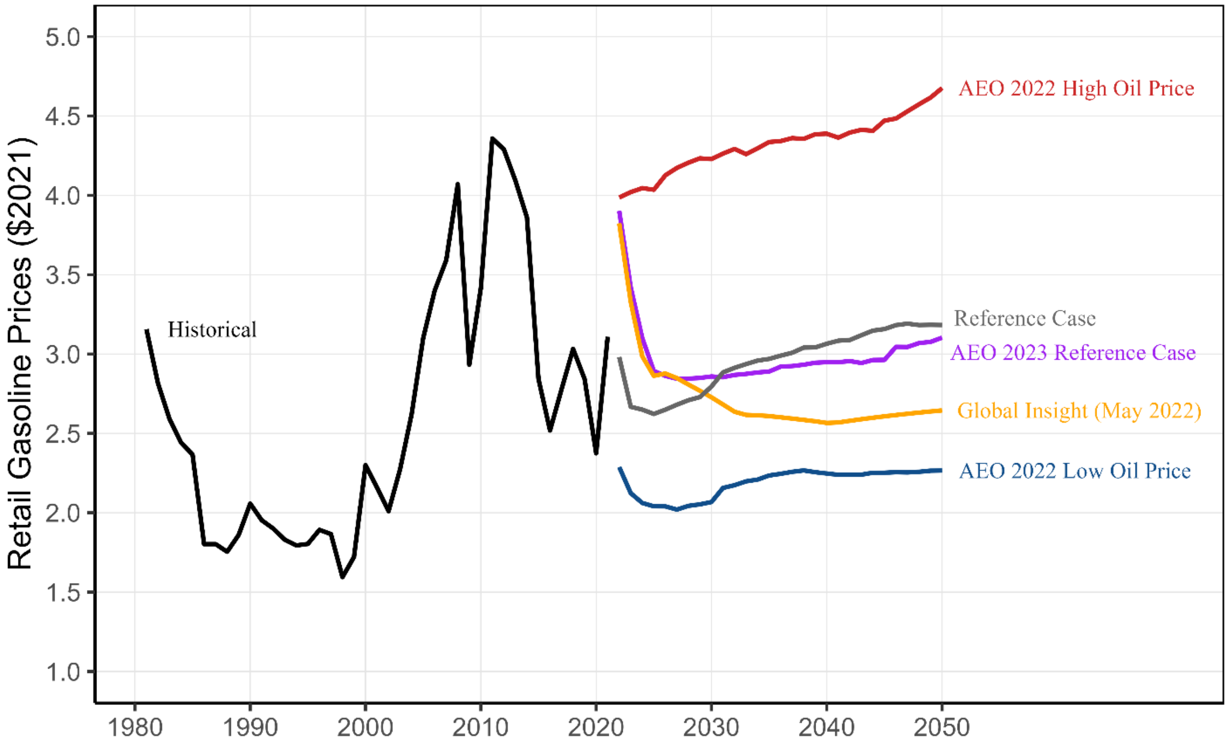
9.2.3. Effect of Economic Parameters

9.2.3.1. Oil Prices

One of the most significant sources of uncertainty in transportation market outcomes is the cost of fuel. Fuel costs affect the program net benefit calculation both in the year when new vehicles are produced, and in subsequent years when vehicles are used. In the central analysis, the rising price of fuel over time creates fuel savings (in dollars) above and beyond the anticipated savings at the time of purchase. Under the high fuel price case, this phenomenon is more pronounced.

Figure 9-12 presents the FP time series for the RC and sensitivity cases alongside historical FP levels in 2021 dollars. The historical trend highlights the amount of price variability in past years. While future trends in prices are uncertain, this sensitivity analysis relies on three price projections: high- and low-price projections from AEO 2022 that rely on EIA assumptions about future oil price trajectories, and a price forecast from the IHS Markit (IHS) GI May 2022 forecast. It is important to note that the AEO 2022 forecasts were released just after the start of the Russian invasion of Ukraine, while the GI May 2022 forecast incorporates the early effects of this conflict on price. Given the moderation in FPs in subsequent months, these price series together illustrate the range of how the invasion affected the expected path of future FPs. In broad terms, the AEO 2022 high, low, and reference price projections represent high, low, and moderate growth trends in FPs. The GI forecast differs from EIA's assumption of moderate growth and instead shows a pattern of retail gasoline price declines after a large increase above 2021 levels in 2022. The series falls between EIA's low oil price forecast and reference forecast values over the longer term. After conducting our central analysis, the 2023 AEO was released. We also include sensitivity runs using the high, low and RC projections and find that results generally mirror what we found using the 2022 AEO. In Figure 9-1 we find that following the early 2020s, the AEO 2023 RC projection settles over the long term to levels slightly below the current RC projection.

Figure 9-12: FP Sensitivity Cases



In the case of increasing FPs—especially the rapid increase in the high oil price scenario—consumers demand more fuel economy in the new vehicle market because each gallon of fuel saved during the 30-month payback period is worth more. In the high oil price scenario, manufacturers adopt more expensive technologies that yield larger improvements in fuel economy in both the No-Action Alternative and the Preferred Alternative. Increasing the baseline fuel savings limits the incremental effect of the change in regulation on the overall quantity of fuel consumption; however, the increase in fuel costs raises the overall value of any fuel savings in the Preferred Alternative. In Table 9-3we find that for MY 2032 the overall fuel cost savings in the Preferred Alternative are about $70 per vehicle higher than the RC in the high oil price scenario, though the total gasoline consumption reduction is about 18 percent lower. Additional costs imposed under the Preferred Alternative are about $90 per vehicle higher in the high oil price scenario than in the RC, meaning that they outweigh the additional fuel cost savings for consumers, and sales of new vehicles are thus expected to be slightly lower than in the RC. The effects of lower oil prices act in the reverse direction, meaning that consumers will value fuel economy gains less, and manufacturers will adopt fewer expensive technologies for this purpose. On balance this will lower the level of tech adoption in the No-Action Alternative, raising the incremental effects of changes in the regulation on the quantity of fuel consumed. However, the value of these effects on costs will be diminished by the lower price of fuel. Our results align with this outcome. Overall, in the low FP case the Preferred Alternative increases the reduction in gasoline consumption by about 45 percent, but the associated fuel cost savings is about $160 lower than in the RC. The increase in technology costs is on par with what we find in the RC, meaning that the net effect of the Preferred Alternative is less beneficial to the consumer. Results for the GI price projection scenario align closely with the low oil price scenario, though the incremental effect of the Preferred Alternative on technology costs is significantly lower than the RC.

In Table 9-2 we find that for LDVs, the high oil price case results in net benefits of approximately $34 billion relative to the No-Action Alternative under a 3 percent DR. This is more than double their level in the RC. Effects in the low oil price case drop to around $5 billion, and $11 billion in the GI RC. These results illustrate the number of channels through which FPs influence social net benefits. For example, relative to the RC, the fuel savings associated with the Preferred Alternative yield only a modest additional benefit in the high oil price case. However, as a result, there is also a smaller amount of additional vehicle use in the high oil price case, and thus a significantly lower number of additional traffic fatalities, and thus SCs.

When we examine results for MY 2038 HDPUVs in Table 9-7, we find that under the high oil price scenario the Preferred Alternative is essentially equivalent to the No-Action Alternative. However, in the low oil price scenario, less technology is adopted in the baseline, meaning that the more stringent standards now bind. As a result, significantly more technology adoption takes place and incremental fuel efficiency improvements are larger in the alternatives. Additional technology costs in this scenario rise to over $2,000 per vehicle, while fuel savings are significantly higher, at just above $5,000 per vehicle. The incremental reduction in gasoline consumption in the Preferred Alternative is significantly larger in the low oil price case than in the RC, around 60 billion gallons. Results under the GI projection case fall between the two, with incremental regulatory costs of $832 per vehicle, and fuel cost savings of $2,217. In Table 9-6, we find that in the high oil price case, the baseline standards no longer bind, and the additional net benefits in the Preferred Alternative relative to the baseline are minimal. On the other hand, net social benefits rise to around $7.7 billion in the low oil price case and $10.8 in the GI forecast case, compared to $2.25 billion in the RC. In these two cases SCs and social benefits are both significantly higher than in the RC, likely due to the new standards having a larger influence on technology adoption and fuel efficiency in the new vehicle fleets relative to what we observe in the RC.

The results of these oil price sensitivities lead to a wide range of potential net benefit outcomes from the Preferred Alternative. This is the product of two important factors. First, the price of fuel is one of the most significant determinants of the value of avoided fuel consumption. Large differences in this metric play a key role in influencing total social benefits. Second, the value of these fuel savings is a direct input into the effective cost metric used to determine technology application. Alongside technology costs, it is a primary factor in determining total SCs. Further, the price series used in this sensitivity analysis (especially the EIA high and low oil price forecasts) represent extremes of potential future price paths in both the near and long-term, with prices ranging from just over $2 per gallon to more than $4.50 per gallon in 2021 dollars. The GI case is much different from the EIA cases in that it represents a consistent decrease in prices from a very high initial level. This reflects the influence of the Russia Ukraine war on prices in the first half of 2022. Given the subsequent fall in oil prices from levels seen during this period, it is worth emphasizing the challenge in forecasting future energy prices with certainty, even over the short term. In evaluating the sensitivity of the model to these oil price cases, it is important to note as well that the high- and low-price cases are not symmetrical. There is a greater difference between the RC and the high case, than the reference and low case. However, there is also no period in the historical series that represents sustained real prices as high as the high oil case beyond 2035. We also note that while they are not considered in this sensitivity case, changes in the projection of oil market conditions will also affect our estimates of the value of reductions in energy security externalities caused by higher standards. The model's sensitivity to these estimates is explored in {Chapter 9.2.3.3}. Finally, it is important to note that differences in our net benefit results between light duty vehicles and HDPUVs are due in part to the restrictions placed on technology adoption by the standard-setting conditions.

9.2.3.2. Macroeconomic Forecasts

The CAFE Model relies on a set of macroeconomic assumptions related to GDP growth, U.S. population, real disposable personal income, and consumer confidence to simulate the economic context in which CAFE regulations are implemented. These values affect the projected size of the new LDV market, the rate at which the on-road fleet turns over, and the total demand for travel. In this analysis, the RC assumptions come from the IHS GI May 2022 Macroeconomic Outlook base case. Along with the case used in this central case, NHTSA uses IHS "pessimistic" and "optimistic" estimates of the aforementioned macroeconomic parameters as sensitivity cases. The "Low GDP (GI Pessimistic)" and "High GDP (GI Optimistic)" sensitivity cases in the tables and figures of Chapter 9.2.1 refer to our implementation of those two growth cases in the CAFE Model.[227] In an attempt to vary only one input component at a time, these cases hold FPs fixed at the RC level. Two additional cases include the corresponding FP series for gasoline and diesel.[228] In addition to these macroeconomic forecasts, we also include cases involving the AEO 2022 "High Economic Growth" and "Low Economic Growth" forecasts. These projections only apply to Real GDP and FPs. In the tables and

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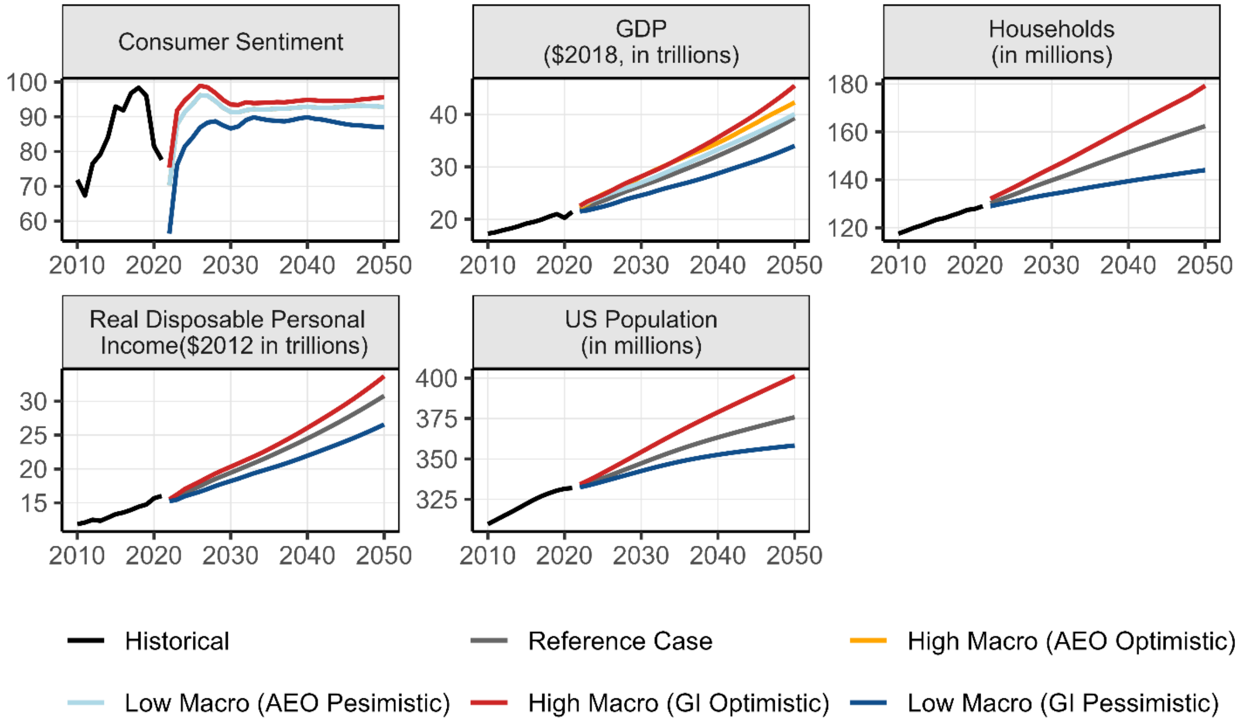
[227] Since does not update pessimistic and optimistic cases at the same frequency as their base case projection, values for years 2022 and later are projected forward by applying the percentage difference between the March 2022 base case and optimistic/pessimistic case values to the May 2022 base case projection.

[228] Because the fuel prices are deviations from the IHS base gasoline price, these results are best compared to the Global Insight oil price scenario.

figures in this chapter we refer to these cases as “Low GDP + Fuel (AEO low)” and “High GDP + Fuel (AEO high)”. Projected macro variables from each of these cases are shown in Figure 9-13.

Figure 9-13: Parameter Input Values for Macroeconomic Sensitivity Cases



The lingering consequences of the COVID-19 pandemic, disruptions to the supply chain, the Russia-Ukraine War, and inflation have only increased the level of uncertainty that would typically be present in any projection of macroeconomic conditions that spans a period as long as the one covered by this analysis. In comparison to the net benefits for LDVs in the RC (see Table 9-2, the net benefits under the GI pessimistic sensitivity case increase by $1.6 billion (using the 3 percent SC-GHG DR), which is primarily the result of lower incremental costs than in the RC. Under the GI optimistic GDP case, net benefits increase by around $500 million, as additional benefits relative to the RC only slightly outstrip increased incremental costs. Incremental fuel cost savings are slightly higher in the pessimistic case while they are lower in the optimistic case primarily due to differences in their effects on new vehicle sales. As both cases produce positive net benefits values similar to those of the RC, this result should provide some measure of confidence that the estimated net benefits in the RC are only modestly sensitive to alternative growth assumptions about the U.S. economy.

We see greater sensitivity when we incorporate alternative fuel projections corresponding to the GI cases. Net benefits decrease to around $9 billion in the GI optimistic case, while they remain stable at around $18.4 billion in the pessimistic case. As discussed in the Chapter 9.2.3.1 of this document, oil prices drive consumers’ willingness to pay for fuel economy improving technology, and thus technology adoption, as well as the value of benefits related to actual fuel savings. We see further evidence of this in our results that combine the AEO sensitivities. In the low growth scenario net benefits fall to $5.4 billion while in the high growth scenario they rise to $34.4 billion. The reason why the optimistic GI forecast and the high growth AEO forecasts change net benefits in opposite directions is caused by the fact that AEO projects lower oil price growth in its low economic growth case, and high price growth in its high growth case, while GI projects lower oil price growth in its optimistic economic forecast but higher oil price growth in its low growth case. Thus, these cases show that in combination with the effects of oil prices, the net benefits from the Preferred Alternative are somewhat sensitive to macro-economic forecasts, though this is largely driven by forecasts for oil prices. We also simulate a separate set of cases corresponding to the same set of side cases from the 2023 AEO. We find that results are not sensitive to changes in macro projections, and that net benefits fall within $5 billion of our RC results.

We simulate the same set of sensitivity cases for HDPUVs and summarize net-benefit results in Table 9-6. We find that for the GI GDP sensitivities that net-benefits are virtually unchanged from the RC. However, both in the case of AEO and GI, when we perturb macro variables and oil prices, results are significantly affected, especially in the cases in which oil prices are projected to be higher than the RC. Using a 3 percent DR, we do not see net-benefits fall below 0, however when we use the AEO high economic growth GDP and oil price forecast, they do become minimal. It is important here to bear in mind that projected gasoline prices in this case are well above $4 per gallon, causing significantly more technology adoption in the No-Action Alternative than in the RC.

9.2.3.3. Oil Market Externalities

For this proposed rulemaking analysis, NHTSA estimated the value of externalities from fuel consumption related to energy security in oil markets. As explained in Draft TSD Chapter 6.2.4, these quantities depend on the short run elasticities of global and domestic petroleum supply and demand, as well as the elasticity of U.S. GDP with respect to global oil prices. There are a range of estimates for these quantities in the literature, and thus a range of potential values for the estimates of energy security externalities. In the RC, NHTSA uses the mean estimates produced from the full set of possible elasticity parameterizations.[229] To evaluate the sensitivity of the CAFE Model results to this parameter, the agency ran two additional cases in which value of oil market externalities was set to the lower 10th percentile value, and the upper 90th percentile value.[230]

Since this quantity measures the value of a societal effect that is not internalized by vehicle owners or manufacturers, there are no effects on the compliance behavior of manufacturers or on the driving behavior of owners. Instead, this parameter simply scales up or down the societal effect of a change in the quantity of oil consumption induced by a regulatory alternative, and thus only affects the overall benefits from a change in regulation and not the costs. In Table 9-2 we find that for LDVs using the high estimate for the externality adds about $2 billion dollars of additional benefits, while using the low value lowers benefits by around $1.6 billion. For HDPUVs, as shown in Table 9-6 HDPUV Costs/Benefits the effects are both less than $200 million compared to the reference case.

9.2.3.4. Rebound Effect

The CAFE Model results are less sensitive to some parameters than others. As seen in Table 9-6, changing the rebound effect in either direction has a moderate impact on net benefits under Alternative PC2LT4. The central analysis uses a rebound effect of 10 percent, and the two sensitivity cases assume 5 percent rebound and 15 percent rebound. Changing the rebound effect increases or decreases the amount of fuel cost savings by about $30 per vehicle (increase when rebound is lowered, decrease when rebound is increased), but the foregone fuel savings are due to changes in travel that provide corresponding mobility benefits that offset the change in fuel savings. The difference in net benefits between the sensitivity cases and Reference Case is attributable to the externalities associated with the change of travel. The effect of these sensitivity cases on VMT for Alternative PC2LT4 relative to Alternative 0 is displayed in Figure 9-14. The range of the sensitivities is a little over 0.25 percent of total light duty VMT at its peak.

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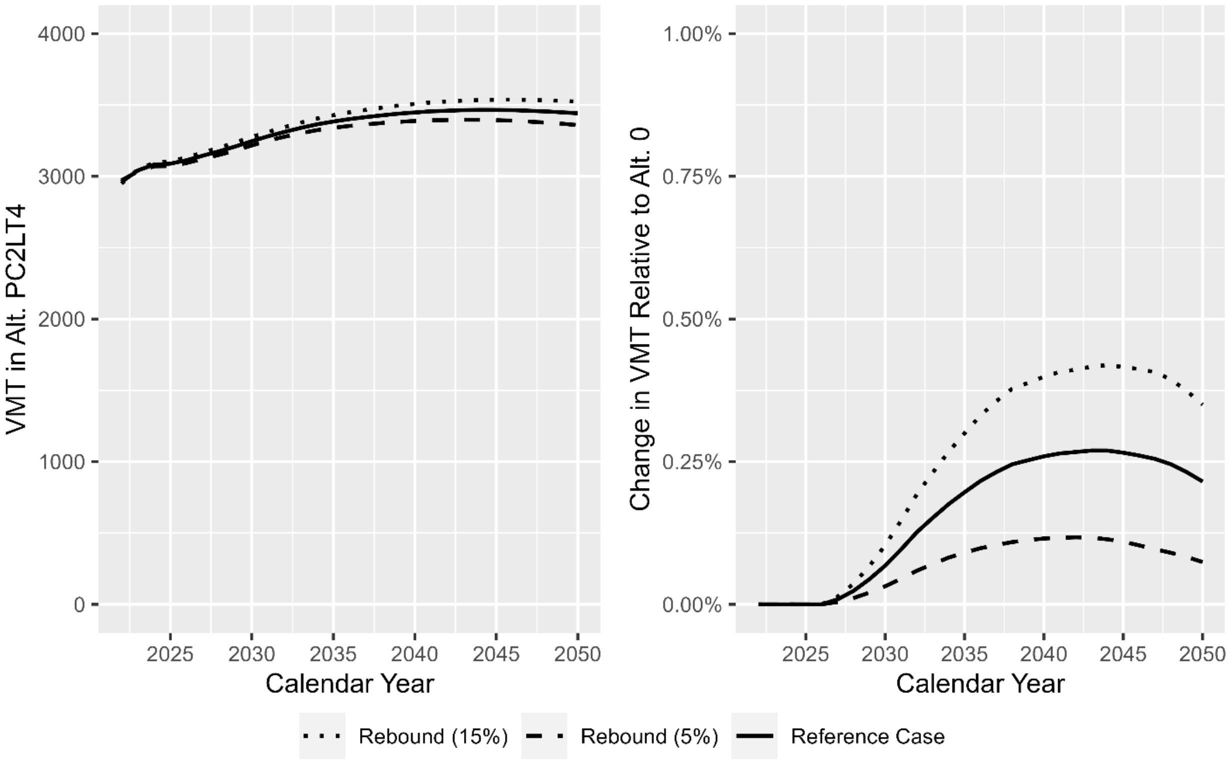
[229] NHTSA took its estimates for these elasticities from the distribution of elasticity estimates listed in Brown (2018). This set includes both recent and older estimates of these elasticities.

[230] We also re-estimated externalities using 2023 AEO projections and include an additional sensitivity case using these values. We do not find our results are sensitive to this change.

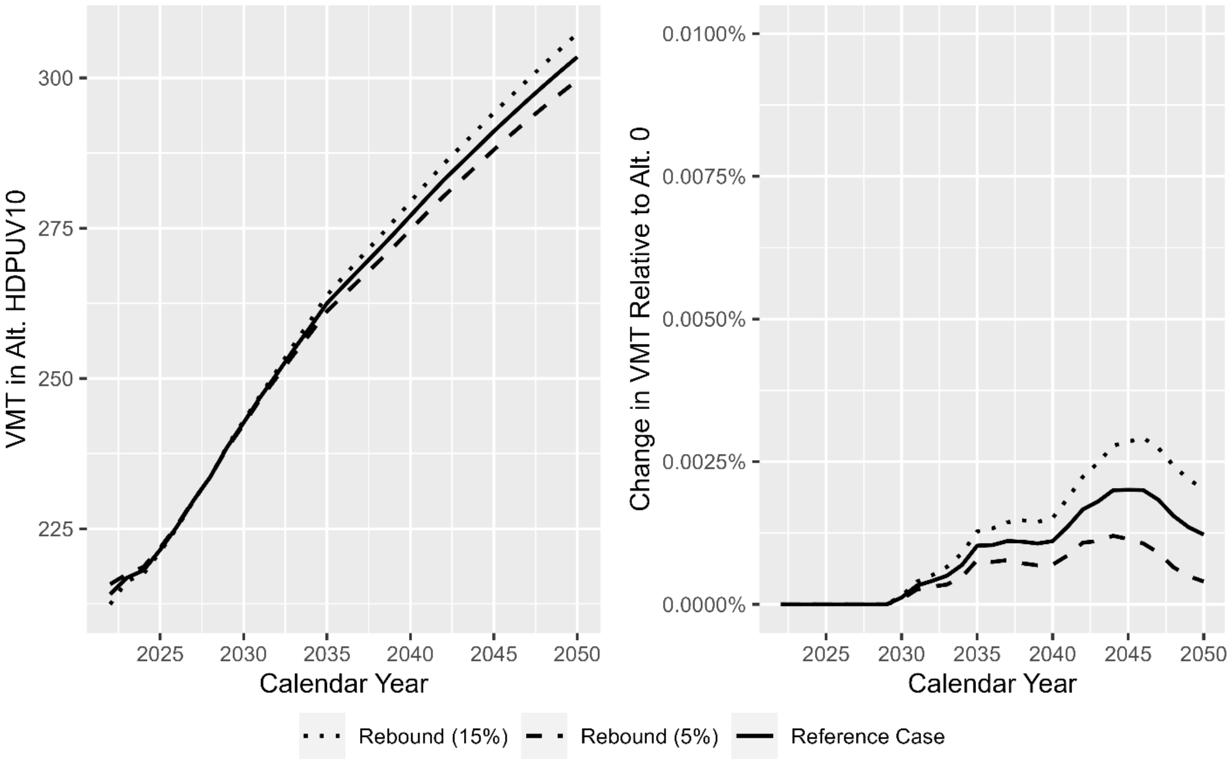
Figure 9-14: Light-Duty Vehicle Miles Traveled in Alternative Rebound Cases



Using a 3 percent DR, assuming a rebound effect of 5 percent results in slightly lower costs and benefits (relative to the RC), and an increase in net benefits, while assuming a rebound effect of 15 percent leads to higher cost and benefit values and a decrease in net benefits relative to the RC. In both cases, benefits change by a magnitude of 4.1 percent, while costs change by a magnitude of 8.5 percent and net benefits change by a magnitude of 11 percent.

When we turn to HDPUVs we see that changes are even more modest. In Figure 9-14 we see that the rebound VMT range is now well under 0.01 percent of total HDPUV VMT. As shown in Table 9-6, SCs and social benefits both increase with the rebound effect. Compared to the reference case, net social benefits increase by about $30 million per year with a 5 percent rebound effect, and decrease about $40 million per year with a 15 percent rebound effect.

Figure 9-15: HDPUV Vehicle Miles Traveled in Alternative Rebound Cases



9.2.3.5. Sales Forecasts

The CAFE Model uses a nominal forecast to project total LDV sales and a projection based on year-to-year AEO growth rates to project HDPUV sales. To test the sensitivity of the model to these modeling choices, NHTSA runs three sensitivity cases each for the total vehicle sales projections of LDVs and HDPUVs. Here it is important to note that these side cases deal specifically with either methodological or input choices that directly impact the baseline sales projections. However, sensitivities that adjust GDP and consumer sentiment, and the number of households will also affect the projected level of sales in the No-Action Alternative and the regulatory alternatives. Thus, sensitivity to changes in baseline sales can be seen as being embedded in these additional sensitivity cases as well.

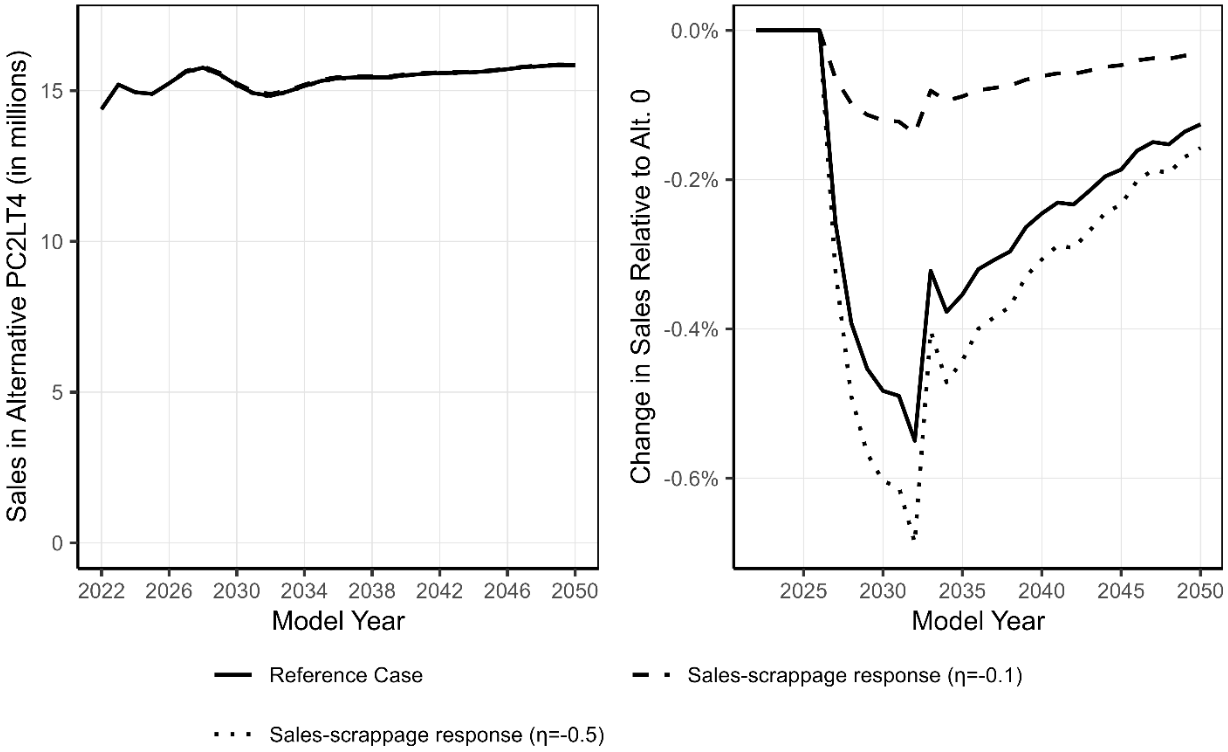
For LDVs we project sales using: 1) the 2022 final rule projection model, 2) the AEO 2022 RC projection for total PC and LC sales, and 3) the 2023 NPRM projection model excluding an intercept adjustment that reconciles the historical sales series used to estimate this model with compliance data used to create the baseline 2022 LD fleet. Since these changes do not affect the costs or benefits of technology adoption for an individual vehicle, they should just tend to amplify or decrease the levels of net benefits that we observe in the RC. Examining their effect on costs and benefits in Table 9-2, we find that this is the case. Costs and benefits are highest in the 2022 final rule model case and lowest in the case in adjusted version of the 2023 NPRM model. Net benefits under a 3 percent DR are about $1.7 billion higher than the RC in the adjusted 2023 NPRM model case and $1.2 billion lower in the 2022 final rule model case, with the 2022 AEO projection case falling in between. Overall, the model is not relatively sensitive to these changes.

For HDPUVs, we modify our sales model by:1) removing the sales growth rate adjustment that we employed to reconcile differences in AEO's sales projection series and the compliance data used to generate the baseline 2022 fleet, 2) using projected sales growth rates from the 2022 AEO's "High Economic Growth" case, and 3) using projected sales growth rates from the 2022 AEO's "Low Economic Growth" case. We find that costs and benefits are both higher in the high growth case, and lower in the low growth case with the projection excluding the sales growth adjustment falling in the middle. In terms of net benefits, we find that under a 3 percent DR, they are $150 million higher than the RC in the high growth case and $460 million lower in the low growth sales case. In none of the cases do net benefits fall near $0, suggesting that our results for this group of vehicles are not sensitive to modeling changes for this component. We also include a projection of sales for these vehicles based on our RC methodology but using the 2023 AEO sales projection. We find that our results are not sensitive to this change.

9.2.3.6. Sales Elasticity

Sensitivity cases with adjusted sales and scrappage responses produce only modest changes in costs and benefits. We include two cases with different sales-scrappage responses, which vary the price elasticity around the central case. The high elasticity case uses a price elasticity of -0.5 and the low elasticity case uses -0.1. Sales effects for LDVs in Alternative PC2LT4 in each of these sensitivities are presented in Figure 9-16.

Figure 9-16: Light-Duty Sales Effects of Alternative Price Elasticity Estimates



The effects of this variation on social net benefits are modest. As shown in Table 9-2, net social benefits in the low elasticity case for LDVs are higher by about $1.9 billion, while they are lower by about $600 million in the high elasticity case. A more elastic consumer response depresses sales when technology costs are passed through to consumers, meaning that the additional benefits of the new technology are somewhat muted by their lower overall penetration into the fleet.

Sales in the HDPUV case do not vary significantly from the baseline in the Preferred Alternative from the RC. As a result, adjusting the elasticity has only minimal effects on sales as shown in Table 9-7. When we examine costs and benefits in Table 9-6 for each of the price elasticity cases, we find that total additional net social benefits under a 3 percent DR only vary from the RC by about $260 million in the low elasticity case, and under $100 million in the high elasticity case. Costs tend to decrease with the magnitude of the elasticity, as fewer vehicles are produced with upgraded technology. Additional social benefits in the Preferred Alternative actually decrease slightly in both sensitivity cases from the levels we observe in the RC.

9.2.3.7. Fleet Share

In this preliminary analysis, NHTSA changed from its past approach of using a parameterized model based on the EIA's National Energy Modeling System (NEMS) model to project the share of PCs and LT in the new LDV fleet. Instead, the agency chose to project baseline fleet share forward from the 2022 baseline fleet using the year-to-year growth rate projections implied by the 2022 AEO. To account for the influence of relative price changes between the PCs and LT across regulatory alternatives, NHTSA used a parameterized binomial logit model which is described in further detail in Draft TSD Chapter 4.2 and in a docket memo. To test the sensitivity of the CAFE Model's results to these modeling choices, the agency ran three additional cases: 1) using the AEO-based share projection but excluding the price-based adjustment between regulatory alternatives, 2) keeping the No-Action Alternative fleet share fixed at AEO 2022 levels, and 3) keeping fleet shares in each alternative fixed at the AEO 2022 levels.

As shown in Table 9-2, excluding the price-based adjustment has little influence on the incremental costs and benefits of the Preferred Alternative. Social net benefits increase by about $500 million under a 3 percent DR. This is due both to a reduction in SCs and an increase in social benefits. In this scenario, the relative price increase associated with adopting fuel economy improving technology in body style does not push consumers to substitute towards the other body style. When we keep baseline fleet shares at their 2022 values, we find only a slight decrease in SCs and benefits, leading to a slight decrease in social net-benefits relative to the RC. When we turn off price response and fix the fleet share at 2022 levels, we find a smaller effect in the same direction. We also include a case in which our projection for fleet share is based on the 2023 AEO projection for sales of PCs and LT. We find that our results are not sensitive to this change.

9.2.3.8. Payback Period

New vehicle buyers have a variety of preferences for vehicle attributes (e.g., seating capacity, interior volume, drive type, 0 to 60 mph time performance, and fuel efficiency, among many others). The current analysis characterizes buyers' preference for fuel economy improvements by the number of years required to offset the initial technology investment with avoided fuel costs – the payback period. Like the 2012, 2016, 2020, and 2022 versions of the CAFE Model, the current version applies the same payback period across all regulatory alternatives. The central analysis uses a 30-month payback period to quantify the average preference for fuel economy improvements in the new vehicle market. To examine the effect of this payback period, the sensitivity cases include a range of alternative payback period lengths (24-, 36-, and 60-month scenarios) as well as one case that eliminates the payback period entirely. With a longer payback period, more costly, but effective, technologies and technologies that offer smaller marginal fuel efficiency improvements become more attractive options. Technologies with higher costs, but also higher effectiveness, can appear more attractive (to both manufacturers and consumers) if the period over which fuel savings is valued is longer. More effective technologies will have higher monthly savings but, with shorter assumed payback periods, there still may not be enough months to accumulate sufficient fuel savings to offset the higher initial cost.

Sensitivity cases that vary payback period lengths for the LDV produce results that are mostly consistent with expectations. For example, in the 60-month payback period scenario, average vehicle costs, lifetime fuel savings, social benefits, and SCs (relative to the baseline) all decrease when compared to the RC. Longer payback periods mean consumers are willing to pay for more "extra" technology (i.e., technology beyond that necessitated by CAFE and CO_2 standards) which manufacturers apply predominantly in the No-Action Alternative, thus reducing the estimated incremental impacts, benefits, and costs of more stringent standards. Net benefits move as expected, increasing to $26.5 billion when we eliminate the payback period entirely and decrease to $6.1 billion in the 60-month payback period case.

The opposite is true (i.e., incremental impacts increase) for shorter payback cases, such as the 24-month payback case. As expected, eliminating the payback period produces fewer vehicles with expensive technology (e.g., PHEVs) in both the No-Action Alternative and the regulatory alternatives. Eliminating the payback period means manufacturers will act as if buyers are not willing to pay anything at all for improved fuel economy, no matter how much they are paying for gasoline. This means that their technology adoption will be driven entirely by the proposed standards, thus increasing the importance of changes in the standards.

The 36-month payback period produces slightly higher incremental SCs and social benefits than the RC. In MY 2032 both baseline and incremental PHEV adoption are significantly higher than in the RC. The incremental adoption of SHEVs is significantly lower than in the RC, suggesting that firms choose to comply with standards by converting to PHEVs which carry higher tech costs, but also secure additional tax credits.

When we analyze results for HDPUVs in Table 9-6, we find the same overall pattern for incremental SCs, social benefits, and social net-benefits. The HDPUV fleet is significantly smaller than the LDV fleet, and even within the HDPUV fleet, vehicles are more heterogenous. Assumptions within our HDPUV analysis can appear to have a larger impact in the results than observed in the LDV fleet because of size differential between fleets. The characterization of the HDPUV fleet is further discussed in Draft TSD Chapter 2 and Preamble Section II.C.

Each of the payback sensitivity results should be interpreted keeping in mind an important reality about model assumptions: they only affect the simulated decisions about which technology manufacturers will apply; the current sales and scrappage modules do not respond to changes in this payback period assumption, but rather to separate payback assumptions (the RC payback period) specified when running the model.

To test the sensitivity of the assumptions used in the sales and scrappage models for LDVs, NHTSA also included a scenario in which fuel savings for technology application were valued at 30-months (as in the central case), but 70,000 miles for the valuation in the sales and scrappage models (twice as long as the 35,000 miles in the central case) representing approximately 5 years of consumer value for fuel economy improvements. We find that SCs decrease by $1.9 billion, while social benefits increase by 1.3 billion. The incremental fuel cost savings and technology costs differ only slightly in this case, although the effect of these costs on sales is much smaller. As a result, the regulation has less of an effect on fleet turnover, allowing more of the fleet to transition to new vehicles.

9.2.3.9. Implicit Opportunity Cost

In the central analysis for the LD fleet, NHTSA's analysis suggests that buyers' perceived reluctance to purchase higher-mpg models is due to the consumer's undervaluation of the expected savings in fuel costs and due to potential market failures including informational asymmetries between consumers, dealerships, and manufacturers; market power; first-mover disadvantages for both consumers and manufacturers, or status quo biases; split incentives between vehicle purchasers and vehicle drivers; behavioral patterns like myopia and loss aversion; and other failures that may prevent consumers from purchasing the optimal level of fuel economy in an unregulated market as discussed in Section 2.1.4 of the PRIA.[231]

Another potential explanation for why buyers have in the past been reluctant to purchase fuel-saving technologies is the potential for tradeoffs between vehicle fuel economy and other vehicle attributes including performance. In the absence of standards, a vehicle producer may adopt a set of technologies that improve fuel economy as well as the other attributes of the vehicle. If standards force the manufacturer to deviate from this set of decisions, by sacrificing improvements in other attributes for improvements in fuel economy, consumers could then face a cost that is not counted in the light-duty reference case analysis.

Results some of from the economics literature support that these tradeoffs have existed in the past. For example, Leard et al. (2023) finds that consumers value performance improvements at three times the rate at which they value improvements in fuel economy, and that foregone improvements in performance from recent changes in CAFE standards have essentially offset consumer welfare improvements from the fully valued savings in fuel costs.[232] However, Leard et al. (2023) acknowledge that their conclusions do not account for a variety of potential market failures around the under provision of fuel economy and insufficient incentives for innovation, and do not account for how the rate of technology adoption may change over time in response to regulatory standards. Klier and Linn (2016) find that if performance tradeoffs resulted from a hypothetical 10% increase in regulatory stringency, U.S. consumers would value the resulting fuel economy gains at levels approximately 65-85% greater than their willingness to pay for any associated forgone horsepower, assuming a discount rate applied to future fuel savings of 10%, assuming consumers value absolute rather than relative horsepower, and assuming that future technological progress will follow historical patterns. Klier and Linn (2012) find that costs to consumers are larger when manufacturers respond over the medium term rather than the short term. Whitefoot et al. (2017) finds using a simulation based approach that observed changes in

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[231] See Rothschild, R. and Schwartz, J. 2021. Tune Up: Fixing Market Failures to Cut Fuel Costs and Pollution from Cars and Trucks. Institute for Policy Integrity. New York University School of Law.

[232] Leard et al. (2023) find that their baseline results for the degree to which consumers undervalue fuel economy differ from Busse et al. (2013). After re-estimating their results using the same dataset as Busse et. al (2013), they find results that are closer to full valuation as in Busse et al. (2013). Conversely, they do not find significant changes when re-estimating results using the methodology in Busse et al. (2013) and their own dataset. Thus, as the authors conclude, results appear to be sensitive to the underlying data used to estimate them.

vehicle attributes are consistent with a model in which manufacturers have an incentive to trade off acceleration performance for fuel economy to lower their costs of compliance (relative to other strategies) with CAFE and GHG standards. While this research suggests that manufacturers may tradeoff attributes like horsepower and weight for improvements in fuel economy to more cost effectively comply with standards, it is important to note that these attributes are only relevant to the opportunity cost to the degree which they are valued by the consumer.

Other research casts doubt on the assumption that consumers have faced considerable attribute-efficiency tradeoffs that have led to net losses in consumer welfare, or would likely face such tradeoffs in the future. (See Huang, Helfand, et al. 2018; Watten, Helfand and Anderson 2021; Helfand and Dorsey-Palmateer 2015). That research, for example, suggests that the presence of fuel-saving technologies has not led to adverse effects on other vehicle attributes, such as performance and noise. Instead, research shows that there are technologies that exist that provide improved fuel economy without hindering performance, and in some cases, while also improving performance (such as high-strength aluminum alloy bodies, turbocharging, and increasing the number of gear ratios in new transmissions). Such research also demonstrates that, in response to regulatory standards, automakers have improved fuel economy without adversely affecting other vehicle attributes. Even as the availability of more fuel-efficient vehicles has increased steadily over time, research has shown that the attitudes of drivers towards those vehicles with improved fuel economy has not been affected negatively. To the extent some performance-efficiency tradeoffs may have occurred in the past, such tradeoffs may decline over time, with technological advancements and manufacturer learning over longer vehicle design periods (Bento 2018; Helfand & Wolverton 2011).

As discussed above, NHTSA analysis showing private benefits in excess of private costs suggests that market failures explain buyer’s perceived reluctance to purchase more fuel-efficient vehicles. NHTSA tests the sensitivity of its central analysis to the potential for opportunity costs of foregone vehicle attributes by assuming instead that this is a result of manufacturers trading off fuel efficiency with other desirable features that consumers also value. Here we include an approximation of potential consumer effects that could result from potential forgone vehicle attribute improvements that exceed the reference case 30-month payback period. As discussed below, these estimates may be overstated due to some potential countervailing effects.

The central case assumes that buyers are willing to pay for fuel economy improvements they expect to repay their higher initial costs within the first 30 months they own a new vehicle. The LD implicit opportunity cost sensitivity case assumes that if consumers are willing to forgo the additional fuel savings that would result from spending more to purchase models that employ additional fuel-saving technology and achieve still higher fuel economy, the value they derive from using the savings in technology costs for other purposes must equal or exceed those forgone fuel savings. NHTSA approximates this value as the discounted value of fuel savings over the first 72 months buyers will own new vehicles (e.g., roughly how long new cars are held by their initial owner) less the undiscounted value of fuel savings over the first 30 months. The agency recognizes that this is a rough, indirect, and uncertain approximation, and the magnitude of the opportunity cost is likely to vary among individual vehicle buyers. The logic underlying this sensitivity is that in a world without market failures, if consumers do not value fuel savings beyond 30 months but standards require manufacturers to make improvements in fuel economy or fuel efficiency that take longer to repay their costs, manufacturers will make accompanying trade-offs to vehicles’ other desirable attributes (e.g., interior space and comfort, carrying capacity, ride quality, performance) or increase prices to recover their higher costs, and in either case buyers will regard the outcome as less desirable than any fuel savings they would realize after 30 months. Imposing these opportunity costs or further price increases on new vehicle buyers thus represents an additional cost of adopting fuel economy or fuel efficiency standards that are more demanding than those prevailing under the No-Action Alternative. Because any trade-off in potential improvements to other attributes are not directly observable (they may have occurred in the future under prevailing standards, but under the maximum feasible standards may not), their value must be inferred indirectly and in aggregate rather than itemized and valued explicitly. Operationally, the CAFE Model includes an “implicit opportunity cost” component that is populated in this sensitivity analysis. In MY 2032, the implicit opportunity cost for LDVs is approximately $277 per vehicle at a 3 percent DR.

However, these estimates do not include potential countervailing effects. If manufacturers do trade off fuel economy and other vehicle attributes, contrary to the assumption of performance neutrality used in calculating compliance costs, our estimates may overstate the out-of-pocket cost of the standards to the consumer.

Some potentially forgone attributes may be associated with various externalities, such as increased accident rates associated with acceleration, and these countervailing effects have not been estimated. Some vehicle attributes may resemble "positional goods" to a degree where consumers derive some utility from a rank order of desirability (e.g., having "best in class acceleration"). In such a case, it is unclear that more stringent standards will impact consumers' relative positions in consumption of such attributes. However, NHTSA does not have sufficient information to determine whether, and to what extent, consumers' utility is a function of positionality.

Ultimately, this sensitivity analysis is not sufficiently robust to include in a primary analysis. Further, we believe that the inclusion of fuel savings benefits in the primary analysis is justified due to potential market failures including informational asymmetries between consumers, dealerships, and manufacturers; market power; first-mover disadvantages for both consumers and manufacturers, or status quo biases; split incentives between vehicle purchasers and vehicle drivers; behavioral patterns like myopia and loss aversion; and other failures that may prevent consumers from purchasing the optimal level of fuel economy in an unregulated market as discussed in Section 2.1.4 of the PRIA.

9.2.3.10. Implicit Opportunity Costs for HDPUVs and Commercial Operator Share

As in the case of light-duty vehicles, NHTSA does not assume that there are any offsetting opportunity costs to improvements in the fuel economy of HDPUVs in the reference case analysis. During the process of preparing its analysis, NHTSA considered the possibility that there are important differences in the types of buyers who make up the market for HDPUVs, in particular a larger share of commercial operators, and that the assumptions implicit in its analysis of light-duty private costs and benefits might apply differently in the HDPUV market.

Since many light duty commercial vehicles are ultimately used in a manner similar to personal vehicles (e.g., rental vehicles represented about 47 percent of commercial light duty sales in May 2023, up from about 39 percent from a year before according to Cox Automotive), it is possible that the preferences of commercial light-duty buyers mirror their non-commercial counterparts, hence minimizing the total cost of buying and operating a vehicle may not be essential to their profit maximation strategy.[233] Given this, the opportunity cost to commercial light-duty buyers would be the same as non-commercial buyers.

However, in the HDPUV market, vehicles perform a more narrow set of functions, and commercial operators in this realm are more likely to seek vehicles with the lowest cost of ownership that can fulfill their business need. It is possible that rather than privately valuing only 30 months of fuel savings from new vehicle purchases, commercial buyers might instead be presumed to be profit-maximizers that choose vehicles offering combinations of attributes that maximize the profits they earn by operating them in commercial service, and if their profits could be improved by selecting a more fuel-efficient model they would do so. In the absence of other market failures, producers would then respond to commercial buyers' demands communicated through the market by supplying more fuel-efficient vehicles.

Under these alternative assumptions, and in the absence of market failures, incremental increases in HDPUV fuel efficiency standards that would generate fuel savings for commercial operators would be accompanied by some sacrifice in other vehicle attributes that imposes costs on commercial operators, or else requiring increases in fuel efficiency would be unnecessary. In our sensitivity analysis, NHTSA has chosen to present two cases in which we assume that such costs offset any net private benefit to commercial buyers of HDPUV vehicles, without explicitly modeling them. In the first case, NHTSA has assumed that half of HDPUV sales are for commercial use while the remaining half are purchased for personal and other non-commercial use. NHTSA calculates net private benefits as the sum of technology costs, lost consumer surplus from reduced new vehicle sales, and safety costs internalized by drivers minus fuel savings, benefits from additional driving, and savings from less frequent refueling. The aggregate opportunity cost to commercial operators of other vehicle attributes presumed to be sacrificed is then calculated as 50% (the share of HDPUV market that are assumed to be commercial operators) of the value of these net private

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[233] See https://www.coxautoinc.com/market-insights/may-2023-fleet-sales/.

benefits.[234] Since there is uncertainty over this quantity, NHTSA ran an additional extreme sensitivity case in which it assumes that all consumers are commercial buyers who would experience opportunity costs that would offset any private fuel saving benefits.

In Table 9-6 we find that after adjusting for this offset for the case in which when commercial operators represent half of the HDPUV market, social net-benefits decrease by just under $900 million. When the entire market is commercial social, net-benefits decrease by around $1.75 billion, and fall close to 0, suggesting that results are sensitive to this assumption. However, assuming the entire market is filled with commercial operators is an extreme assumption that is at odds with available evidence from the current composition of the market, and the projected future market share of commercial operators.

NHTSA's analysis suggests that market failures affect the heavy-duty vehicle market, which plays a role in limiting the adoption of fuel efficiency improving technologies. Many heavy-duty vehicle purchasers are individual consumers, who may be subject to the same behavioral and market failures mentioned above, such as loss aversion, asymmetrical information, and status quo bias. Some institutional (e.g., government) or commercial actors may also experience those same behavioral biases. Commercial actors in the heavy-duty market may also experience other market failures and uncertainties, including short-termism, principal-agent split incentives, uncertainty about the performance and service needs of new technologies and first-mover disadvantages for consumers, uncertainty about the resale market, and market power and first-mover disadvantages among manufacturers.[235] Consistent with NHTSA's approach for light-duty, full fuel savings benefits are included in the central case.

9.2.4. Effect of Social and Environmental Parameters

9.2.4.1. Electricity Grid Assumptions

Given the anticipated growth in electrified vehicles over the next 25-30 years, in response to market forces, fuel efficiency improvements, and anticipated baseline growth in electrification adoption, it is important to understand where the electricity utilized to fuel these vehicles is being sourced. The CAFE Model assumes an AEO business-as-usual forecast for electricity generation, which is updated each year by the US EIA. To better follow how deviations from this forecast assumption may affect costs and benefits as well as total emissions from the light duty and HDPUV fleets, we model two additional forecasts that assume increasing rates of renewable energy use in the US electricity grid mix. In particular, these two sensitivity cases model changes to upstream CAFE emission factors for GHGs and criteria pollutants based on their relative grid mix. We have chosen to test how these two "clean grid" forecasts will affect this proposed action because current US electricity markets have already started to reflect the following changes: increased adoption of renewables, accelerated coal plant retirements, and a potential plateau in natural gas production.[236,237,238] For further discussion on this clean grid sensitivity analysis and underlying assumptions, please refer to the accompanying docket memo.[239]

The proposal's No-Action Alternative applies a grid mix from the AEO 2022 RC to determine upstream emission factors in the 2022 version of the GHGs, Regulated Emissions, and Energy Use in Transportation

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[234] To approximate the commercial share of the HDPUV market we reviewed data submitted to the State of California by Truck and Engine Manufacturers Association on HDPUV sales in that state. We determined that roughly half of vehicles sold were pickup trucks intended for personal use. See https://view.officeapps.live.com/op/view.aspx?src=https%3A%2F%2Fww2.arb.ca.gov%2Fsites%2Fdefault%2Ffiles%2F2018-11%2F181204emaanalysis_0.xlsx&wdOrigin=BROWSELINK. (Accessed: May 31, 2023). Data was submitted in advance of the California Air Resources Board's Dec. 4, 2018 Public Workshop Meeting to Provide an Update on Light- and Heavy-Duty Fleet Requirements and Public Workgroup to discuss Advanced Clean Trucks Regulation. More info: https://ww2.arb.ca.gov/our-work/programs/advanced-clean-trucks/act-meetings-workshops.

[235] E.g., Birky et. al (2017) note that small manufacturerers are hesitent to enter the market due to fear of competition from the large OEMs. Also, Lowell and Culkin (2021) notes that the classes in this group remain dominated by the "big 3" US car companies.

[236] Isabella O'Malley (Associated Press) for PBS NewsHour Electricity generated from renewables surpassed coal in the U.S. last year. Published: 23 March 2023. Available at: https://www.pbs.org/newshour/science/electricity-generated-from-renewables-surpassed-coal-in-the-u-s-last-year. (Accessed: May 31, 2023).

[237] M. Tyson Brown (EIA) for Today in Energy. Nearly a quarter of the operating U.S. coal-fired fleet scheduled to retire by 2029. Published: 7 Nov 2022 Available at: https://www.eia.gov/todayinenergy/detail.php?id=54559. (Accessed: May 31, 2023).

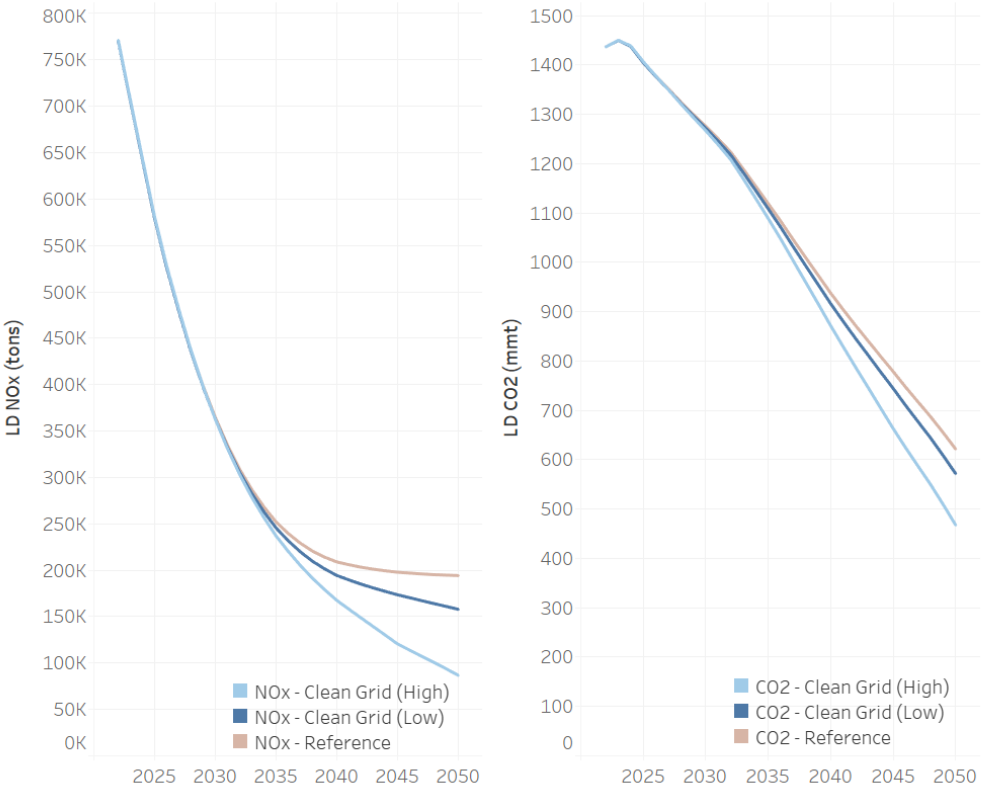
[238] J. Robinson, S&P Global Commodity Insights. US gas production growth outlook in 2023 dims amid falling IRRs, slower rig activity. Published: 8 Feb 2023 Available at: https://www.spglobal.com/commodityinsights/en/market-insights/latest-news/natural-gas/020823-us-gas-production-growth-outlook-in-2023-dims-amid-falling-irrs-slower-rig-activity. (Accessed: May 31, 2023).

[239] See "Clean Grid Sensitivity Cases: 2023 CAFE Notice for Proposed Rulemaking" memorandum, which can be found under References and Supporting Material in the rulemaking Docket No. NHTSA-2023-0022.

(GREET) model, released annually by Argonne National Laboratory.[240] In addition to the GREET 2022 default grid mix, we entered two other custom “clean grid” mix formulations into GREET to compare against the RC: one from AEO 2022 Low Renewables Cost side case and another from the National Renewable Energy Laboratory (NREL) 95% Electrification by 2050 scenario (2021 Standard Scenarios).[241] The AEO forecast assumes less growth in electricity from renewables than the more ambitious NREL forecast, which projects a 95% transition to low-carbon electricity sources by 2050. Considering their relative rates of decarbonization, we refer to the AEO Low Renewable Cost forecast as the “Clean Grid-Low” case and the NREL forecast as the “Clean Grid-High” case.

Our findings show that upstream emissions from the combined LD and HDPUV fleets could be noticeably affected by the national grid mix. For both GHGs and criteria pollutants, the clean grid sensitivity cases show how, particularly after the early 2030s, additional adoption of renewable energy used to power the electric grid could result in fewer criteria pollutants and CO_2 emissions. The Clean Grid-Low case shows some emission benefits over the RC and the Clean Grid-High case shows more pronounced emission benefits over the reference and marked benefits over the Clean Grid-Low case. Figure 9-17 summarizes baseline (i.e., No-Action Alternative) LD emission trends for an example criteria pollutant (NOx) and example GHG (CO_2) across all fuel types. We find that NOx decreases quickly over the first 10-15 years across all forecasts and then begins to level off. While CO_2 shows some slight initial growth, it then drops precipitously through 2050. As shown in Figure 9-17, HDPUVs have highly related but not identical trends as LD emissions.

Figure 9-17: CAFE modeling of LD fleet emission inventories for key pollutants under the Reference, Clean Grid-Low, and Clean Grid-High cases by CY: NOx (left) and CO_2 (right)



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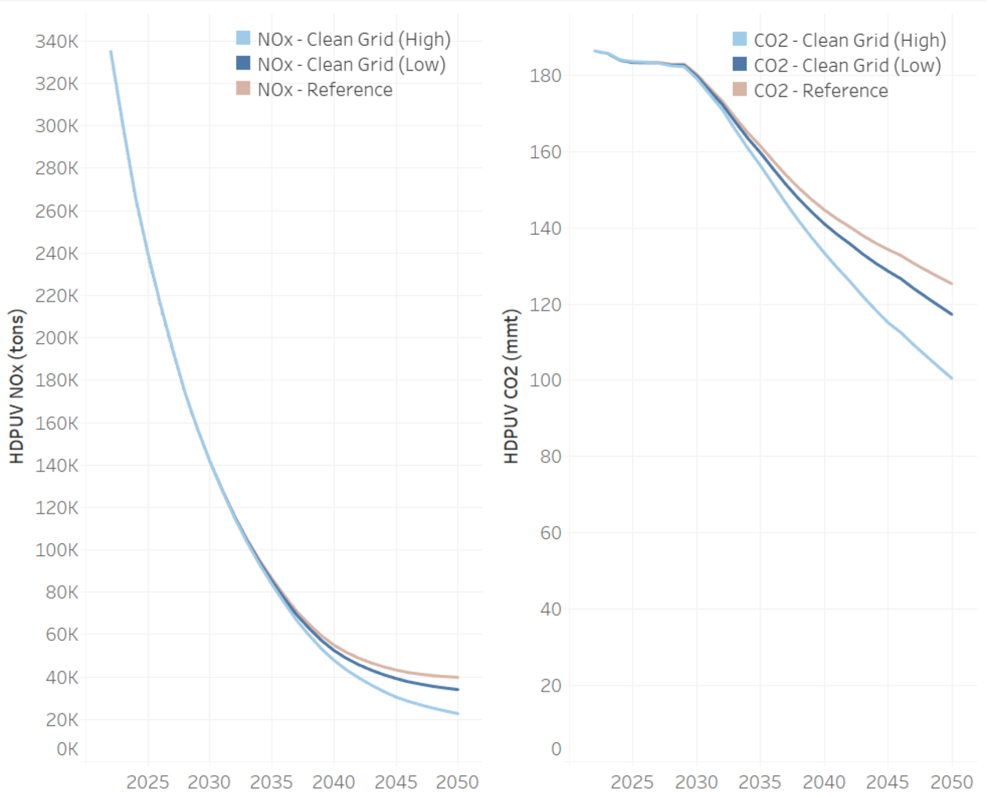
[240] NHTSA used the 2022 AEO forecast for this sensitivity case as it represented the most up-to-date projections at the time of modeling. NHTSA will consider using newer forecasts for the final rule.

[241] The AEO Low Renewables Cost forecast data can be found on EIA’s interactive data browser (https://www.eia.gov/outlooks/aeo/data/browser) and similarly the NREL 95% Electrification by 2050 forecast data can be found on their scenario viewer (https://scenarioviewer.nrel.gov/?project=c85d86ff-f6ec-4812-925b-ceb9a1465506&mode=download&layout=DAC%20View).

Figure 9-18: CAFE modeling of emission inventories of HDPUV for key pollutants under the reference and two clean grid cases by CY: NOx (left) and CO_2 (right)



Although total LD and HDPUV emissions decrease in the future as a result of CAFE and fuel efficiency improvements and anticipated baseline growth in electrification, emissions from electricity to power electrified vehicles in the LD and HDPUV fleets are projected to grow. Figure 9-19 and Figure 9-20 show how upstream emissions from LD and HDPUV electrified vehicles are expected to change over time. In both the reference and Clean Grid-Low cases, upstream emissions from EVs increase through 2050, though to a lesser extent in the Clean Grid-Low case than the RC. The Clean Grid-High case, which projects a 95% transition to low-carbon electricity sources by 2050, produces a decline in electricity emissions from the LD and HDPUV fleets after a period of growth.

Figure 9-19: CAFE modeling of LD upstream electricity emission inventories for key pollutants under the reference and two clean grid cases by CY: NOx (left) and CO₂ (right)

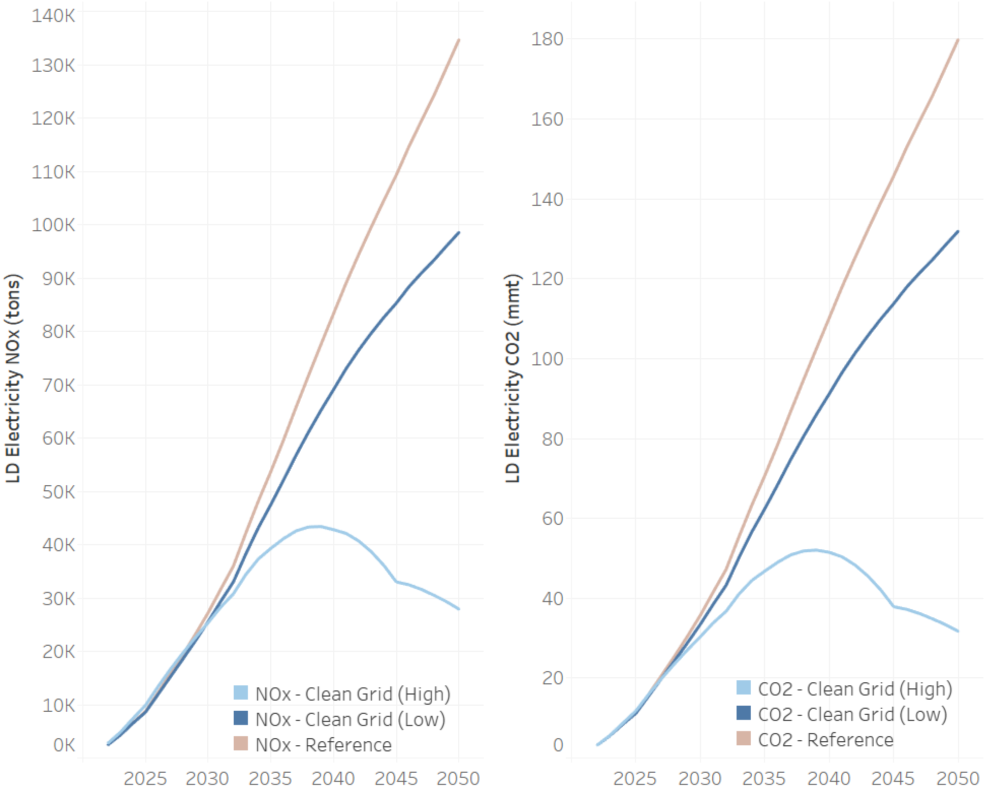
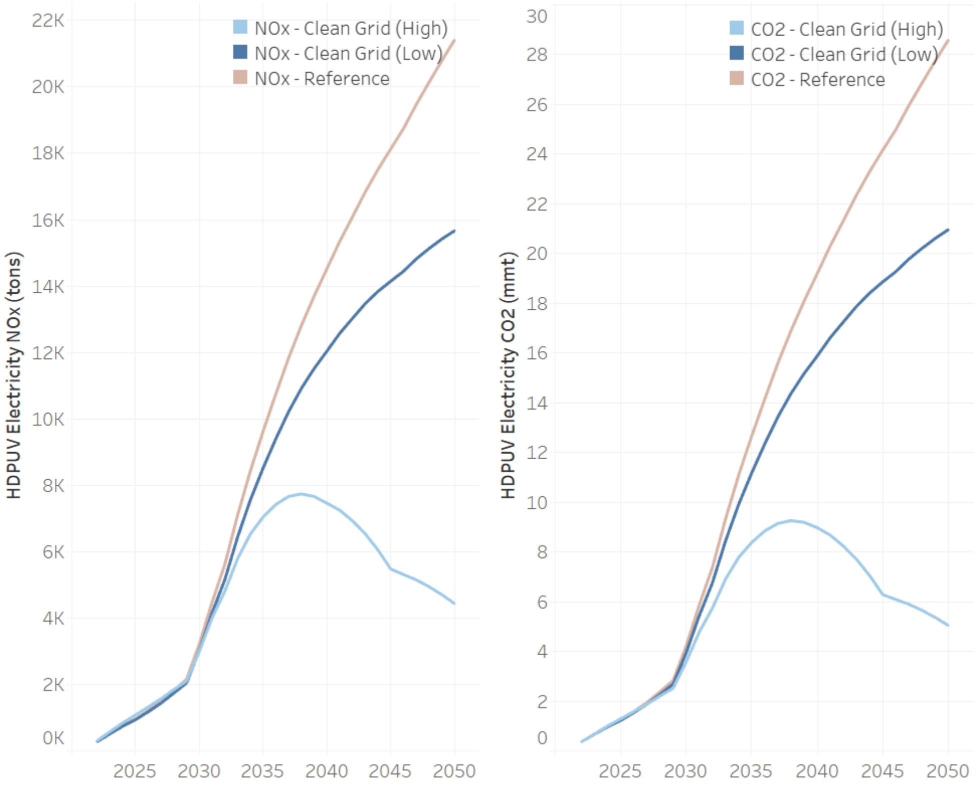


Figure 9-20 CAFE modeling of HDPUV upstream electricity emission inventories for key pollutants under the reference and two clean grid cases by CY: NOx (left) and CO_2 (right)



As these two clean grid cases only modify upstream CAFE emission factors for GHGs and criteria pollutants based on their relative grid mix, the only monetized changes in net social benefits from the RC are a result of avoided health damage costs of criteria pollutants and avoided SC-GHG values. No other incremental costs, such as changes in the levelized costs of electricity as the grid decarbonizes, have been considered in the CAFE modeling of these net benefit estimates.

Assuming the reference 3% DR, we find that the AEO clean grid low forecast generates an additional $300 million in net benefits over the vehicle lifetimes modeled in the proposed LD CAFE standards (MY1983-2032) and an additional $100 million in net benefits in the proposed HDPUV standards (CY 2022-2050) beyond the No-Action Alternative. In a similar comparison to the reference net benefits under a 3% DR, the clean grid high forecast would produce an additional $900 million above the LD RC and an additional $310 million above the HDPUV RC.

9.2.4.2. Mass-Size Safety and Crash Avoidance

Estimates regarding the future safety impacts of CAFE requirements reflect our best judgment regarding the evolution of factors that affect vehicle safety. Nevertheless, there is some uncertainty regarding the values applied to the CAFE safety analysis. These uncertainties include (1) the joint effects of the mass effects model across vehicle classes; (2) estimates of driver behavior; and (3) the effectiveness of crash avoidance technologies. To address these uncertainties, we perform five sensitivity analyses that adjust underlying safety parameters for both the light duty and HDPUV fleets. Table 9-10 provides values for the number of fatalities, SCs, and social benefits for alternatives PC2LT4 and HDPUV10. Below those values the table provides the difference in these outcomes when different safety assumptions are applied to alternative PC2LT4 and HDPUV10 respectively.[242] In each of the following sensitivity checks, all inputs are held

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[242] While changes in the safety parameters affect fatalities, non-fatal injuries and property damage crashes, Table 9-10 provides only differences in fatalities. Changes in net social benefit of each scenario includes the social value of non-fatal injuries, and property damage crashes attributable to changes in the sensitivity paratmeter.

constant other than the noted safety parameter. The models use a 3% DR for dollar valuations. Fatalities are not discounted.

(1) Adjustments to the mass parameters influence the assumed average mass disparity between vehicles in crashes. A lower mass disparity between vehicles reduces fatalities and a higher mass disparity increases fatalities. For the light duty fleet, lowering the mass disparity parameter reduces the number of fatalities attributable to alternative PC2LT4 by 1,294. Increasing the mass disparity parameter results in an additional 1,292 fatalities. For HDPUV fleet, there is no discernable change in fatalities for HDPUV10 under these sensitivity tests.

For the light duty fleet, the gain in net social benefits from assuming a low mass safety parameter is $7.4 billion. Conversely the loss from assuming a high mass safety parameter is a $7.4 billion reduction relative to PC2LT4. The relative difference in net social benefits for the HDPUV fleet is a gain of $14 million dollars from the low mass parameter, and a loss of $14 million from assuming a high mass parameter.

(2) Since the 2019 COVID pandemic, traffic and vehicle fatalities have increased across U.S. roadways. This increase is a deviation from previous trends, and we do not yet know whether or how fast fatalities will decline to pre-pandemic levels (or even lower), though they have leveled off and declined slightly from 2021 to 2022. As a sensitivity analysis we apply 2022 fatality rates as a baseline from which to estimate future fatalities occurring under PC2LT4. This results in an additional 223 deaths. For HDPUV fleet, there is one additional fatality for HDPUV10 under these sensitivity tests.

For the light duty fleet, the additional loss in net social benefits from using 2022 fatalities rates as a baseline is $2.2 billion. For the HDPUV, the additional loss in net social benefits from using 2022 fatalities rates as a baseline is approximately $40 million.

(3) Many crash avoidance technologies are nascent, and the future effectiveness of these technologies is uncertain. Higher technology effectiveness rates tend to increase the SC of delaying new vehicles from entering the fleet. Lower technology effectiveness rates tend to reduce the SC of slowing vehicle turnover, since the relative safety difference between new vehicles and old vehicles on the road decreases. Under the sensitivity analysis assuming low effectiveness of these technologies there would be an additional 24 fatalities. Under a scenario with high technological effectiveness there would be 33 fewer deaths. There is no discernable effect of the HDPUV fleet under alternative HDPUV10 under either sensitivity case.

For the light duty fleet, the gain in net social benefits from assuming a low technological effectiveness is $0.2 billion. Conversely the loss from assuming a high technological effectiveness is a $0.1 billion reduction relative to PC2LT4. The relative difference in net social benefits for the HDPUV fleet is less than $10 million dollars in magnitude.

Table 9-10: Relative differences between RC and sensitivity cases, Light Duty and HDPUV Fleets, 3% Social DR, 3% SC-GHG DR

	Light Duty				HDPUV			
Scenario	Fatalities	Total social costs ($b)	Total social benefits ($b)	Net social benefits ($b)	Fatalities	Total social costs ($)	Total social benefits ($b)	Net social benefits ($b)
Reference	693	58.6	75.5	16.8	1	2.073	4.319	2.246
Sensitivity Cases	**Difference From Reference PC2LT4**				**Difference From Reference HDPUV10**			
Mass-size-safety (low)	-1,294	-7.7	-0.3	7.4	0	-0.001	0.014	0.014
Mass-size-safety (high)	1,292	7.7	0.3	-7.4	0	0.001	-0.014	-0.014

Crash avoidance (low)	24	0.2	0.4	0.2	0	0.001	0.008	0.007
Crash avoidance (high)	-33	-0.1	-0.2	-0.1	0	-0.001	-0.005	-0.004
2022 FR fatality rates	223	0.7	-1.4	-2.2	1	<-0.001	-0.037	-0.036

9.2.5. Effect of Policy-Related Parameters

9.2.5.1. Standard-setting conditions

EPCA places a set of conditions on the consideration of the fuel economy of AFVs and the application of compliance credits when determining maximum feasible fuel economy standards for PCs and LT. Specifically, 49 U.S.C. 32902(h) states that when determining maximum feasible CAFE standards, NHTSA:

1. may not consider the fuel economy of dedicated automobiles,
2. shall consider dual fueled automobiles to be operated only on gasoline or diesel fuel, and
3. may not consider, when prescribing a fuel economy standard, the trading, transferring, or availability of credits under 49 U.S.C. 32903.[243]

Section V.A.5.a.5 (titled “Factors that NHTSA is Prohibited from Considering”) of the NPRM Preamble discusses these provisions in greater detail.

As discussed in that section, NHTSA interprets 32902(h) as applying to the agency’s consideration of MY that are the subject of the rulemaking at hand, but not to MY beyond the rulemaking time frame. To evaluate the effects of extending these conditions beyond the rulemaking time frame (in this instance, beyond MY 2032), NHTSA conducted three additional sensitivity cases:

1. extending standard-setting conditions to MY 2035,
2. extending standard-setting conditions to MY 2050, and
3. extending standard-setting conditions to all MYs.

In general, the impact of extending the EPCA condition years reduces the estimated net social benefits of the Preferred Alternative. Compared to the RC, extending these:

- to 2035 results in a 1.6 billion dollar increase in SCs, a 1.5 billion dollar decrease in social benefits, and a 3.1 billion dollar decrease in net social benefits;
- to 2050 results in a 5.2 billion dollar decrease in SCs, a 15.4 billion dollar decrease in social benefits, and a 10.2 billion dollar decrease in net social benefits;
- to all MYs results in a 13.8 billion dollar decrease in SCs, a 22.9 billion dollar decrease in social benefits, and a 9.1 billion dollar decrease in net social benefits.

As the number of constrained years increase, gasoline consumption, CO_2 emissions, and criteria emissions increase as well. Importantly, while each of these metrics remain negative—indicating a continued overall reduction—for each case, the magnitude of that reduction decreases as the number of constrained years increase. Conversely, electricity consumption decreases as the number of constrained years increase. Also, as the number of constrained years increase, the number of fatalities and the reduction in the number of deaths resulting from criteria emissions decrease as well. These results are predictable because they reflect the hypothetical future scenario in which manufacturers do not apply additional BEVs even after the rulemaking time frame – the use of which would otherwise be reducing gasoline consumption, CO_2 emissions, and downstream criteria emissions, and increasing electricity consumption.

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[243] 49 U.S.C. 32902.

In MY 2032, the technology penetration simulations resulted in a slight increase in the adoption of SHEVs and PHEVs for two of these three sensitivity cases. Compared to the RC, extending these:

- to MY 2035 has no effect on the number of SHEVs and PHEVs in MY 2032,
- to MY 2050 results in a 0.9 percent increase in the number of SHEVs and PHEVs in MY 2032,
- to all MYs results in a 3.6 percent increase in the number of SHEVs and PHEVs in MY 2032.

On average, when compared to the RC, MY 2032 vehicle costs are:

- $7 per vehicle lower when standard-setting conditions are extended to MY 2035,
- $114 per vehicle lower when standard-setting conditions are extended to MY 2050,
- $315 per vehicle lower when standard-setting conditions are extended to all MYs.

9.2.5.2. Tax credit

In the central analysis, NHTSA includes the impact of two tax credit provisions of the IRA: the CVC, and the AMPC. The former is paid to purchasers of qualifying clean vehicles, while the latter is paid to the manufacturers of qualifying battery cells and modules. NHTSA recognizes that there is uncertainty over both the value of each credit that vehicles employing these technologies will qualify for, and the degree to which these credits are captured by consumers and manufacturers. For example, the incentives have requirements related to mineral sourcing, the price of new vehicles, and the income of purchasers that may limit the ability of some vehicles and batteries to qualify for the incentive. Furthermore, the incidence of these credits will in practice be split between consumers and producers, and the overall shares captured by each will depend on the elasticities of supply and demand, as well as the pricing and manufacturing strategies of producers.

NHTSA tested the sensitivity of both of these assumptions for its analysis. First, we set the values of the CVC and the AMPC to $0 in the “No EV Tax Credits” case. This simulates the impact of assuming that no vehicles or batteries qualify for the IRA credits. In a separate case we simulate the effect of just removing the AMPC. In Table 9-2, we show that compared to the RC, removing the APMC decreases net social benefits by $2.2 billion under 3 percent discounting, and removing both APMC and CVC decreases net social benefits by $2.8 billion. This is due to greater technology adoption, specifically, PHEV adoption (which is made more cost-effective with the tax credits) in lieu of SHEV adoption in the baseline of our RC. As a result, our RC requires less incremental improvement in fuel economy to meet tighter standards than our side cases in which the tax credits are absent. We find larger impacts in the HDPUV fleet. In Table 9-6 each adjustment increases the social net benefits of the Preferred Alternative by around $20 billion for the HDPUV fleet. We next evaluated increasing the average value of the CVC from $5,000 to its maximum possible value of $7,500 for each qualifying vehicle. This scenario assumes that every vehicle with qualifying technology would meet the mineral sourcing requirements in the IRA, as well as the pricing and income requirements. We find that this has a significant impact on net benefits, as they drop to just under $5 billion. Since producers receive a larger benefit in this case relative to the RC, they apply more costly, but also more fuel-efficient technology (converting vehicles to PHEVs) in the No-Action Alternative. As a result, increasing the standards does not force as much additional technology adoption (fewer vehicles are transitioned to SHEVs for example) and the technology the increased standard does force is in some cases driven by the presence of the tax credits, and less cost effective. This causes the Preferred Alternative to have a less beneficial impact. In the HDPUV fleet we find that net benefits are actually slightly negative in this case. The findings suggest that the PC and LT fleet’s results are somewhat sensitive to the average value of the realized credits. HDPUV results show greater sensitivity to these assumptions, though the cases used to test this sensitivity represent the most extreme possible outcomes and are not likely to resemble reality.

We next evaluate the effect of adjusting our central assumption that the incidence of the credits is split evenly between producers and consumers. In our RC, any credit captured by producers effectively decreases the cost of production for the vehicle, while any share captured by consumers decreases the price paid. In our sensitivity analysis we tested the impact of allowing consumers to capture 75 percent of the credits (“Consumer tax credit share 75%”), and 25 percent of the credits (“Consumer tax credit share 25%”). In the first case we would expect technology adoption to be lower in the baseline, since producers must pay a higher price in the compliance simulation for technology eligible for the tax credit. In the second case we would expect technology adoption to be higher (the tax credit reduces compliance technology costs more than it does in the central analysis), but for overall sales to suffer (the prices consumers face are higher than in the central analysis). For LDVs we find that PHEV adoption rates in the no action alternative are indeed lower by about 2.9 percent. As shown in Table 9-2, under 3 percent discounting of benefits, we find in the ”Consumer tax credit share 75%” scenario that net social benefits associated with the Preferred Alternative are slightly higher than in the RC for LD. In the HDPUV fleet, net benefits are much more sensitive, as they rise by around $17 billion. Without being able to capture as much of the value of the tax credits, manufacturers produce significantly fewer BEVs and PHEVs in the HDPUV No Action alternative. As a result, the standards in the Preferred Alternative bind for a larger share of the fleets, and lead to more incremental BEV and PHEV adoption in this case and produce more additional net benefits to society. In the “Consumer tax credit share 25%” scenario, when we allow producers to capture more of the credits, we find that net benefits from the Preferred Alternative shrink significantly, to $3.2 billion for the LD fleet and just below 0 for HDPUVs. Together these results indicate that the ability for manufacturers to capture more of the credit is important in determining their technology adoption decisions, as they over-comply significantly in the No-Action Alternative when they receive 75 percent of the credits. When manufacturers receive less of the credit, the HDPUV side sees a larger impact, where the Preferred Alternative’s higher standards bind for more of the manufacturers and generate significantly more incremental BEV and PHEV technology adoption than in the RC. This is less true of the LD fleet, where making this assumption only causes the Preferred Alternative’s impact on fuel cost savings to increase by about $15 per vehicle as shown in Table 9-3. Technology adoption in the LD fleet remains fairly close to the levels found in our central analysis even when the share of tax credits for manufacturers decreases. In the HDPUV fleet, this change in assumptions causes a dramatic shift from BEV to SHEV technology, whereas in the LD fleet manufacturers primarily switch from producing PHEVs to SHEVs. Their adoption of BEV technology in the years prior to our standard setting years remains fairly constant.

9.2.5.3. Adjusted Nominal Civil Penalty Rate

EPCA allows manufacturers who do not achieve compliance with a CAFE standard in a given model year and who cannot apply credits sufficient to cover the compliance shortfall to pay civil penalties to the Federal Government. On November 2, 2015, the President signed into law the Federal Civil Penalties Inflation Adjustment Act Improvements Act of 2015 (2015 Act) (Pub. L. No. 114-74, Sec. 701), which amended the Federal Civil Penalties Inflation Adjustment Act of 1990 (FCPIAA) (Pub. L. No. 101-410). The 2015 Act requires Federal agencies to:

1. adjust the level of civil monetary penalties with an initial “catch-up” adjustment through an interim final rule (IFR), and
2. make subsequent annual adjustments.[244]

It also directed the OMB to issue guidance on implementing the required annual adjustment no later than December 15 of each year.[245]

In its April 1, 2022 Final Rule, NHTSA:

1. clarified that the initial “catch-up” civil penalty rate of $14, which it codified in its July 5, 2016 IFR,[246] applies to MY 2019 through MY 2021 and
2. codified a civil penalty rate of $15 for MY 2022.[247]

In the analysis supporting this proposal, we used the MY 2021 and MY 2022 civil penalty rates that were previously codified by the agency. However, when we began the analysis, OMB had yet to issue guidance on the civil penalty adjustment for MY 2023. In accordance with OMB guidance to adjust civil penalty amounts for inflation on an annual basis, NHTSA estimated a single inflation rate and used it to estimate civil penalty amounts for MY 2023 through MY 2050.

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[244] 28 U.S.C. 2461.
[245] *Ibid.*
[246] 81 FR 43529 (July 5, 2016).
[247] 87 FR 19007 (April 1, 2022).

On December 15, 2022, OMB released OMB Memorandum M-23-05,[248] which provided instructions on how to calculate the 2023 annual civil penalty adjustment. The MY 2023 civil penalty calculated using the OMB adjustment rate differed from the MY 2023 civil penalty we calculated using the estimated inflation adjustment rate. To evaluate how using the OMB civil penalty adjustment for MY 2023 affect the results of our analysis, NHTSA repeated the RC analysis of CAFE standards with inputs that reflected that adjustment. Table 9-1, Table 9-2, and Table 9-3 show the results of the sensitivity case.

Overall, the impact of using the MY 2023 civil penalty calculated with the OMB adjustment rate is relatively small. There is a 2.7 percent decrease in SCs and a 1.0 percent increase in social benefits compared to RC—which means the adjusted civil penalty rate would result in some additional net benefits. The technology penetration simulations resulted in a 1.0 percent increase in electrification technology (SHEV and PHEV) in MY 2032, compared to the RC. On average, vehicle cost in the sensitivity case is approximately $36 lower per vehicle when compared to the RC.

9.2.5.4. Petroleum Equivalency Factor

In the CAFE program, as required by law,[249] AFVs receive a fuel economy adjustment called the petroleum equivalency factor (PEF), which adjusts fuel economy based on the portion of electricity used to power vehicles in the LD fleet.[250] By statute, the DOE calculates and sets the PEF for use in the CAFE program.[251]

The PEF value for EVs[252] has remained unchanged since the year 2000 – set at a value of 82,049 Wh/gal; recently, the DOE has proposed an update to the PEF value, removing the (1.0/0.15) fuel content factor(FCF) and updating electric grid assumptions, ultimately adjusting the PEF to 23,160 Wh/gal – roughly 28% of the PEF's original value – for BEVs starting in MY 2027.[253] NHTSA has incorporated this proposed PEF into its RC analysis for this proposal.

The effects of the original PEF value (82,049 Wh/gal – used in previous CAFE rulemakings) were analyzed as a sensitivity case; we refer to this case as the FCF) case, as the circa-2000 PEF value includes this FCF within its calculation. The FCF sensitivity case is discussed below, alongside the RC in relation to No Action and regulatory action under the preferred alternative.

As expected, manufacturers' technology compliance pathways change based on how much weight is given to the BEVs in their fleet and how these BEVs contribute to their CAFE compliance values. For the FCF sensitivity, in the absence of CAFE standards (i.e., the no-action case), manufacturers that build BEVs have relatively high compliance CAFE values with relatively few BEVs in their fleets.[254] In response to CAFE standards, they add traditional ICE technology like HCR and TURBO technology, but do not need to add as much SHEV or PHEV technology (that is somewhat more expensive than ICE technology) because their BEVs carry most of the weight in improving their fleet fuel economy compliance values. In the reference case, manufacturers must add more of *both* traditional ICE and SHEV/PHEV technology to improve their fleet fuel economy compliance values. The following paragraphs discuss the technology penetration rates between the RC (with the newly proposed PEF value) and the FCF sensitivity case (with the original PEF value).

PHEV penetration was similar among all No Action scenarios – resulting in 2.9% penetration for both the RC and FCF case. Under the preferred alternative, the RC yielded a PHEV penetration of 7.5%; the FCF case resulted in 6.5% PHEV penetration – less penetration compared to the RC but within a similar range.

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[248] OMB Memorandum M-23-05, Implementation of Penalty Inflation Adjustments for 2023, Pursuant to the Federal Civil Penalties Inflation Adjustment Act Improvements Act of 2015, published December 15, 2022, guided agencies on annual adjustment requirements for 2023.

[249] 49 U.S.C. 32904(a)(2)(B).

[250] The PEF is not applicable towards the HDPUV fleet.

[251] 49 U.S.C. 32904(a)(2)(B).

[252] See 10 CFR part 474.

[253] 88 FR 21525 (Apr. 11. 2023).

[254] See also 88 FR 21530 (April 11, 2023) ("This approach demonstrates how the current PEF value leads to overvaluation of EVs in determining fleetwide CAFE compliance, which allows manufacturers to maintain less efficient ICE vehicles in their fleet by utilizing a few EV models to comply with the CAFE standards.").

The RC yielded the highest SHEV penetration for both the No Action and preferred alternative – 21.9% and 36.9% of the LD fleet, respectively. Conversely, lower SHEV values resulted from the FCF PEF sensitivity case – 18.4% SHEV penetration under No Action and 26.9% under the preferred alternative.

The FCF PEF case resulted in higher penetration rates of more conventional technologies like HCR technology under both No Action and under the preferred alternative – 20.3% and 16.2% of the fleet, respectively. Note that for HCR technology, the No Action values yield higher tech penetration compared to the preferred alternative – the RC showing the greatest change between No Action and regulatory action, 19.2% and 12.9%, respectively.

The FCF PEF case also resulted in higher TURBO technology (TURBO0, TURBOE, TURBOD, TURBO1, and TURBO2 combined) penetration under both No Action and under the preferred alternative (24.0)% and 16.6% of the LD fleet, respectively. The RC resulted in lower TURBO penetration – 21.9% under No Action and 9.7% under the preferred alternative.

Between the two PEF values, net social benefits (the difference between total SCs and total social benefits) vary minimally. The RC, under the 3% DR, yields net social benefits of $16.8B, under the preferred alternative over No Action; in contrast, the FCF PEF case yields lower social benefits – $14.0B. We note that net social benefits values are still positive under both PEF values.

Under the 7% DR, the RC yields net social benefits of $8.3B, under the preferred alternative over No Action. The FCF PEF case yields lower net social benefits, still in proximity to the other case values, at 7.8$B. As is the case under the 3% DR, net social benefits values are still positive under both PEF values.

The consumer-specific benefits (the difference between regulatory cost and retail fuel expenditure) for each PEF value (both RC and the FCF sensitivity case) show a cost savings for consumers under the preferred alternative over No Action. The RC, which uses the newly proposed PEF value of 23,160 Wh/gal, yields a per-vehicle cost savings of $112; the original FCF PEF value of 82,049 Wh/gal yields a somewhat-higher per-vehicle cost savings of $212.

As with other sensitivity cases in this analysis, there are differences in additional metrics, such as gasoline and electricity consumption as well as CO_2 emissions. The largest difference in gasoline consumption between PEF values was observed under the RC – resulting in 88 billion gallons of gasoline less under the preferred alternative compared to No Action. The FCF PEF case yielded a smaller difference – 56 billion gallons less under the preferred alternative compared to No Action.

The greatest difference in electricity consumption was also observed under the RC – 312 TWh more energy was consumed under the preferred alternative compared to No-Action Alternative. The FCF PEF yielded a smaller difference – 160 TWh between the preferred alternative and No-Action Alternative.

The RC resulted in the greatest difference in CO_2 emissions between the preferred alternative and No Action – 885 MMT CO_2 less under regulatory action, while the FCF PEF case resulted in a smaller difference – 569 MMT CO_2 less under the preferred alternative compared to No-Action Alternative.

See Table 9-4 for additional metrics for all sensitivity cases and further discussion of the results in Chapter 9.2.1.

9.2.5.5. Adjusted MDPCS Stringency

Any manufacturer’s domestically manufactured PC fleet must meet the greater of either 27.5 mpg on average, or ‘92 percent of the average fuel economy projected by the Secretary for the combined domestic and nondomestic passenger automobile fleets manufactured for sale in the U.S. by all manufacturers in the model year, which projection shall be published in the Federal Register when the standard for that model year is promulgated in accordance with 49 U.S.C. 32902(b).’[255] The MDPCS must be determined at the time an overall PC standard is promulgated and published. Any time NHTSA establishes or changes a PC standard for a model year, the MDPCS must also be evaluated or re-evaluated and established accordingly. Unlike the

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[255] U.S.C. 32902(b)(4)(B).

attribute-based standard, the MDPCS is a fixed standard and does not adjust with changes in consumer demand and production.

As discussed in the Federal Register notice promulgating final CAFE and CO_2 standards for PCs and LT produced during MYs 2021-2026,[256] NHTSA established MDPCSs that are offset from values computed based on the agency's current forecast of manufacturers' average future requirements under the new attribute-based PC standards. Section V.A.2 (titled "Separate Standards for Passenger Cars, Light Trucks, and Heavy-Duty Pickups and Vans, and Minimum Standards for Domestic Passenger Cars") of the Preamble discusses the basis for and size of these offsets.

NHTSA is proposing to continue employing the offset for MYs 2027-2032. Due to time constraints, the agency did not include the offset in the CAFE Model input; however, the agency will do so for the final rule. To evaluate the effect of revising model inputs to reflect these offsets on the analytical results, NHTSA repeated the RC analysis of CAFE standards, while changing model inputs such that MDPCSs reflected the offsets.

This sensitivity analysis shows no changes in estimated achieved CAFE levels or regulatory costs. On average, the gasoline consumption, electricity consumption and vehicle price did not change between this sensitivity and the RC. Similarly, the SCs and social benefits did not change for the adjusted MDPCS and the RC. Table 9-4 does not show any notable change in technology penetration indicating that the proposed approach resulted in no changes in key metrics for this sensitivity case.

The offset MDPCSs do slightly increase the quantities of compliance credits projected to be earned by Karma and Lucid. However, as discussed in the above-mentioned notice, the CAFE Model does not attempt to simulate credit trading between manufacturers, and because Karma and Lucid cannot use these credits, the analysis shows the additional credits earned by Karma and Lucid expiring over time.

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[256] 85 FR 25127 (April 30, 2020).