DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Parts 531, 533, 535, and 537

[NHTSA–2023–0022]

RIN 2127–AM55

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

AGENCY: National Highway Traffic Safety Administration (NHTSA).

ACTION: Notice of proposed rulemaking.

SUMMARY: NHTSA, on behalf of the Department of Transportation (DOT), is proposing new fuel economy standards for passenger cars and light trucks and fuel efficiency standards for model years (MYs) 2027–31 that increase at a rate of 2 percent per year for passenger cars and 4 percent per year for light trucks, and new fuel efficiency standards for heavy-duty pickup trucks and vans (HDPUVs) for MYs 2030–2035 that increase at a rate of 10 percent per year. NHTSA is also setting forth proposed augural standards for MY 2032 passenger cars and light trucks, that would increase at 2 percent and 4 percent year over year, respectively, as compared to the prior year's standards. NHTSA currently projects that the proposed standards would require an industry fleet-wide average for passenger cars and light trucks of roughly 58 miles per gallon (mpg) in MY 2032 and an industry fleet-wide average for HDPUVs of roughly 2.6 gallons per 100 miles in MY 2038. NHTSA further projects that the proposed standards would reduce average fuel outlays over the lifetimes of passenger cars and light trucks by $1,043 and of HDPUVs by $439. These proposed standards are directly responsive to the agency's statutory mandate to improve energy conservation and reduce the nation's energy dependence on foreign sources.

DATES:

Comments: Comments are requested on or before October 16, 2023. See the **SUPPLEMENTARY INFORMATION** section on ''Public Participation,'' below, for more information about written comments.

Public Hearings: NHTSA will hold one virtual public hearing during the public comment period. The agency will announce the specific date and web address for the hearing in a supplemental **Federal Register** notice. The agency will accept oral and written comments on the rulemaking documents and will also accept comments on the Draft Environmental Impact Statement (DEIS) at this hearing. The hearing will start at 9 a.m. Eastern time and continue until everyone has had a chance to speak. See the **SUPPLEMENTARY INFORMATION** section on ''Public Participation,'' below, for more information about the public hearing.

ADDRESSES: You may send comments, identified by Docket No. NHTSA–2023–0022, by any of the following methods:

- *Federal eRulemaking Portal: https://www.regulations.gov.* Follow the instructions for submitting comments.
- *Fax:* (202) 493–2251.
- *Mail:* Docket Management Facility, M–30, U.S. Department of Transportation, West Building, Ground Floor, Rm. W12–140, 1200 New Jersey Avenue SE, Washington, DC 20590.
- *Hand Delivery:* Docket Management Facility, M–30, U.S. Department of Transportation, West Building, Ground Floor, Rm. W12–140, 1200 New Jersey Avenue SE, Washington, DC 20590, between 9 a.m. and 4 p.m. Eastern time, Monday through Friday, except Federal holidays.

Instructions: All submissions received must include the agency name and docket number or Regulatory Information Number (RIN) for this rulemaking. All comments received will be posted without change to *https://www.regulations.gov,* including any personal information provided. For detailed instructions on sending comments and additional information on the rulemaking process, see the ''Public Participation'' heading of the **SUPPLEMENTARY INFORMATION** section of this document.

Docket: For access to the dockets or to read background documents or comments received, please visit *https://www.regulations.gov,* and/or Docket Management Facility, M–30, U.S. Department of Transportation, West Building, Ground Floor, Rm. W12–140, 1200 New Jersey Avenue SE, Washington, DC 20590. The Docket Management Facility is open between 9 a.m. and 4 p.m. Eastern time, Monday through Friday, except Federal holidays.

FOR FURTHER INFORMATION CONTACT: For technical and policy issues, Joseph Bayer, CAFE Program Division Chief, Office of Rulemaking, National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, Washington, DC 20590; email: *joseph.bayer@dot.gov.* For legal issues, Rebecca Schade, NHTSA Office of Chief Counsel, National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, Washington, DC 20590; email: *rebecca.schade@dot.gov.*

SUPPLEMENTARY INFORMATION:

Table of Acronyms and Abbreviations

Abbreviation	Term
AAA	American Automobile Association.
AALA	American Automotive Labeling Act.
AC	Air Conditioning.
ACC	Advanced Clean Cars.
ACC I	Advanced Clean Cars I.
ACC II	Advanced Clean Cars II.
ACME	Adaptive Cylinder Management Engine.
ACT	Advanced Clean Trucks.
ADEAC	Advanced cylinder deactivation.
ADEACD	advanced cylinder deactivation on a dual overhead camshaft engine.
ADEACS	advanced cylinder deactivation on a single overhead camshaft engine.
ADSL	Advanced diesel engine.
AEO	Annual Energy Outlook.
AER	All-Electric Range.
AERO	Aerodynamic improvements.
AFV	Alternative fuel vehicle.
AHSS	advanced high strength steel.
AIS	Abbreviated Injury Scale.
AMPC	Advanced Manufacturing Production Tax Credit.
AMTL	Advanced Mobility Technology Laboratory.

Abbreviation	Term
ANL	Argonne National Laboratory.
ANSI	American National Standards Institute.
APA	Administrative Procedure Act.
AT	traditional automatic transmissions.
AWD	All-Wheel Drive.
BEA	Bureau of Economic Analysis.
BEV	Battery electric vehicle.
BGEPA	Bald and Golden Eagle Protection Act.
BISG	Belt Mounted integrated starter/generator.
BMEP	Brake Mean Effective Pressure.
BNEF	Bloomberg New Energy Finance.
BPT	Benefit-Per-Ton.
BSFC	Brake-Specific Fuel Consumption.
BTW	Brake and Tire Wear.
CAA	Clean Air Act.
CAFE	Corporate Average Fuel Economy.
CARB	California Air Resources Board.
CBI	Confidential Business Information.
CEGR	Cooled Exhaust Gas Recirculation.
CEQ	Council on Environmental Quality.
CFR	Code of Federal Regulations.
CH_4	Methane.
CI	Compression Ignition.
CNG	Compressed Natural Gas.
CO	Carbon Monoxide.
CO_2	Carbon Dioxide.
COVID	Coronavirus disease of 2019.
CPM	Cost Per Mile.
CR	Compression Ratio.
CRSS	Crash Report Sampling System.
CVC	Clean Vehicle Credit.
CVT	Continuously Variable Transmissions.
CY	Calendar year.
CZMA	Coastal Zone Management Act.
DCT	Dual Clutch Transmissions.
DD	Direct Drive.
DEAC	Cylinder Deactivation.
DEIS	Draft Environmental Impact Statement.
DFS	Dynamic Fleet Share.
DMC	Direct Manufacturing Cost.
DOE	Department of Energy.
DOHC	Dual Overhead Camshaft.
DOI	Department of the Interior.
DOT	Department of Transportation.
DPM	Diesel Particulate Matter.
DR	Discount Rate.
DSLI	Advanced diesel engine with improvements.
DSLIAD	Advanced diesel engine with improvements and advanced cylinder deactivation.
EETT	Electrical and Electronics Technical Team.
EF	Emission Factor.
EFR	Engine Friction Reduction.
EIA	U.S. Energy Information Administration.
EIS	Environmental Impact Statement.
EISA	Energy Independence and Security Act.
EJ	Environmental Justice.
E.O	Executive Order.
EPA	U.S. Environmental Protection Agency.
EPCA	Energy Policy and Conservation Act.
EPS	Electric Power Steering.
EFR	Engine Friction Reduction.
ESA	Endangered Species Act.
ETDS	Electric Traction Drive System.
EV	Electric Vehicle.
FCC	Fuel Consumption Credits.
FCEV	Fuel Cell Electric Vehicle.
FCIV	Fuel Consumption Improvement Value.
FCV	Fuel Cell Vehicle.
FE	Fuel Efficiency.
FHWA	Federal Highway Administration.
FIP	Federal Implementation Plan.
FMVSS	Federal Motor Vehicle Safety Standards.
FMY	Final Model Year.
FRIA	Final Regulatory Impact Analysis.
FTP	Federal Test Procedure.

Abbreviation	Term
FWCA	Fish and Wildlife Conservation Act.
FWD	Front-Wheel Drive.
FWS	U.S. Fish and Wildlife Service.
GCWR	Gross Combined Weight Rating.
GDP	Gross Domestic Product.
GES	General Estimates System.
GGE	Gasoline Gallon Equivalents.
GHG	Greenhouse Gas.
GM	General Motors.
gpm	gallons per mile.
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation.
GVWR	Gross Vehicle Weight Rating.
GWh	Gigawatt hours.
HD	Heavy-Duty.
HDPUV	Heavy-Duty Pickups and Vans.
HEG	High Efficiency Gearbox.
HEV	Hybrid Electric Vehicle.
HFET	Highway Fuel Economy Test.
HVAC	Heating, Ventilation, and Air Conditioning.
IACC	improved accessories.
IAV	IAV Automotive Engineering, Inc.
ICCT	The International Council on Clean Transportation.
ICE	Internal Combustion Engine.
IIHS	Insurance Institute for Highway Safety.
IPCC	Intergovernmental Panel on Climate Change.
IQR	Interquartile Range.
IRA	Inflation Reduction Act.
IWG	Interagency Working Group.
LD	Light-Duty.
LDB	Low Drag Brakes.
LDV	Light-Duty Vehicle.
LE	Learning Effects.
LEV	Low-Emission Vehicle.
LFP	Lithium Iron Phosphate.
LIB	Lithium-Ion Batteries.
LIVC	Late Intake Valve Closing.
LT	Light truck.
MAX	maximum values.
MBTA	Migratory Bird Treaty Act.
MD	Medium-Duty.
MDHD	Medium-Duty Heavy-Duty.
MDPCS	Minimum Domestic Passenger Car Standard.
MDPV	Medium-Duty Passenger Vehicle.
MIN	minimum values.
$MMTCO_2$	Million Metric Tons of Carbon Dioxide.
MMY	Mid-Model Year.
MOU	Memorandum of Understanding.
MOVES	Motor Vehicle Emission Simulator.
MOVES3	latest version of MOVES.
MPG	Miles Per Gallon.
mph	Miles Per Hour.
MR	Mass Reduction.
MSRP	Manufacturer Suggested Retail Price.
MY	Model Year.
NAAQS	National Ambient Air Quality Standards.
NADA	National Automotive Dealers Association.
NAICS	North American Industry Classification System.
NAS	National Academy of Sciences.
NCA	Nickel Cobalt Aluminum.
NEMS	National Energy Modeling System.
NEPA	National Environmental Policy Act.
NESCCAF	Northeast States Center for a Clean Air Future.
NHPA	National Historic Preservation Act.
NHTSA	National Highway Traffic Safety Administration.
NMC	Nickel Manganese Cobalt.
NO_X	Nitrogen Oxide.
NPRM	Notice of Proposed Rulemaking.
NRC	National Research Council.
NREL	National Renewable Energy Laboratory.
NTTAA	National Technology Transfer and Advancement Act.
NVH	Noise-Vibration-Harshness.
NVPP	National Vehicle Population Profile.
OCR	Optical Character Recognition.
OEM	Original Equipment Manufacturer.

Abbreviation	Term
OHV	Overhead Valve.
OMB	Office of Management and Budget.
OPEC	Organization of the Petroleum Exporting Countries.
ORNL	Oak Ridge National Laboratories.
PC	Passenger Car.
PEF	Petroleum Equivalency Factor.
PHEV	Plug-in Hybrid Electric Vehicle.
PM	Particulate Matter.
$PM_{2.5}$	fine particulate matter.
PMY	Pre-Model Year.
PRA	Paperwork Reduction Act of 1995.
PRIA	Preliminary Regulatory Impact Analysis.
PS	Power Split.
RC	Reference Case.
REMI	Regional Economic Models, Inc.
RIN	Regulation identifier number.
ROLL	Tire rolling resistance.
RPE	Retail Price Equivalent.
RRC	Rolling Resistance Coefficient.
SAE	Society of Automotive Engineers.
SBREFA	Small Business Regulatory Enforcement Fairness Act.
SC	Social Cost.
SCC	Social Cost of Carbon.
SEC	Securities and Exchange Commission.
SGDI	Stoichiometric Gasoline Direct Injection.
SHEV	Strong Hybrid Electric Vehicle.
SI	Spark Ignition.
SIP	State Implementation Plan.
SKIP	refers to skip input in market data input file.
SO_2	Sulfur Dioxide.
SOC	State of Charge.
SOHC	Single Overhead Camshaft.
SO_X	Sulfur Oxide.
SPR	Strategic Petroleum Reserve.
SULEV	Super-Ultra Low Emission Vehicles.
SUV	Sport Utility Vehicle.
SwRI	Southwest Research Institute.
TAR	Technical Assessment Report.
TSD	Technical Support Document.
UAW	United Automobile, Aerospace & Agricultural Implement Workers of America.
UMRA	Unfunded Mandates Reform Act of 1995.
VCR	Variable Compression Ratio.
VMT	Vehicle Miles Traveled.
VOC	Volatile Organic Compounds.
VSL	Value of a Statistical Life.
VTG	Variable Turbo Geometry.
VTGE	Variable Turbo Geometry (Electric).
VVL	Variable Valve Lift.
VVT	Variable Valve Timing.
WF	Work Factor.
ZEV	Zero Emission Vehicle.

Does this action apply to me?

This proposal affects companies that manufacture or sell new passenger automobiles (passenger cars), non-passenger automobiles (light trucks), and HDPUV, as defined under NHTSA's Corporate Average Fuel Economy (CAFE) regulations.[1] Regulated categories and entities include:

Category	NAICS codes [A]	Examples of potentially regulated entities
Industry	335111 336112	Motor Vehicle Manufacturers.
Industry	811111 811112 811198 423110	Commercial Importers of Vehicles and Vehicle Components.
Industry	335312 336312	Alternative Fuel Vehicle Converters.

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[1] "Passenger car," "light truck," and "heavy-duty pickup trucks and vans" are defined in 49 CFR part 523.

Category	NAICS codes [A]	Examples of potentially regulated entities
	336399	
	811198	

[A] North American Industry Classification System (NAICS).

This list is not intended to be exhaustive, but rather provides a guide regarding entities likely to be regulated by this action. To determine whether particular activities may be regulated by this action, you should carefully examine the regulations. You may direct questions regarding the applicability of this action to the persons listed in **FOR FURTHER INFORMATION CONTACT**.

Table of Contents

I. Executive Summary

NHTSA, on behalf of the DOT, is proposing new corporate average fuel economy (CAFE) standards for passenger cars and light trucks[2] for MYs 2027–2032,[3] and new fuel efficiency standards for heavy-duty pickup trucks and vans[4] (HDPUVs) for MYs 2030–2035. This proposal responds to NHTSA's statutory obligation to set CAFE and HDPUV standards at the maximum feasible level that the agency determines vehicle manufacturers can achieve in each MY, in order to improve energy conservation.[5] Improving energy conservation by raising CAFE and HDPUV standard stringency not only helps consumers save money on fuel, but also improves national energy security and reduces harmful emissions.

Based on the information currently before us, NHTSA estimates that this proposal, if implemented, would reduce gasoline consumption by 88 billion gallons relative to baseline levels for passenger cars and light trucks, and by approximately 2.6 billion gallons relative to baseline levels for HDPUVs through calendar year 2050. Reducing fuel consumption has multiple benefits—it improves our nation's energy security, it saves consumers money, and reduces harmful pollutant emissions that lead to adverse human and environmental health outcomes and climate change. NHTSA estimates that this proposal, if implemented, could reduce carbon dioxide (CO_2) emissions by 885 million metric tons for passenger cars and light trucks, and by 22 million metric tons for HDPUVs through calendar year 2050. While consumers would pay more for new vehicles upfront, we estimate that they would save money on fuel costs over the lifetimes of those new vehicles—lifetime fuel savings exceed modeled regulatory costs by roughly $100, on average, for passenger car and light truck buyers of MY 2032 vehicles, and roughly $300, on average, for HDPUV buyers of MY 2038 vehicles. Net benefits for the preferred alternative for passenger cars and light truck are estimated to be $16.8 billion at a 3 percent discount rate (DR), and $8.4 billion at a 7 percent DR, and for HDPUVs, net benefits are estimated to be $2.2 billion at a 3 percent DR, and $1.4 billion at a 7 percent DR.

NHTSA's proposal is also consistent with Executive Order (E.O.) 14037, "Strengthening American Leadership in Clean Cars and Trucks," (August 5, 2021), which directs the Secretary of Transportation (by delegation, NHTSA) to develop rulemakings under Energy Independence and Security Act of 2007 (EISA)[6] to consider beginning work on a rulemaking to establish new fuel economy standards for passenger cars and light trucks beginning with MY 2027 and extending through at least MY 2030, and to consider beginning work on a rulemaking to establish new fuel efficiency standards for HDPUVs beginning with MY 2028 and extending through at least MY 2030, consistent with applicable law.[7]

The record for this proposal comprised this Notice of Proposed Rulemaking (NPRM), a Draft Technical

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[2] Passenger cars are generally sedans, station wagons, and two-wheel drive crossovers and sport utility vehicles (CUVs and SUVs), while light trucks are generally four-wheel drive sport utility vehicles, pickups, minivans, and passenger/cargo vans. "Passenger car" and "light truck" are defined more precisely at 49 CFR part 523.

[3] As discussed further below, NHTSA is proposing six MYs of standards for each fleet, and notes that the final year of standards proposed for passenger cars and light trucks, MY 2032, is "augural," as in the 2012 final rule that established CAFE standards for MYs 2017 and beyond.

[4] HDPUVs are generally Class 2b/3 work trucks, fleet SUVs, work vans, and cutaway chassis-cab vehicles. "Heavy-duty pickup trucks and vans" are more precisely defined at 49 CFR part 523.

[5] *See* 49 U.S.C. 32902.

[6] *See* 49 U.S.C. Chapter 329, generally.

[7] *Id,* Sec. 2.

Support Document (Draft TSD), a Preliminary Regulatory Impact Assessment (PRIA), and a Draft EIS, along with extensive analytical documentation, supporting references, and many other resources. Most of these resources are available on NHTSA's website,[8] and other references not available on NHTSA's website can be found in the rulemaking docket, the docket number of which is listed at the beginning of this preamble.

The proposal considers a range of regulatory alternatives for each fleet, consistent with NHTSA's obligations under the Administrative Procedure Act (APA), National Environmental Policy Act (NEPA) and E.O. 12866. Specifically, NHTSA considered four regulatory alternatives for passenger cars and light trucks, as well as the No-Action Alternative. Each alternative is labeled for the type of vehicle and the rate of increase in fuel economy stringency, for example, PC1LT3 represents a 1 percent increase in Passenger Car standards and a 3 percent increase in Light Truck standards. We include three regulatory alternatives for HDPUVs, each representing different possible rates of year-over-year increase in the stringency of new fuel economy and fuel efficiency standards, as well as the No-Action Alternative. For example, HDPUV4 represents a 4 percent increase in fuel efficiency standards applicable to HDPUVs. The regulatory alternatives are as follows: [9]

TABLE I–1—REGULATORY ALTERNATIVES UNDER CONSIDERATION FOR MYS 2027–2032 PASSENGER CAR AND LIGHT TRUCK CAFE STANDARDS [10]

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

TABLE I–2—REGULATORY ALTERNATIVES UNDER CONSIDERATION FOR MYS 2030–2035 HDPUV FUEL EFFICIENCY STANDARDS [11]

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

NHTSA is proposing to increase stringency at 2 percent per year for passenger cars and at 4 percent per year for light trucks, year over year from MY 2027 through MY 2032, and at 10 percent per year for HDPUVs, year over year from MY 2030 through MY 2035. The regulatory alternatives representing these proposals are called ''PC2LT4'' for passenger cars and light trucks, and ''HDPUV10'' for HDPUVs. NHTSA tentatively concludes that these levels are the maximum feasible for these MYs as discussed in more detail in Section V of this preamble. NHTSA is proposing standards that rise at a more rapid rate for light trucks than for passenger cars. As explained in more detail below, the agency believes that there is more room to improve the fuel economy of light trucks, in a cost-effective way, and that the benefits of requiring more improvement from light trucks will be significant given their high usage and the fact that they make up an ever-larger percentage of the overall fleet. Passenger cars, on the other hand, have been improving at a rapid rate for many years in succession, and the available improvements for that fleet are fewer, particularly given the statutory constraints that prevent NHTSA from considering the fuel economy of battery electric vehicles (BEVs) in determining maximum feasible CAFE standards.[12] NHTSA notes that due to the statutory constraints that prevent NHTSA from considering the fuel economy of dedicated alternative fueled vehicles, the full fuel economy of dual-fueled alternative fueled vehicles, and the availability of over-compliance credits when determining what standards are maximum feasible, many aspects of our analysis are different from what they would otherwise be without the statutory restrictions—in particular, the technologies chosen to model possible compliance options, the estimated costs, benefits, and achieved levels of fuel economy, as well as the current and projected adoption of alternative fueled vehicles. NHTSA evaluates the results of that constrained analysis by weighing the four enumerated statutory factors to determine which standards are maximum feasible.

In this action, NHTSA is proposing six MYs of standards for each fleet. For passenger cars and light trucks, NHTSA notes that the final year of standards proposed, MY 2032, is ''augural,'' as in the 2012 final rule which established CAFE standards for MYs 2017 and beyond. Augural standards mean that they are NHTSA's best estimate of what the agency would propose, based on the information currently before it, if the

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[8] See National Highway Traffic Safety Administration. 2023. Corporate Average Fuel Economy. Available at: *https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.* (Accessed: May 31, 2023).

[9] In a departure from recent CAFE rulemaking trends, we have applied different rates of stringency increase to the passenger car and the light truck fleets. Rather than have both fleets increase their respective standards at the same rate, light truck standards will increase at a different rate than passenger car standards. Each action alternative evaluated for this proposal has a passenger car fleet rate-of-increase of fuel economy lower than the rate-of-increase of fuel economy for the light truck fleet. As discussed in Section III below, this is primarily due to NHTSA's assessment that manufacturers have already made substantial progress in technology application to passenger cars, such that the possibility for further fuel economy improvements to Internal Combustion Engine- and hybrid-based vehicles is relatively limited, while there appears to be much more room to improve in the light truck fleet. This is consistent with NHTSA's obligation to set maximum feasible CAFE standards separately for passenger cars and light trucks (*see* 49 U.S.C. 32902), which gives NHTSA discretion, by law, to set CAFE standards that increase at different rates for cars and trucks. Again, the reasons for this approach are discussed in Section III of this preamble. Section V of this preamble also discusses in greater detail how this approach carries out NHTSA's responsibility under EPCA to set maximum feasible standards for both passenger cars and light trucks.

[10] Percentages in the table represent the year of year reduction in gal/mile applied to the mpg values on the target curves shown in Figure 1–1. The reduction in gal/mile results in an incrase mpg.

[11] For HDPUVs, the different regulatory 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 passenger car and light truck standards, because HDPUV standards are measured using a fuel consumption metric, year-over-year percent changes do actually represent gallon/mile differences across the work-factor range. Under each action alternative, the stringency changes at the same percentage rate in each model year in the rulemaking time frame.

[12] 49 U.S.C. 32902(h) states that when determining what levels of CAFE standards are maximum feasible, NHTSA ''(1) may not consider the fuel economy of dedicated automobiles [including battery-electric vehicles]; (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 section 32903.''

agency had authority to set CAFE standards for more than five MYs in one action. The augural standards do not, and will not, have any effect in themselves and will not be binding unless adopted in a subsequent rulemaking. Consistent with past practice, NHTSA is including augural standards for MY 2032 to give its best estimate of what those standards would be to provide as much predictability as possible to manufacturers and to be consistent with the time frame of the proposed Environmental Protection Agency (EPA) standards for greenhouse gas (GHG) emissions from motor vehicles. Due to statutory lead time constraints for HDPUV standards, NHTSA's proposal for HDPUV standards must begin with MY 2030. There is no restriction on the number of MYs for which NHTSA may set HDPUV standards, so none of the HDPUV standards are augural. NHTSA also requests comment on a scenario where the regulatory alternatives would extend only through MY 2032, which coincides with the time frame of the EPA proposed GHG standards for this vehicle segment.

NHTSA requests comment on the full range of standards encompassed between the No-Action Alternative and Alternative PC6LT8 for MYs 2027–2032 Passenger Cars, as well as comments on the range of standards encompassed for light trucks, and on the full range of standards encompassed between the No-Action Alternative and Alternative HDPUV14 for MYs 2030–2035 HDPUVs. NHTSA expressly asks for comment on combinations of standards that may not be explicitly identified in this proposal, including standards between the No-Action Alternative and PC1/LT3, as well as between PC3/LT5 and PC6/LT8. NHTSA also notes that passenger car and light truck stringency may move independently of one another, and that rates of increase may vary by model year.

The proposed CAFE standards remain vehicle-footprint-based, like the current CAFE standards in effect since MY 2011, and the proposed HDPUV standards remain work-factor-based, like the HDPUV standards established in the 2011 ''Phase 1'' rulemaking and continued to be used in 2016 ''Phase 2'' rulemaking. The footprint of a vehicle is the area calculated by multiplying the wheelbase times the track width, essentially the rectangular area of a vehicle measured from tire to tire where the tires hit the ground. The work factor (WF) of a vehicle is a unit established to measure payload, towing capability, and whether or not a vehicle has four-wheel drive. This means that the proposed standards are defined by mathematical equations that represent linear functions relating vehicle footprint to fuel economy targets for passenger cars and light trucks,[13] and relating WF to fuel consumption targets for HDPUVs.

The target curves for passenger cars, light trucks, and compression-ignition and spark-ignition HDPUVs are set forth below; curves for MYs prior to the years of the rulemaking time frame are included in the figures for context. NHTSA underscores that the equations and coefficients defining the curves are the CAFE and HDPUV standards, and not the mpg and gallon/100-mile estimates that the agency currently estimates could result from manufacturers complying with the proposed curves. We provide mpg and gallon/100-mile estimates for ease of understanding after we illustrate the footprint curves, but the equations and coefficients are the actual standards.

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[13] Generally, passenger cars have more stringent targets than light trucks regardless of footprint, and smaller vehicles will have more stringent targets than larger vehicles, because smaller vehicles are generally more fuel efficient No individual vehicle or vehicle model need meet its target exactly, but a manufacturer's compliance is determined by how its average fleet fuel economy compares to the average fuel economy of the targets of the vehicles it manufactures.

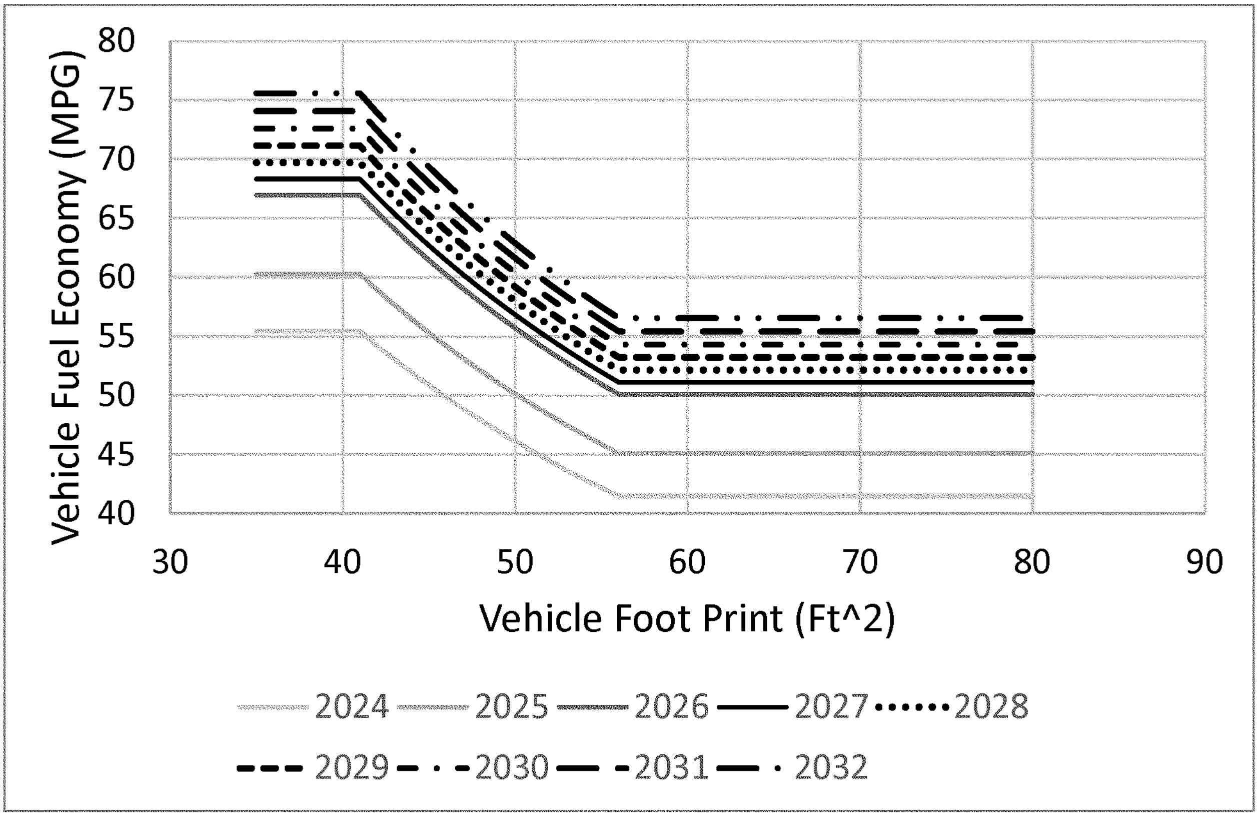

Figure I-1: Preferred Alternative PC2LT4, Passenger Car Fuel Economy, Target Curves

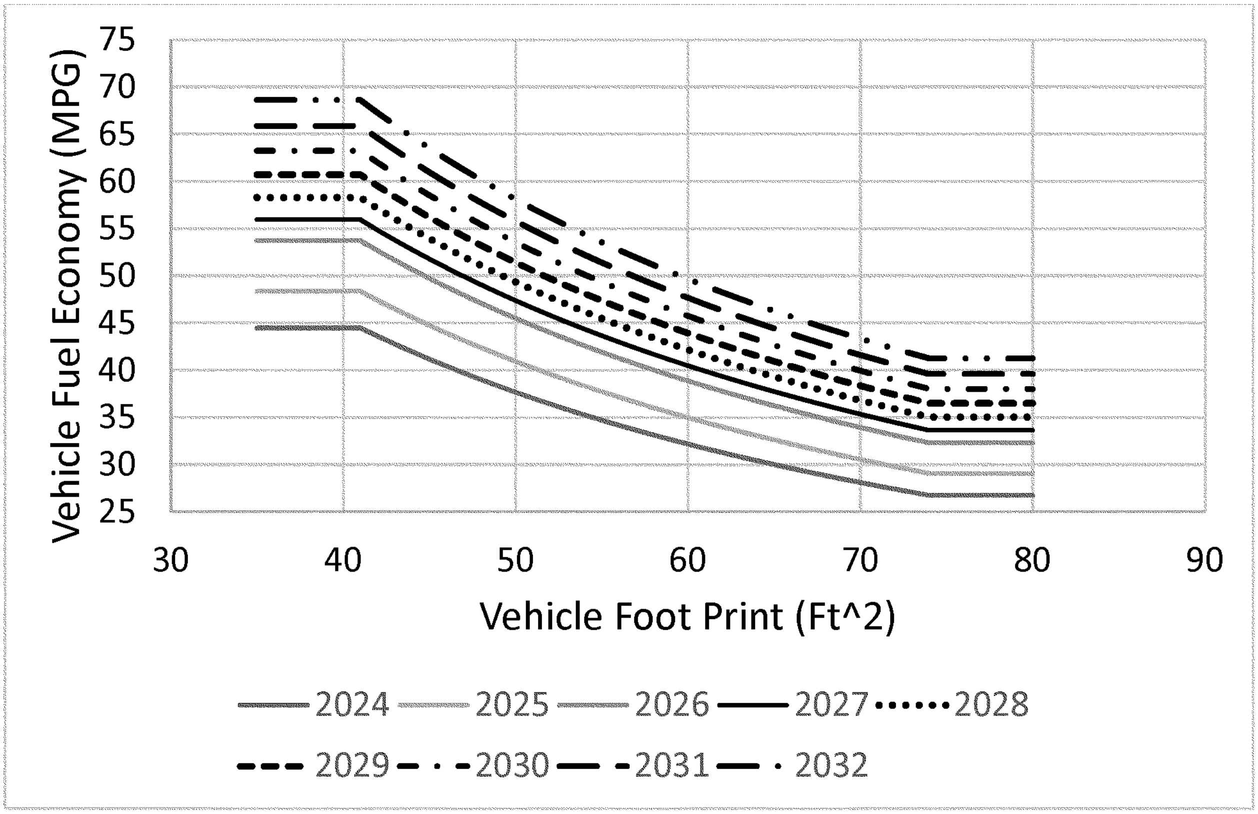

Figure I-2: Preferred Alternative PC2LT4, Light Truck Fuel Economy, Target Curves

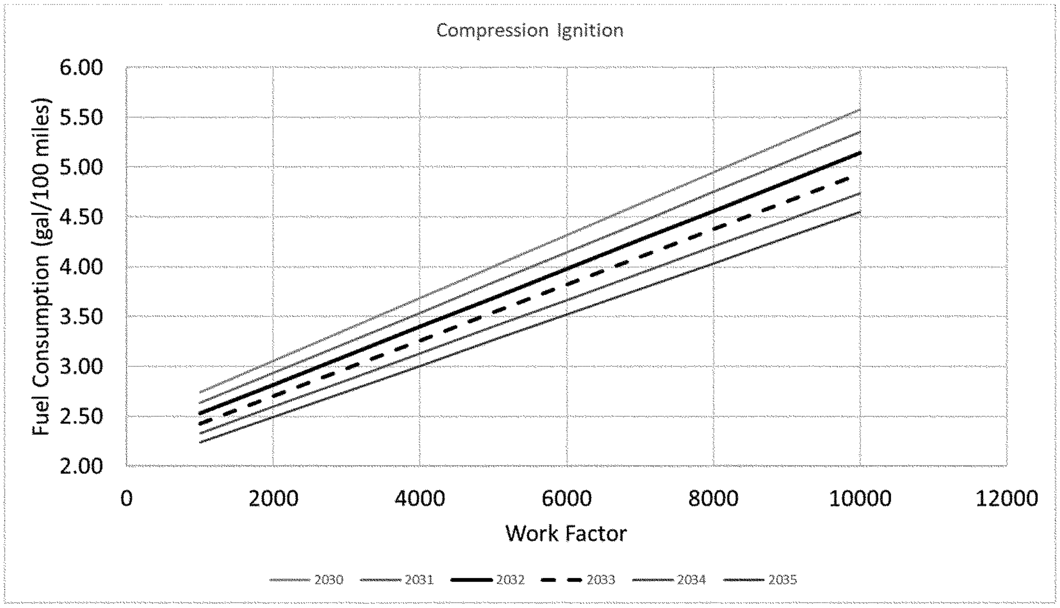

Figure I-3: Preferred Alternative HDPUV10, HDPUV Fuel Efficiency – Compression Ignition (CI) Vehicles, Target Curves

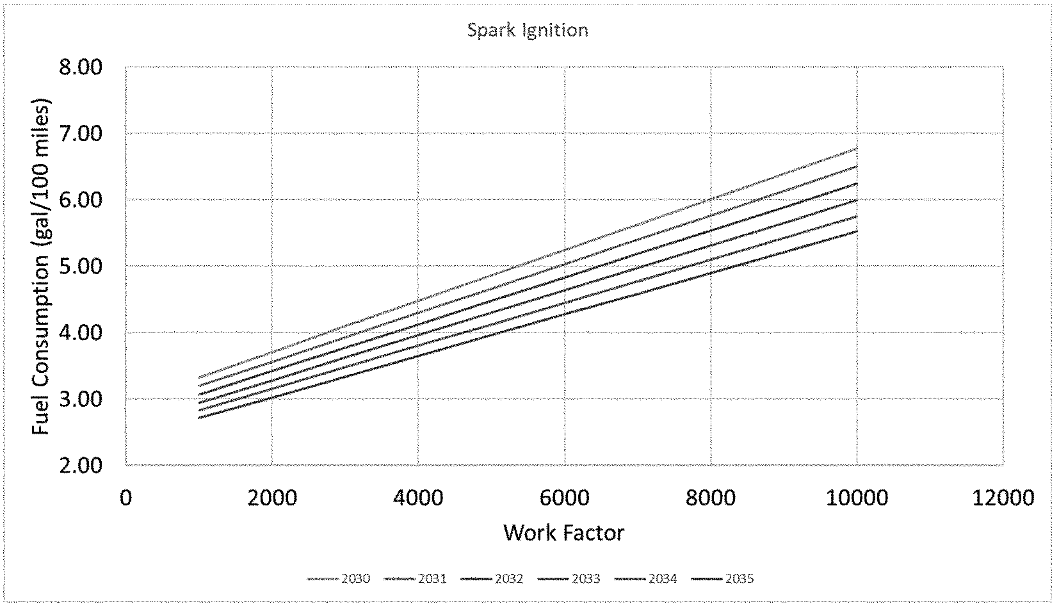

Figure I-4: Preferred Alternative HDPUV10, HDPUV Fuel Efficiency – Spark Ignition Engine (SI)Vehicles, Target Curves

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NHTSA is also proposing new minimum domestic passenger car CAFE standards (MDPCS) for MYs 2027–2032 as required by the Energy Policy and Conservation Act of 1975 (EPCA), as amended by the EISA, and applied to vehicles defined as manufactured in the United States. Section 32902(b)(4) of 49 U.S.C. requires NHTSA to project the minimum domestic standard when it promulgates passenger car standards for a MY, so the minimum standards are estimated as specific mpg values and will be finalized as specific mpg values when NHTSA sets final passenger car standards for MYs 2027–2032. NHTSA retains the 1.9 percent offset first used in the 2020 final rule, reflecting prior differences between passenger car footprints originally forecast by the agency and passenger car footprints as they occurred in the real world, such that the minimum domestic passenger car standard is as shown in the table below. NHTSA requests comment on this approach.

TABLE I–3—PROPOSED MINIMUM DOMESTIC PASSENGER CAR STANDARD WITH OFFSET

[mpg]

MY 2027	MY 2028	MY 2029	MY 2030	MY 2031	MY 2032
54.1 ...	55.3	56.4	57.5	58.7	59.9

Recognizing that many readers think about CAFE standards in terms of the mpg values that the standards are projected to eventually require, NHTSA currently estimates that the proposed standards would require roughly 57.8 mpg in MY 2032, on an average industry fleet-wide basis, for passenger cars and light trucks. NHTSA notes both that real-world fuel economy is generally 20–30 percent lower than the estimated required CAFE level stated above,[14] and also that the actual CAFE standards are the footprint target curves for passenger cars and light trucks. This last note is important, because it means that the ultimate fleet-wide levels will vary depending on the mix of vehicles that industry produces for sale in those MYs. NHTSA also calculates and presents ''estimated achieved'' fuel economy levels, which differ somewhat from the estimated required levels for each fleet, for each year.[15] NHTSA estimates that the industry-wide average fuel economy achieved in MY 2032 for passenger cars and light trucks combined could increase from about 53.6 mpg under the No-Action Alternative to 57.6 mpg under the proposed standards.

TABLE I–4—ESTIMATED REQUIRED AVERAGE AND ESTIMATED ACHIEVED AVERAGE OF CAFE LEVELS

[mpg] for passenger cars and light trucks, preferred alternative PC2LT4

Fleet	MY 2027	MY 2028	MY 2029	MY 2030	MY 2031	MY 2032
Passenger Cars:						
Estimated Required	60.0	61.2	62.5	63.7	65.1	66.4
Estimated Achieved	63.5	65.3	67.5	69.3	71.3	72.8
Light Trucks:						
Estimated Required	44.4	46.2	48.2	50.2	52.2	54.4
Estimated Achieved	44.2	45.7	47.5	49.0	50.9	52.4
Combined:						
Estimated Required[16]	48.4	50.1	51.9	53.8	55.7	57.8
Estimated Achieved	49.0	50.5	52.3	54.0	56.0	57.6

To the extent that manufacturers appear to be over-complying in our analysis with required fuel economy levels in the passenger car fleet, NHTSA notes that this is due to the inclusion of several all-electric manufacturers in the baseline analysis, which affects the overall average achieved levels. Manufacturers with more traditional fleets do not over-comply at such high levels in our analysis, and our analysis considers the compliance paths for both manufacturer groups. In contrast, while it looks like manufacturers are falling short of required fuel economy levels in the light truck fleet (and choosing instead to pay civil penalties), NHTSA notes that this appears to be the result of a relatively small number of companies, which affects the overall average achieved levels. The agency's overall assessment is that the light truck standards are maximum feasible even though they may be challenging for some individual companies to achieve. Please see Section V.D of this preamble for more discussion on these topics and how the agency has considered them in determining maximum feasible standards for this proposal.

For HDPUVs, NHTSA currently projects that the standards would require, on an average industry fleet-wide basis for the HDPUV fleet, roughly 2.638 gallons per 100 miles[17] in MY 2035. HDPUV standards are attribute-based like passenger car and light truck standards, so here, too, ultimate fleet-wide levels will vary depending on what industry produces for sale.

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[14] CAFE compliance is evaluated per 49 U.S.C. 32904(c) Testing and Calculation Procedures, which states that the EPA Administrator (responsible under EPCA/EISA for measuring vehicle fuel economy) shall use the same procedures used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle) or comparable procedures. Colloquially, this is known as the 2-cycle test. The ''real-world'' or 5-cycle evaluation includes the 2-cycle tests, and three additional tests that are used to adjust the city and highway estimates to account for higher speeds, air conditioning use, and colder temperatures. In addition to calculating vehicle fuel economy, EPA is responsible for providing the fuel economy data that is used on the fuel economy label on all new cars and light trucks, which uses the ''real-world'' values. In 2006, EPA revised the test methods used to determine fuel economy estimates (city and highway) appearing on the fuel economy label of all new cars and light trucks sold in the U.S., effective with 2008 model year vehicles.

[15] NHTSA's analysis reflects that manufacturers nearly universally make the technological improvements prompted by CAFE standards at times that coincide with existing product ''refresh'' and ''redesign'' cycles, rather than applying new technology every year regardless of those cycles. It is significantly more cost-effective to make fuel-economy-improving technology updates when a vehicle is being updated anyway. See TSD 2.2.1.7 for additional discussion about manfacturer refresh and redesign cycles.

[16] There is no actual legal requirement for combined passenger car and light truck fleets, but NHTSA presents information this way in recognition of the fact that many readers will be accustomed to seeing such a value.

[17] The HDPUV standards measure compliance in direct fuel consumption and uses gallons consumed per 100 miles of operation as a metric. *See* 49 CFR 535.6.

TABLE I–5—ESTIMATED REQUIRED AVERAGE AND ESTIMATED ACHIEVED AVERAGE OF FUEL EFFICIENCY LEVELS (gal/100 MILES FOR HDPUVS, PREFERRED ALTERNATIVE HDPUV10)

	MY 2030	MY 2031	MY 2032	MY 2033	MY 2034	MY 2035
Estimated Required	4.427	4.051	3.646	3.255	2.930	2.638
Estimated Achieved	3.266	2.764	2.759	2.160	2.157	2.153

For all fleets, average requirements and average achieved CAFE and HDPUV fuel efficiency levels would ultimately depend on manufacturers' and consumers' responses to standards, technology developments, economic conditions, fuel prices, and other factors.

NHTSA recognizes that the 2022 rule for MYs 2024–2026 involved higher rates of increase based on our assessment at the time of what technologies were available for deployment in that fleet. Our technical analysis for this proposal keeps that same general framework as the 2022 final rule, but as applied to a more-recent fleet that includes the vehicles that will be subject to the 2024–2026 standards. Thus, since May 2022, NHTSA has updated technologies considered in our analysis (removing technologies which are already universal or nearly so and technologies which are exiting the fleet, adding certain advanced engine technologies;[18]) updated macroeconomic input assumptions, as with each round of rulemaking analysis; improved user control of various input parameters; updated our approach to modeling manufacturers' expected compliance with states' Zero Emission Vehicle (ZEV) programs; accounted for potential changes to DOE's Petroleum Equivalency Factor (PEF), which is proposed to be changed,[19] for the baseline assumptions; expanded accounting for Federal incentives such as Inflation Reduction Act programs; expanded procedures for estimating new vehicle sales and fleet shares; updated inputs for projecting aggregate light-duty Vehicle Miles Traveled (VMT); and added various output values and options.[20]

NHTSA tentatively concludes, as we explain in more detail below, that Alternative PC2LT4 is the maximum feasible alternative that manufacturers can achieve for MYs 2027–2032 passenger cars and light trucks, based on a variety of reasons. Energy conservation is still paramount, for the consumer benefits, energy security benefits, and environmental benefits that it provides. Moreover, although the vehicle fleet is undergoing a significant transformation now and in the coming years, for reasons other than the CAFE standards, NHTSA believes that a significant percentage of the on-road (and new) vehicle fleet may remain propelled by internal combustion engines (ICEs) through 2032. NHTSA believes that the alternative we are proposing will encourage manufacturers producing those ICE vehicles during the standard-setting time frame to achieve significant fuel economy, improve energy security, and reduce harmful pollution by a large amount. At the same time, NHTSA is proposing standards that our estimates suggest will continue to save consumers money and fuel over the lifetime of their vehicles, particularly light truck buyers, while being economically practicable and technologically feasible for manufacturers to achieve.

Although Alternatives PC3LT5 and PC6LT8 would conserve more energy and provide greater fuel savings benefits and certain pollutant emissions reductions, NHTSA's statutorily-constrained analysis currently estimates that those alternatives may not be achievable for many manufacturers in the rulemaking time frame. Additionally, compliance with those more stringent alternatives would impose significant costs on individual consumers without corresponding fuel savings benefits large enough to, on average, offset those costs. Within that framework, NHTSA's analysis suggests that the more stringent alternatives could push more technology application than would be economically practicable, given anticipated baseline activity that will already be consuming manufacturer resources and capital. In contrast to Alternatives PC3LT5 and PC6LT8, Alternative PC2LT4 comes at a cost we believe the market can bear without creating consumer acceptance or sales issues, appears to be much more achievable, and will still result in consumer net benefits on average. The proposed alternative also achieves large fuel savings benefits and significant reductions in emissions. NHTSA tentatively concludes Alternative PC2LT4 is the appropriate choice given this record.

For HDPUVs, NHTSA tentatively concludes, as explained in more detail below, that Alternative HDPUV10 is the maximum feasible alternative that manufacturers can achieve for MYs 2030–2035 HDPUVs. It has been seven years since NHTSA revisited HDPUV standards, and our analysis suggests that there is much opportunity for cost-effective improvements in this segment, broadly speaking. At the same time, we recognize that these vehicles are primarily used to conduct work for a large number of businesses. Although Alternative HDPUV14 would conserve more energy and provide greater fuel savings benefits and CO_2 emissions reductions, it is significantly more costly than HDPUV10, and NHTSA currently estimates that Alternative HDPUV10 is the most cost-effective under a variety of metrics and at either a 3 percent or a 7 percent DR, while still being appropriate and technologically feasible. NHTSA is allowed to consider electrification in determining maximum feasible standards for HDPUVs. As a result, NHTSA tentatively concludes that HDPUV10 is the appropriate choice given the record discussed in more detail below, and we believe it balances EPCA's overarching objective of energy conservation while remaining cost-effective and technologically feasible.

For passenger cars and light trucks, NHTSA estimates that this proposal would reduce average fuel outlays over the lifetimes of MY 2032 vehicles by about $1,043 per vehicle, while increasing the average cost of those vehicles by about $932 over the baseline, at a 3 percent DR. With climate benefits and all other benefits and costs discounted at 3 percent, when considering the entire CAFE fleet for MYs 1983–2032, NHTSA estimates $58.6 billion in monetized costs and $75.5 billion in monetized benefits attributable to the proposed standards, such that the present value of aggregate net monetized benefits to society would be $16.8 billion.[21]

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[18] See Draft TSD Chapter 1.1 for a complete list of technologies added or removed from the analysis.

[19] For more information on DOE's proposal, see 88 FR 21525. For more information on how DOE's proposal affects NHTSA's results in this proposal, please see Chapter 9 of the PRIA.

[20] See TSD Chapter 1.1 for a detailed discussion of analysis updates.

[21] These values are from our ''model year'' analysis, reflecting the entire fleet from MYs 1983–2032, consistent with past practice. Model year and

For HDPUVs, NHTSA estimates that this proposal could reduce average fuel outlays over the lifetimes of MY 2038 vehicles by about $439 per vehicle, while increasing the average cost of those vehicles by about $131 over the baseline, at a 3 percent DR. With climate benefits and all other benefits and costs discounted at 3 percent, when considering the entire on-road HDPUV fleet for CYs 2022–2050, NHTSA estimates $2.1 billion in monetized costs and $4.3 billion in monetized benefits attributable to the proposed standards, such that the present value of aggregate net monetized benefits to society would be $2.2 billion.[22]

These assessments do not include important unquantified effects, such as energy security benefits, equity and distributional effects, and certain air quality benefits from the reduction of toxic air pollutants and other emissions, among other things, so that the net benefit estimate is a conservative one.[23] 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.

Table I–6 presents aggregate benefits and costs for new vehicle buyers and for the average individual new vehicle buyer.

TABLE I–6—BENEFITS AND COSTS FOR THE LIGHT DUTY (LD) AND HDPUV PREFERRED ALTERNATIVES

[2021$, 3 percent annual DR, 3 percent SC–GHG DR]

	PC2LT4	HDPUV10
Aggregate Buyer Benefits and Costs ($b):		
Costs	43.3	1.4
Benefits	59.4	3.2
Net Benefits	16.1	1.7
Aggregate Societal Benefits and Costs (including buyer, $b):		
Costs	58.6	2.1
Benefits	75.5	4.3
Net Benefits	16.8	2.2
Per-vehicle ($):		
Regulatory Costs	932	131
Lifetime Fuel Savings	1,043	439

Notes: Total buyer costs and benefits include those presented in more detail in Table V–6 and Table V–7. Societal costs and benefits include those presented in more detail in Table V–8 and Table V–9. Aggregate light-duty measures are computed for the lifetimes of the total light-duty fleet produced through MY 2032. Aggregate HDPUV measures are computed for the on-road HDPUV fleet for CYs 2022–2050. Per-vehicle costs are those for MY 2032 (LD) and MY 2038 (HDPUV).

NHTSA recognizes that EPA has recently issued a proposal to set new multi-pollutant emissions standards for MYs 2027 and later light-duty (LD) and medium-duty (MD) vehicles.[24] EPA describes its proposal as building upon EPA's final standards for Federal GHG emissions standards for passenger cars and light trucks for MYs 2023 through 2026 and leverages advances in clean car technology to unlock benefits to Americans ranging from reducing pollution, to improving public health, to saving drivers money through reduced fuel and maintenance costs.[25] EPA's proposed standards would phase in over MYs 2027 through 2032.[26]

NHTSA coordinated with EPA in developing our proposal to avoid inconsistencies and produce requirements that are consistent with NHTSA's statutory authority. The proposals nevertheless differ in important ways. First, NHTSA's proposal, consistent with its statutory authority and mandate under EPCA/EISA, focuses on improving vehicle fuel economy and not directly on reducing vehicle emissions—though reduced emissions are a follow-on effect of improved fuel economy. Second, the biggest difference between the two proposals is due to EPCA/EISA's statutory prohibition against NHTSA considering the fuel economy of dedicated alternative fueled vehicles, including BEVs, and including the full fuel economy of dual-fueled alternative fueled vehicles in determining the maximum feasible fuel economy level that manufacturers can achieve for passenger cars and light trucks, even though manufacturers may use BEVs and dual-fueled alternative fuel vehicles (AFV) to comply with CAFE standards. EPA is not prohibited from considering BEVs as a compliance option. EPA's proposal is informed by, among other considerations, trends in the automotive industry (including the proliferation of announced investments by automakers in electrifying their fleets), tax incentives under the Inflation Reduction Act (IRA), and other forces that are leading to a rapid transition in the automotive industry away from ICEs.[27] NHTSA, in contrast, may *not* consider BEVs as a compliance option for the passenger car and light truck fleets even though manufacturers may, in fact, use BEVs to comply with CAFE standards. This constraint means that not only are NHTSA's stringency rates of increase different from EPA's but also the shapes

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calendar year perspectives are discussed in more detail below in this section.

[22] These values are from our ''calender year'' analysis, reflecting the on-the-road fleet from CYs 2022–2050. Model year and calendar year perspectives are discussed in more detail below in this section.

[23] These cost and benefit estimates are based on many different and uncertain inputs, and NHTSA has conducted several dozen sensitivity analyses varying individual inputs to evaluate the effect of that uncertainty. For example, while NHTSA's reference case analysis constrains the application of high compression ratio engines to some vehicles based on performance and other considerations, we also conducted a sensitivity analysis that removed all of those constraints. Results of this and other sensitivity analyses are discussed in Section IV.D of this preamble, in Chapter 9 of the PRIA, and (if large or otherwise significant) in Section V.D of this preamble.

[24] See Enviromental Protection Agency. 2023. Proposed Rule: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles. Last revised: May 25, 2023. Available at: *https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-multi-pollutant-emissions-standards-model.* (Accessed: May 31, 2023).

[25] *Id.*

[26] *Id.*

[27] Enviromental Protection Agency. 2023. Proposed Rule: Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles. EPA–420–F–23–009. Offce of Transportation and Air Quality. Available at: *https://www.epa.gov/regulations-emissions-vehicles-and-engines/proposed-rule-multi-pollutant-emissions-standards-model.* (Accessed: May 31, 2023).

of our standards are different based upon the different scopes.

Recognizing that the agencies are implementing statutory mandates to set maximum feasible fuel economy standards and to address dangerous air pollution, and that both standards affect the same fleet of vehicles, we seek comment on how best to optimize the effectiveness of NHTSA's standards consistent with the statutory factors. Our statutorily constrained simulated industry response shows a reasonable path forward to compliance with CAFE standards, but we want to stress that our analysis simply shows feasibility and does not dictate a required path to compliance. Because the standards are performance-based, manufacturers are always free to apply their expertise to find the appropriate technology path that best meets all desired outcomes. Indeed, as explained in greater detail later on in this proposal, it is entirely possible and reasonable that a vehicle manufacturer will use technology options to meet NHTSA's proposed standards that are significantly different from what NHTSA's analysis for this proposal suggests given the statutory constraints under which it operates. NHTSA will coordinate with EPA to ensure NHTSA's standards take account of statutory objectives and constraints while minimizing compliance costs. NHTSA seeks input to help inform these objectives.

As discussed before, NHTSA does not face the same statutory limitations in setting standards for HDPUVs as it does in setting standards for passenger cars and light trucks. This allows NHTSA to consider a broader array of technologies in setting maximum feasible standards for HDPUVs. However, we are still considerate of factors that allow these vehicles to maintain utility and do work for the consumer when we set the standards.

Additionally, NHTSA has considered and accounted for manufacturers' expected compliance with California's Advanced Clean Cars (ACC) and Advanced Clean Trucks (ACT) regulations in our analysis, as part of the analytical baseline.[28] We find that manufacturers will comply with ZEV requirements in California and a number of other states in the absence of CAFE standards, and accounting for that expected compliance allows us to present a more realistic picture of the state of fuel economy even in the absence of changes to the CAFE standards. Reflecting expected compliance with the ZEV mandates in the analysis improves the accuracy of the baseline in reflecting the state of the world without the revised CAFE standards, and thus the information available to decision-makers in their decision as to what standards are maximum feasible and to the public in commenting on those standards.

A number of other improvements and updates have been made to the analysis since the 2022 final rule based on NHTSA analysis, new data, and stakeholder meetings for this NPRM. Table I–7 summarizes these, and they are discussed in much more detail below and in the documents accompanying this preamble.

Table I–7—Key Analytical Updates From the 2022 Final Rule[29]

Key Updates

- Update analysis fleet from MY2020 to MY2022.
- Addition of HDPUV, and required updates across entire model.
- Update technologies considered in the analysis.
  - Addition of HCRE, HCRD and updated Diesel technology models.
  - Removal of EFR,[30] DSLIAD,[31] manual transmissions, AT6L2, EPS,[32] IACC,[33] LDB,[34] SAX, and some P2 combinations.
- User control of additional input parameters.
- Updated modeling approach to manufacturers' expected compliance with states' ZEV programs.
- Expanded accounting for Federal Incentives, such as the Inflation Reduction Act.
- Expanded procedures for estimating new vehicle sales and fleet shares.
- VMT coefficient updates.
- Additional output values and options.

NHTSA notes that while the current estimates of costs and benefits are important considerations and are directed by E.O. 12866, cost-benefit analysis provides only one informative data point in addition to the host of considerations that NHTSA must balance by statute when determining maximum feasible standards. Specifically, for passenger cars and light trucks, NHTSA is required to consider 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. For HDPUVs, NHTSA is required to consider three statutory factors—whether standards are appropriate, cost-effective, and technologically reasonable—to determine whether the standards it adopts are maximum feasible.[35] As will be discussed further below, NHTSA tentatively concludes that Alternatives PC2LT4 and HDPUV10 are maximum feasible on the basis of these respective factors, and the cost-benefit analysis, while informative, is not one of the statutorily-required factors. NHTSA also considered several dozen sensitivity cases varying different inputs and concluded that even when varying inputs resulted in changes to net benefits or (on rare occasions) changed the relative order of regulatory alternatives in terms of their net benefits, those changes were not significant enough to outweigh our tentative conclusion that Alternatives PC2LT4 and HDPUV10 are maximum feasible.

NHTSA further notes that CAFE and HDPUV standards apply only to new vehicles, meaning that the costs attributable to new standards are ''front-loaded'' because they result primarily from the application of fuel-saving technology to new vehicles. By contrast, the impact of new CAFE and HDPUV standards on fuel consumption and energy savings, air pollution, and GHGs—and the associated benefits to society—occur over an extended time, as drivers buy, use, and eventually scrap these new vehicles. By accounting for many MYs and extending well into the future to 2050, our analysis accounts for these differing patterns in impacts, benefits, and costs. Given the front-loaded costs versus longer-term benefits, it is likely that an analysis extending even further into the future would find additional net present benefits.

The bulk of our analysis for passenger cars and light trucks presents a ''model year'' (MY) perspective rather than a ''calendar year'' (CY) perspective. The MY perspective considers the lifetime impacts attributable to all passenger cars and light trucks produced prior to MY 2033, accounting for the operation of these vehicles over their entire lives (with some MY 2032 vehicles estimated to be in service as late as 2050). This approach emphasizes the role of the MYs for which new standards are being proposed, while accounting for the potential light truck that the proposed standards could induce some changes in

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[28] Specifically, we include the main provisions of the ACC I, ACC II, and ACT programs, as discussed further below in Section II.C.5.a.

[29] For a detailed list of updates to the CAFE Analysis please see Draft TSD Chapter 1.1.

[30] Engine Friction Reduction.

[31] Advanced Diesel Engine with Improvements and Advanced Cylinder Deactivation.

[32] Electric Power Steering.

[33] Improved Accessories.

[34] Low-drag Brakes.

[35] 49 U.S.C. 32902(k).

the operation of vehicles produced prior to MY 2027 (for passenger cars and light trucks), and that, for example, some individuals might choose to keep older vehicles in operation, rather than purchase new ones.

The CY perspective we present includes the annual impacts attributable to all vehicles estimated to be in service in each CY for which our analysis includes a representation of the entire registered passenger car, light truck, and HDPUV fleet. For this proposal, this CY perspective covers each of CYs 2022–2050, with differential impacts accruing as early as MY 2022.[36] Compared to the MY perspective, the CY perspective emphasizes MYs of vehicles produced in the longer term, beyond those MYs for which standards are currently being proposed.

The tables below summarize estimates of selected impacts viewed from each of these two perspectives, for each of the regulatory alternatives considered in this proposal.

Table I–8—Selected Cumulative Effects—Passenger Cars and Light Trucks—MY and CY Perspectives [37]

	PC1LT3	PC2LT4 (preferred alternative)	PC3LT5	PC6LT8
Avoided Gasoline Consumption (billion gallons)				
MYs 1983–2032	−23	−30	−34	−47
CYs 2022–2050	−65	−88	−115	−207
Additional Electricity Consumption (TWh) [38]				
MYs 1983–2032	79	99	91	139
CYs 2022–2050	218	312	408	975
Reduced CO_2 Emissions (mmt)				
MYs 1983–2032	−236	−301	−346	−482
CYs 2022–2050	−654	−885	−1,155	−2,011

Table I—9: Selected Cumulative Effects—HDPUVs—CY Perspective

	HDPUV4	HDPUV10 (preferred alternative)	HDPUV14
Avoided Gasoline Consumption (billion gallons)			
CYs 2022–2050	−0.1	−2.6	−11.8
Additional Electricity Consumption (TWh) [39]			
CYs 2022–2050	1.1	24.2	101.0
Reduced CO_2 Emissions (mmt)			
CYs 2022–2050	−0.9	−22.3	−101.3

Table I–10—Estimated Monetized Costs and Benefits—Passenger Cars and Light Trucks—MY and CY Perspectives by Alternative and Social DR, 3% SC–GHG DR [40] [41]

	PC1LT3		PC2LT4 (preferred alternative)		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

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[36] For a presentation of effects by CY, please see Chapter 8.2.4.6 of the PRIA.

[37] PRIA Chapter 1, Figure 1–1 provides a graphical comparison of energy sources and their relative change over the standard setting years.

[38] The additional electricity use is attributed to an increase in the number of 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.

[39] Total Gigawatt hours.

[40] Climate benefits are based on reductions in CO_2, CH_4, and N_2O emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC–GHG model average at 2.5 percent, 3 percent, and 5 percent DRs; 95th percentile at 3 percent DR), which each increase over time. For the presentational purposes of this table and other similar summary tables, we show the benefits associated with the average global SC–GHG at a 3 percent DR, 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 DR 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 DR as used in the underlying SC–GHG values for internal consistency.

[41] For this and similar tables in this section, net benefits may differ from benefits minus costs due to rounding.

TABLE I–10—ESTIMATED MONETIZED COSTS AND BENEFITS—PASSENGER CARS AND LIGHT TRUCKS—MY AND CY PERSPECTIVES BY ALTERNATIVE AND SOCIAL DR, 3% SC–GHG DR [40] [41]—Continued

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 I–11—ESTIMATED MONETIZED COSTS AND BENEFITS—HDPUVS—CY PERSPECTIVE BY ALTERNATIVE AND SOCIAL DR, 3% SC–GHG DR [42]

	HDPUV4		HDPUV10 (preferred alternative)		HDPUV14	
Monetized Benefits ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
CYs 2022–2050	0.11	0.07	4.32	2.43	17.43	10.12
Monetized Costs ($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

Our net benefit estimates are likely to be conservative both because (as discussed above) our analysis only extends to MY 2032 and CY 2050 (LD) and CY 2050 (HDPUV), and because there are additional important health, environmental, and energy security benefits that could not be fully quantified or monetized. Finally, for purposes of comparing the benefits and costs of proposed CAFE and HDPUV standards to the benefits and costs of other Federal regulations, policies, and programs under the Regulatory Right-to-Know Act,[43] we have computed ''annualized'' benefits and costs, as follows:

TABLE I–12—ESTIMATED ANNUALIZED MONETIZED COSTS AND BENEFITS—PASSENGER CARS AND LIGHT TRUCKS—MY AND CY PERSPECTIVES BY ALTERNATIVE AND SOCIAL DR, 3% SC–GHG DR [44] [45]

	PC1LT3		PC2LT4 (preferred alternative)		PC3LT5		PC6LT8	
Monetized Benefits ($billion)								
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1983–2032	2.3	2.7	2.9	3.4	3.4	4	4.7	5.4
CYs 2022–2050	7.8	7.2	10.6	9.7	13.6	12.4	22.8	20.6

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[42] Climate benefits are based on reductions in CO_2, CH_4, and N_2O emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC–GHG model average at 2.5 percent, 3 percent, and 5 percent DRs; 95th percentile at 3 percent DR), which each increase over time. For the presentational purposes of this table and other similar summary tables, we show the benefits associated with the average 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 DR 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 DR as used in the underlying SC–GHG values for internal consistency.

[43] See *https://www.whitehouse.gov/omb/information-regulatory-affairs/reports/* for examples of how this reporting is used by the Federal Government.

[44] Climate benefits are based on reductions in CO_2, CH_4, and N_2O emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC–GHG model average at 2.5 percent, 3 percent, and 5 percent DRs; 95th percentile at 3 percent DR), which each increase over time. For the presentational purposes of this table and other similar summary tables, we show the benefits associated with the average 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 DR 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 DR as used in the underlying SC–GHG values for internal consistency.

[45] For this and similar tables in this section, net benefits may differ from benefits minus costs due to rounding.

TABLE I–12—ESTIMATED ANNUALIZED MONETIZED COSTS AND BENEFITS—PASSENGER CARS AND LIGHT TRUCKS—MY AND CY PERSPECTIVES BY ALTERNATIVE AND SOCIAL DR, 3% SC–GHG DR [44] [45]—Continued

Monetized Costs ($billion)								
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1983–2032	1.8	2.3	2.3	2.8	3.1	3.8	4.1	5.1
CYs 2022–2050	6.1	5.3	8.2	7.1	12.5	10.6	20.1	16.8
Monetized Net Benefits ($billion)								
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1983–2032	0.5	0.5	0.7	0.6	0.3	0.2	0.6	0.3
CYs 2022–2050	1.8	1.9	2.4	2.6	1.1	1.7	2.7	3.8

TABLE I–13—ESTIMATED ANNUALIZED MONETIZED COSTS AND BENEFITS—HDPUVS BY ALTERNATIVE AND SOCIAL DR, CY PERSPECTIVE, 3% SC–GHG DR [46]

	HDPUV4		HDPUV10 (preferred alternative)		HDPUV14	
Monetized Benefits ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
CYs 2022–2050	0.006	0.006	0.23	0.20	0.91	0.82
Monetized Costs ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
CYs 2022–2050	0.005	0.003	0.11	0.08	0.49	0.38
Monetized Net Benefits ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
CYs 2022–2050	0.001	0.002	0.12	0.12	0.42	0.44

It is also worth emphasizing that, although NHTSA is prohibited from considering the availability of certain flexibilities in making our determination about the levels of CAFE standards that would be maximum feasible, manufacturers have a variety of flexibilities available to aid their compliance. Section VI of this preamble summarizes these flexibilities. NHTSA is proposing changes to some of these flexibilities as shown in Table I–14 and Table I–15.

TABLE I–14—OVERVIEW OF COMPLIANCE FLEXIBILITY CHANGES FOR CAFE PROGRAM (VEHICLES WITH A GROSS VEHICLE WEIGHT RATING (GVWR) OF 8,500 LBS. OR LESS AND MEDIUM-DUTY PASSENGER VEHICLES (MDPVS) WITH A GVWR BETWEEN 8,501 AND 10,000 LBS.)

Determining average fleet performance		
Component	*General description*	*Proposed changes in NPRM?*
AC efficiency Fuel Consumption Improvement Value (FCIV).	This adjustment to the results from the 2-cycle testing accounts for fuel consumption improvement from technologies that improve AC efficiency that are not accounted for in the 2-cycle testing. The AC efficiency FCIV program began in MY 2017.	Yes: Proposed changes to 49 CFR 531.6 and 533.6 to eliminate AC efficiency FCIVs for BEVs starting in MY 2027.

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[46] Climate benefits are based on reductions in CO_2, CH_4, and N_2O emissions and are calculated using four different estimates of the social cost of each greenhouse gas (SC–GHG model average at 2.5 percent, 3 percent, and 5 percent DRs; 95th percentile at 3 percent DR), which each increase over time. For the presentational purposes of this table and other similar summary tables, we show the benefits associated with the average 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 DR 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 DR as used in the underlying SC–GHG values for internal consistency.

TABLE I–14—OVERVIEW OF COMPLIANCE FLEXIBILITY CHANGES FOR CAFE PROGRAM (VEHICLES WITH A GROSS VEHICLE WEIGHT RATING (GVWR) OF 8,500 LBS. OR LESS AND MEDIUM-DUTY PASSENGER VEHICLES (MDPVS) WITH A GVWR BETWEEN 8,501 AND 10,000 LBS.)—Continued

Determining average fleet performance		
Component	*General description*	*Proposed changes in NPRM?*
Off-cycle FCIV	This adjustment to the results from the 2-cycle testing accounts for fuel consumption improvement from technologies that are not accounted for or not fully accounted for in the 2-cycle testing. The off-cycle FCIV program began in MY 2017.	Yes: Proposing changes to 49 CFR 531.6 and 533.6 to eliminate off-cycle menu FCIVs for BEVs and to eliminate the 5-cycle and alternative approvals starting in MY 2027. PHEVs retain benefits. Proposing a 60-day response deadline for requests for information regarding off-cycle requests for MY 2025–2026.
Advanced full-size pickup trucks FCIV	This adjustment increases a manufacturer's average fuel economy for hybridized and other performance-based technologies for MY 2017 and 2024.	No proposed changes. The program is set to sunset in MY 2024 and NHTSA is not proposing to extend it.

TABLE I–15—OVERVIEW OF COMPLIANCE FOR HEAVY-DUTY FUEL EFFICIENCY PROGRAM FOR PICKUP AND VANS

[Vehicles with a GVWR between 8,500 and 14,000 lbs.]

Determining average fleet performance and certification flexibilities		
Component	*General description*	*Proposed changes in NPRM?*
Advanced technology credit multiplier	In the 2016 Phase 2 Final Rule, EPA and NHTSA explained that manufacturers may increase advanced technology credits by a 3.5 multiplier for plug-in hybrid electric vehicles, 4.5 for all-electric vehicles, and 5.5 for fuel cell vehicles through My 2027	Yes: Proposed technical amendments to accurately reflect changes contemplated by 2016 final rule establishing requirements for Phase 2. The multiplier for advanced technology credits ends after MY 2027.
Innovative and off-cycle technology credits.	Manufacturer may generate credits for vehicle or engine families or subconfigurations having fuel consumption reductions resulting from technologies not reflected in the Greenhouse Gas Emissions Model (GEM) simulation tool or in the FTP chassis dynamometer.	Yes: Proposed changes to eliminate innovative and off-cycle technology credits for heavy-duty pickup trucks and vans.
Credit Transfers	Manufacturers may transfer advanced technology credits across averaging sets.	Yes: Proposed technical amendment to reflect, as intended in the 2016 Phase 2 rule that advanced technology credits may not be transferred across averaging sets for Phase 2 and beyond.[47]

The following sections of this preamble discuss the technical foundation for the agency's analysis, the regulatory alternatives considered in this proposal, the estimated effects of the regulatory alternatives, the basis for NHTSA's tentative conclusion that the proposed standards are maximum feasible, and NHTSA's approach to compliance and enforcement. The extensive record supporting NHTSA's tentative conclusion is documented in this preamble, in the Draft TSD, the PRIA, the Draft EIS, and the additional materials on NHTSA's website and in the rulemaking docket. NHTSA seeks comment on all aspects of this proposal.

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[47] Docket ID NHTSA–2020–0079–0001.

II. Technical Foundation for NPRM Analysis

A. Why is NHTSA conducting this analysis?

When NHTSA proposes new regulations, it generally presents an analysis that estimates the impacts of those regulations, and the impacts of other regulatory alternatives. These analyses derive from statutes such as the Administrative Procedure Act (APA) and NEPA, from E.O.s (such as E.O. 12866 and 13563), and from other administrative guidance (*e.g.,* Office of Management and Budget (OMB) Circular A–4). For CAFE and HDPUV standards, the EPCA, as amended by the EISA, contains a variety of provisions that NHTSA seeks to account for analytically. Capturing all of these requirements analytically means that NHTSA presents an analysis that spans a meaningful range of regulatory alternatives, that quantifies a range of technological, economic, and environmental impacts, and that does so in a manner that accounts for EPCA/EISA's various express requirements for the CAFE and HDPUV programs (*e.g.,* passenger cars and light trucks must be regulated separately; the standard for each fleet must be set at the maximum feasible level in each MY; etc.).

NHTSA's proposed standards are thus supported by extensive analysis of potential impacts of the regulatory alternatives under consideration. Along with this preamble, a Draft TSD, a Preliminary Regulatory Impact Analysis (PRIA), and a Draft EIS, together provide a detailed enumeration of related methods, estimates, assumptions, and results. These additional analyses can be found in the rulemaking docket for this proposal [48] and on NHTSA's website.[49]

This section provides further detail on the key features and components of NHTSA's analysis. It also describes how NHTSA's analysis has been constructed specifically to reflect governing law applicable to CAFE and HDPUV standards (which may vary between programs). Finally, the discussion reviews how NHTSA's analysis has been expanded and improved in response to comments received on the 2021 proposal,[50] as well as additional work conducted over the last year. Further improvements may be made in the future based on comments received to this proposal, on the 2021 National Academies of Sciences (NAS) Report,[51] and on other work generally previewed in these rulemaking documents. The analysis for this proposal aided NHTSA in implementing its statutory obligations, including the weighing of various considerations, by reasonably informing decision-makers about the estimated effects of choosing different regulatory alternatives.

1. What are the key components of NHTSA's analysis?

NHTSA's analysis makes use of a range of data (*i.e.,* observations of things that have occurred), estimates (*i.e.,* things that may occur in the future), and models (*i.e.,* methods for making estimates). Two examples of *data* include (1) records of actual odometer readings used to estimate annual mileage accumulation at different vehicle ages and (2) CAFE compliance data used as the foundation for the ''analysis fleets'' containing, among other things, production volumes and fuel economy/fuel efficiency levels of specific configurations of specific vehicle models produced for sale in the U.S. Two examples of *estimates* include (1) forecasts of future Gross Domestic Product (GDP) growth used, with other estimates, to forecast future vehicle sales volumes and (2) technology cost estimates, which include estimates of the technologies' ''direct cost,'' marked up by a ''retail price equivalent'' (RPE) factor used to estimate the ultimate cost to consumers of a given fuel-saving technology, and an estimate of ''cost learning effects'' (*i.e.,* the tendency that it will cost a manufacturer less to apply a technology as the manufacturer gains more experience doing so).

NHTSA uses the CAFE Compliance and Effects Modeling System (usually shortened to the ''CAFE Model'') to estimate manufacturers' potential responses to new CAFE, HDPUV, and GHG standards and to estimate various impacts of those responses. DOT's Volpe National Transportation Systems Center (often simply referred to as the ''Volpe Center'') develops, maintains, and applies the model for NHTSA. NHTSA has used the CAFE Model to perform analyses supporting every CAFE rulemaking since 2001. The 2016 ''Phase 2'' rulemaking [52] establishing the most recent HDPUV standards also used the CAFE Model for analysis.

The basic design of the CAFE Model is as follows: The system first estimates how vehicle manufacturers might respond to a given regulatory scenario, and from that potential compliance solution, the system estimates what impact that response will have on fuel consumption, emissions, safety impacts, and economic externalities. In a highly summarized form, Figure II–1 shows the basic categories of CAFE Model procedures and the sequential flow between different stages of the modeling. The diagram does not present specific model inputs or outputs, as well as many specific procedures and model interactions. The model documentation accompanying this proposal presents these details, and Chapter 1 of the Draft TSD contains a more detailed version of this flow diagram for readers who are interested.

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[48] Docket No. NHTSA–2023–0022, which can be accessed at *https://www.regulations.gov.*

[49] See National Highway Traffic Safety Administration. 2023. Corporate Average Fuel Economy. Available at: *https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.* (Accessed: May 31, 2023).

[50] 86 FR 49602 (Sept. 3, 2021).

[51] National Academies of Sciences, Engineering, and Medicine. 2021. Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy—2025–2035. Washington, DC. The National Academies Press. Available at: *https://nap.nationalacademies.org/catalog/26092/assessment-of-technologies-for-improving-light-duty-vehicle-fuel-economy-2025-2035* (Accessed: May 31, 2023) and for hard-copy review at DOT headquarters.

[52] 81 FR 73478 (October 25, 2016).

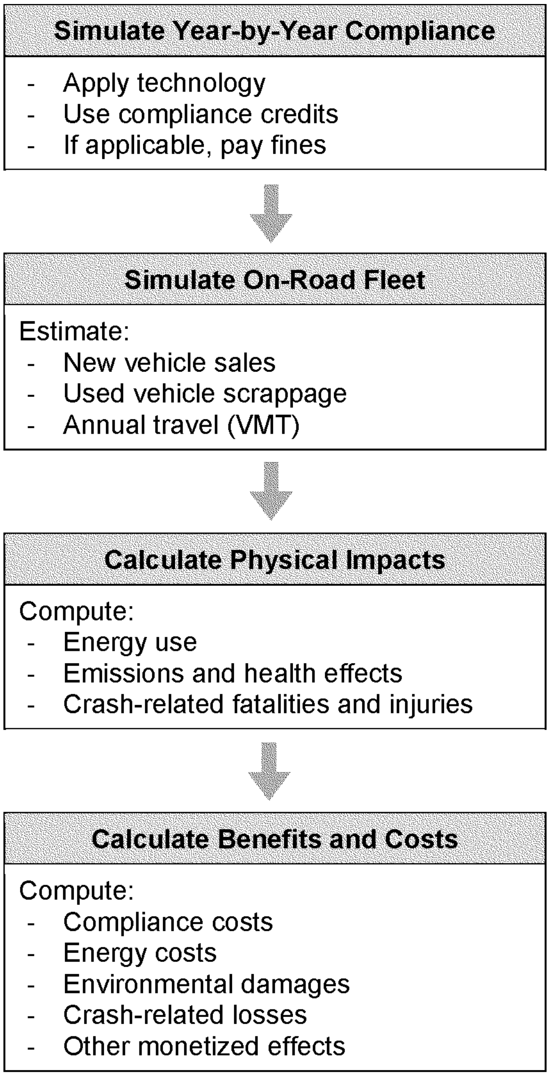

Figure II-1: CAFE Model Procedures and Logical Flow

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More specifically, the model may be characterized as an integrated system of models. For example, one model estimates manufacturers' responses, another estimates resultant changes in total vehicle sales, and still another estimates resultant changes in fleet turnover (*i.e.,* scrappage). Additionally, and importantly, the model does not determine the form or stringency of the standards. Instead, the model applies inputs specifying the form and stringency of standards to be analyzed and produces outputs showing the impacts of manufacturers working to meet those standards, which become part of the basis for comparing different potential stringencies. A regulatory scenario, meanwhile, involves specification of the form, or shape, of the standards (*e.g.,* flat standards, or linear or logistic attribute-based standards), scope of passenger car, light truck, and HDPUV regulatory classes, and stringency of the CAFE or HDPUV standards for each MY to be analyzed. For example, a regulatory scenario may define CAFE or HDPUV standards for a particular class of vehicles that increase in stringency by a given percent per year for a given number of consecutive years.

Manufacturer compliance simulation and the ensuing effects estimation, collectively referred to as compliance modeling, encompass numerous subsidiary elements. Compliance simulation begins with a detailed user-provided initial forecast of the vehicle models offered for sale during the simulation period.[53] The compliance simulation then attempts to bring each manufacturer into compliance with the standards defined by the regulatory scenario contained within an input file developed by the user.[54]

Estimating impacts involves calculating resultant changes in new vehicle costs, estimating a variety of costs (*e.g.,* for fuel) and effects (*e.g.,* CO_2 emissions from fuel combustion) occurring as vehicles are driven over their lifetimes before eventually being scrapped, and estimating the monetary value of these effects. Estimating impacts also involves consideration of consumer responses—*e.g.,* the impact of vehicle fuel economy/efficiency, operating costs, and vehicle price on consumer demand for passenger cars, light trucks, and HDPUVs. Both basic analytical elements involve the

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[53] Because the CAFE Model is publicly available, anyone can develop their own initial forecast (or other inputs) for the model to use. The DOT-developed Market Data Input file that contains the forecast for this proposal is available on NHTSA's website at *https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-compliance-and-effects-modeling-system.*

[54] With appropriate inputs, the model can also be used to estimate impacts of manufacturers' potential responses to new CO_2 standards and to California's ZEV program.

application of many analytical inputs. Many of these inputs are developed *outside* of the model and not *by* the model. For example, the model *applies* fuel prices; it does not *estimate* fuel prices.

NHTSA also uses EPA's Motor Vehicle Emission Simulator (MOVES) model to estimate ''vehicle'' or ''downstream'' emission factors (EF) for criteria pollutants,[55] and uses four Department of Energy (DOE) and DOE-sponsored models to develop inputs to the CAFE Model, including three developed and maintained by DOE's Argonne National Laboratory (ANL). The agency uses the DOE Energy Information Administration's (EIA's) National Energy Modeling System (NEMS) to estimate fuel prices,[56] and uses ANL's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) model to estimate emissions rates from fuel production and distribution processes.[57] DOT also sponsored DOE/ANL to use ANL's Autonomie full-vehicle modeling and simulation system to estimate the fuel economy/efficiency impacts for over a million combinations of technologies and vehicle types.[58] The Draft TSD and PRIA describe details of our use of these models. In addition, as discussed in the Draft EIS accompanying this proposal, DOT relied on a range of climate models to estimate impacts on climate, air quality, and public health. The Draft EIS discusses and describes the use of these models.

To prepare for analysis supporting this proposal, DOT has refined and expanded the CAFE Model through ongoing development. Examples of such changes, some informed by past external comment, made since 2022 include:[59]

- Addition of HDPUV, and associated required updates across entire model
- Updated technologies considered in the analysis
  - ○ Addition of HCRE, HCRD and updated diesel technology models[60]
  - ○ Removal of EFR, DSLIAD, manual transmissions, AT6L2, EPS, IACC, LDB, SAX, and some P2 combinations[61]
- User control of additional input parameters
- Updated modeling approach to manufacturers' expected compliance with states' ZEV programs
- Expanded accounting for Federal incentives, such as the IRA
- Expanded procedures for estimating new vehicle sales and fleet shares
- VMT coefficient updates

These changes reflect DOT's long-standing commitment to ongoing refinement of its approach to estimating the potential impacts of new CAFE and HDPUV standards. The Draft TSD elaborates on these changes to the CAFE Model, as well as changes to inputs to the model for this analysis.

NHTSA underscores that this analysis uses the CAFE Model in a manner that explicitly accounts for the fact that in producing a single fleet of vehicles for sale in the United States, manufacturers make decisions that consider the combination of CAFE/HDPUV standards, EPA GHG standards, and various policies set at sub-national levels (*e.g.,* ZEV sales mandates, set by California and adopted by many other states). These regulations have important structural and other differences that affect the strategy a manufacturer could pursue in designing a fleet that complies with each of the above. As explained, NHTSA's analysis reflects a number of statutory and regulatory requirements applicable to CAFE/HDPUV and EPA GHG standard-setting. As stated previously, NHTSA will coordinate with EPA to optimize the effectiveness of NHTSA's standards while minimizing compliance costs, informed by public comments from all stakeholders and consistent with the statutory factors. NHTSA seeks input to help inform these objectives.

2. How do requirements under EPCA/EISA shape NHTSA's analysis?

EPCA contains multiple requirements governing the scope and nature of CAFE standard setting. Some of these have been in place since EPCA was first signed into law in 1975, and some were added in 2007, when Congress passed EISA and amended EPCA. EISA also gave NHTSA authority to set standards for HDPUVs, and that authority was generally less constrained than for CAFE standards. NHTSA's modeling and analysis to inform standard setting is guided and shaped by these statutory requirements. EPCA/EISA requirements regarding the technical characteristics of CAFE and HDPUV standards and the analysis thereof include, but are not limited to, the following:

Corporate Average Standards: Section 32902 of 49 U.S.C. requires standards for passenger cars, light trucks, and HDPUVs to be corporate average standards, applying to the average fuel economy/efficiency levels achieved by each corporation's fleets of vehicles produced for sale in the U.S.[62] The CAFE Model calculates the CAFE and CO_2 levels of each manufacturer's fleets based on estimated production volumes and characteristics, including fuel economy/efficiency levels, of distinct vehicle models that could be produced for sale in the U.S.

Separate Standards for Passenger Cars, Light Trucks, and HDPUVs: Section 32902 of 49 U.S.C. requires the Secretary of Transportation to set CAFE standards separately for passenger cars and light trucks and allows the Secretary to prescribe separate standards for different classes of heavy-duty (HD) vehicles like HDPUVs. The CAFE Model accounts separately for differentiated standards and compliance pathways for passenger cars, light trucks, and HDPUVs when it analyzes CAFE/HDPUV or GHG standards.

Attribute-Based Standards: Section 32902 of 49 U.S.C. requires the Secretary of Transportation to define CAFE standards as mathematical functions expressed in terms of one or more vehicle attributes related to fuel economy, and NHTSA has extended this approach to HDPUV standards as well through regulation. This means that for

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[55] See *https://www.epa.gov/moves.* This proposal uses version MOVES3 (the latest version at the time of analysis), available at *https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves.*

[56] See *https://www.eia.gov/outlooks/aeo/.* This proposal uses fuel prices estimated using the Annual Energy Outlook (AEO) 2022 version of NEMS (see *https://www.eia.gov/outlooks/aeo/tables_ref.php.*).

[57] Information regarding GREET is available at *https://greet.es.anl.gov/.* This proposal uses the 2022 version of GREET.

[58] As part of the ANL simulation effort, individual technology combinations simulated in Autonomie were paired with ANL's BatPaC model to estimate the battery cost associated with each technology combination based on characteristics of the simulated vehicle and its level of electrification. Information regarding ANL's BatPaC model is available at *https://www.anl.gov/cse/batpac-model-software.* In addition, the impact of engine technologies on fuel consumption, torque, and other metrics was characterized using GT–POWER simulation modeling in combination with other engine modeling that was conducted by IAV Automotive Engineering, Inc. (IAV). The engine characterization ''maps'' resulting from this analysis were used as inputs for the Autonomie full-vehicle simulation modeling. Information regarding GT–POWER is available at *https://www.gtisoft.com/gt-power/.*

[59] A more detailed list can be found in Chapter 1.1 of the Draft TSD.

[60] See technologies descriptions in Draft TSD Chapter 3.

[61] See technologies description in 87 FR 25710 (May 2, 2022).

[62] This differs from certain other types of vehicle standards, such as safety standards. For example, every vehicle produced for sale in the U.S. must, on its own, meet all applicable Federal motor vehicle safety standards (FMVSS), but no vehicle produced for sale must, on its own, meet Federal fuel economy or efficiency standards. Rather, each manufacturer is required to produce a mix of vehicles that, taken together, achieve an average fuel economy/efficiency level no less than the applicable minimum level.

a given manufacturer's fleet of vehicles produced for sale in the U.S. in a given regulatory class and MY, the applicable minimum CAFE requirement (or maximum HDPUV fuel consumption requirement) is computed based on the applicable mathematical function, and the mix and attributes of vehicles in the manufacturer's fleet. The CAFE Model accounts for such functions and vehicle attributes explicitly.

Separately Defined Standards for Each Model Year: Section 32902 of 49 U.S.C. requires the Secretary of Transportation (by delegation, NHTSA) to set CAFE standards (separately for passenger cars and light trucks)[63] at the maximum feasible levels in each MY. Fuel efficiency levels for HDPUVs must also be set at the maximum feasible level, in tranches of (at least) 3 MYs at a time. The CAFE Model represents each MY explicitly, and accounts for the production relationships between MYs.[64]

Separate Compliance for Domestic and Imported Passenger Car Fleets: Section 32904 of 49 U.S.C. requires the EPA Administrator to determine CAFE compliance separately for each manufacturer's fleets of domestic passenger cars and imported passenger cars, which manufacturers must consider as they decide how to improve the fuel economy of their passenger car fleets.[65] The CAFE Model accounts explicitly for this requirement when simulating manufacturers' potential responses to CAFE standards, and combines any given manufacturer's domestic and imported cars into a single fleet when simulating that manufacturer's potential response to GHG standards (because EPA does not have separate standards for domestic and imported passenger cars).

Minimum CAFE Standards for Domestic Passenger Car Fleets: Section 32902 of 49 U.S.C. requires that domestic passenger car fleets meet a minimum standard, which is calculated as 92 percent of the industry-wide average level required under the applicable attribute-based CAFE standard, as projected by the Secretary at the time the standard is promulgated. The CAFE Model accounts explicitly for this requirement when simulating manufacturer compliance with CAFE standards and sets this requirement aside when simulating manufacturer compliance with GHG standards.

Civil Penalties for Noncompliance: Section 32912 of 49 U.S.C. (and implementing regulations) prescribes a rate (in dollars per tenth of a mpg) at which the Secretary is to levy civil penalties if a manufacturer fails to comply with a passenger car or light truck CAFE standard for a given fleet in a given MY, after considering available credits. Some manufacturers have historically demonstrated a willingness to pay civil penalties rather than achieving full numerical compliance across all fleets. The CAFE Model calculates civil penalties (adjusted for inflation) for CAFE shortfalls and provides means to estimate that a manufacturer might stop adding fuel-saving technologies once continuing to do so would effectively be more ''expensive'' (after accounting for fuel prices and buyers' willingness to pay for fuel economy) than paying civil penalties. The CAFE Model does not allow civil penalty payment as an option for EPA's GHG standards or NHTSA's HDPUV standards.[66]

Dual-Fueled and Dedicated Alternative Fuel Vehicles: For purposes of calculating passenger car and light truck CAFE levels used to determine compliance, 49 U.S.C. 32905 and 32906 specify methods for calculating the fuel economy levels of vehicles operating on alternative fuels to gasoline or diesel, such as electricity. In some cases, after MY 2020, methods for calculating AFV fuel economy are governed by regulation. The CAFE Model is able to account for these requirements explicitly for each vehicle model. However, 49 U.S.C. 32902 prohibits consideration of the fuel economy of dedicated AFVs, and requires that dual-fueled AFVs' fuel economy, such as plug-in electric vehicle (EVs), be calculated as though they ran only on gasoline or diesel, when NHTSA determines the maximum feasible fuel economy level that manufacturers can achieve in a given year for which NHTSA is establishing CAFE standards. The CAFE Model therefore has an option to be run in a manner that excludes the additional application of dedicated AFVs and counts only the gasoline fuel economy of dual-fueled AFVs, in MYs for which maximum feasible standards are under consideration. As allowed under NEPA for analysis appearing in Environmental Impact Statements (EIS) that help inform decision makers about the environmental impacts of CAFE standards, the CAFE Model can also be run without this analytical constraint. The CAFE Model does account for dedicated and dual-fueled AFVs when simulating manufacturers' potential responses to EPA's GHG standards because the Clean Air Act (CAA), under which the EPA derives its authority to set GHG standards for motor vehicles, contains no restrictions in using AFVs for compliance. There are no specific statutory directions in EISA with regard to dedicated and dual-fueled AFV fuel efficiency for HDPUVs, so the CAFE Model reflects relevant regulatory provisions by calculating fuel consumption directly per 49 U.S.C. 32905 and 32906 specified methods.

ZEV Mandates: The CAFE Model can simulate manufacturers' compliance with state-level ZEV mandates applicable in California and ''Section 177''[67] states. This approach involves identifying specific vehicle model/configurations that could be replaced with BEVs and converting to BEVs only enough vehicle models to meet the manufacturer's compliance obligations under state-level ZEV mandates, before beginning to consider the potential that other technologies could be applied toward compliance with CAFE, HDPUV, or GHG standards.

Creation and Use of Compliance Credits: Section 32903 of 49 U.S.C. provides that manufacturers may earn CAFE ''credits'' by achieving a CAFE level beyond that required of a given passenger car or light truck fleet in a given MY and specifies how these credits may be used to offset the amount by which a different fleet falls short of its corresponding requirement. These provisions allow credits to be ''carried forward'' and ''carried back'' between MYs, transferred between regulated classes (domestic passenger cars, imported passenger cars, and light trucks), and traded between manufacturers. However, credit use for passenger car and light truck compliance is also subject to specific statutory limits. For example, CAFE compliance credits can be carried

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[63] Chaper 329 of title 49 of the U.S. Code uses the term ''non-passenger automobiles,'' while NHTSA uses the term ''light trucks'' in its CAFE regulations. The terms' meanings are identical.

[64] For example, a new engine first applied to a given mode/configuration in MY 2027 will most likely persist in MY 2028 of that same vehicle model/configuration, in order to reflect the fact that manufacturers do not apply brand-new engines to a given vehicle model every single year. The CAFE Model is designed to account for these real-world factors.

[65] There is no such requirement for light trucks or HDPUVs.

[66] While civil penalties are an option in the HDPUV fleet, the penalties for noncompliance are significantly higher, and thus manufactures will try to avoid paying them. Setting the model to disallow civil penalties acts to best simulate this behavior. If the model does find no option other than ''paying a civil penalty'' in the HDPUV fleet, this cost should be considered a proxy for credit purchase. NHTSA seeks comment on whether and how to model civil penalties for HDPUVs for the final rule.

[67] The term ''Section 177'' states refers to states which have elected to adopt California's standards in lieu of Federal requirements, as allowed under section 177 of the CAA.

forward a maximum of five MYs and carried back a maximum of three MYs. Also, EPCA/EISA caps the amount of credits that can be transferred between passenger car and light truck fleets and prohibits manufacturers from applying traded or transferred credits to offset a failure to achieve the applicable minimum standard for domestic passenger cars. The CAFE Model can simulate manufacturers' potential use of CAFE credits carried forward from prior MYs or transferred from other fleets.[68] Section 32902 of 49 U.S.C. prohibits consideration of manufacturers' potential application of CAFE compliance credits when determining the maximum feasible fuel economy level that manufacturers can achieve for their fleets of passenger cars and light trucks. The CAFE Model can be operated in a manner that excludes the application of CAFE credits for a given MY under consideration for standard setting, and NHTSA operated the model with that constraint for the purpose of determining the appropriate CAFE standard for passenger cars and light trucks. No such statutory restrictions exist for setting HDPUV standards. For modeling EPA's GHG standards, the CAFE Model does not limit transfers because the CAA does not limit them. Insofar as the CAFE Model can be exercised in a manner that simulates trading of GHG compliance credits, such simulations treat trading as unlimited.[69]

Statutory Basis for Stringency: Section 32902 of 49 U.S.C. requires the Secretary of Transportation (by delegation, NHTSA) to set CAFE standards for passenger cars and light trucks at the maximum feasible levels that manufacturers can achieve in a given MY, considering technological feasibility, economic practicability, the need of the United States to conserve energy, and the impact of other motor vehicle standards of the Government on fuel economy. For HDPUV standards, which must also achieve the maximum feasible improvement, the similar yet distinct factors of appropriateness, cost-effectiveness, and technological feasibility must be considered. EPCA/EISA authorizes the Secretary of Transportation (by delegation, NHTSA) to interpret these factors, and as the Department's interpretation has evolved, NHTSA has continued to expand and refine its qualitative and quantitative analysis to account for these statutory factors. For example, one of the ways that economic practicability considerations are incorporated into the analysis is through the technology effectiveness determinations: the Autonomie simulations reflect the agency's judgment that it would not be economically practicable (nor, for HDPUVs, appropriate) for a manufacturer to ''split'' an engine shared among many vehicle model/configurations into myriad versions each optimized to a single vehicle model/configuration.

National Environmental Policy Act: NEPA requires NHTSA to consider the environmental impacts of its actions in its decision-making processes, including for CAFE standards. The Draft EIS accompanying this proposal documents changes in emission inventories as estimated using the CAFE Model, but also documents corresponding estimates—based on the application of other models documented in the Draft EIS—of impacts on the global climate, on air quality, and on human health.

Other Aspects of Compliance: Beyond these statutory requirements applicable to DOT, EPA, or both are a number of specific technical characteristics of CAFE, HDPUV, and/or GHG regulations that are also relevant to the construction of this analysis, like the ''off-cycle'' technologies fuel economy/emissions improvements that apply for both CAFE and GHG compliance. Although too little information is available to account for these provisions explicitly in the same way that NHTSA has accounted for other technologies, the CAFE Model includes and makes use of inputs reflecting NHTSA's expectations regarding the extent to which manufacturers may earn such credits, along with estimates of corresponding costs. Similarly, the CAFE Model includes and makes use of inputs regarding credits EPA has elected to allow manufacturers to earn toward GHG levels (not CAFE or HDPUV) based on the use of air conditioner refrigerants with lower global warming potential, or on the application of technologies to reduce refrigerant leakage. In addition, the CAFE Model accounts for EPA ''multipliers'' for certain AFVs, based on current regulatory provisions or on alternative approaches. Although these are examples of regulatory provisions that arise from the exercise of discretion rather than specific statutory mandate, they can materially impact outcomes.

3. What updated assumptions does the current model reflect as compared to the 2022 final rule?

Besides the updates to the CAFE Model described above, any analysis of regulatory actions that will be implemented several years in the future, and whose benefits and costs accrue over decades, requires a large number of assumptions. Over such time horizons, many, if not most, of the relevant assumptions in such an analysis are inevitably uncertain. Each successive CAFE analysis seeks to update assumptions to better reflect the current state of the world and the best current estimates of future conditions.

A number of assumptions have been updated since the 2022 final rule. As discussed below, NHTSA has updated its ''analysis fleet'' from a MY 2020 reference to a MY 2022 reference for passenger cars and light trucks and has built an updated HDPUV analysis fleet (the last HDPUV analysis fleet was built in 2016). NHTSA has also updated estimates of manufacturers' compliance credit ''holdings,'' updated fuel price projections to reflect the U.S. EIA's 2022 Annual Energy Outlook (AEO), updated

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[68] The CAFE Model does not explicitly simulate the potential that manufacturers would carry CAFE or GHG credits back (*i.e.,* borrow) from future model years, or acquire and use CAFE compliance credits from other manufacturers. At the same time, because EPA has elected not to limit credit trading, the CAFE Model can be exercised (for purposes of evaluating GHG standards) in a manner that simulates unlimited (a.k.a. ''perfect'') GHG compliance credit trading throughout the industry (or, potentially, within discrete trading ''blocs''). For purposes of analyzing CAFE standards, NHTSA believes it is challenging to predict precisely how manufacturers may choose to use these particular flexibilities in the future: for example, while it is reasonably foreseeable that a manufacturer who over-complies in one year may ''coast'' through several subsequent years relying on that over-compliance rather than making further technology improvements, it is harder to know whether manufacturers will rely on future technology investments to offset prior-year shortfalls, or whether/how manufacturers will trade credits with market competitors rather than making their own technology investments. Historically, carry-back and trading have been much less utilized than carry-forward, for a variety of reasons including higher risk and preference not to 'pay competitors to make fuel economy improvements we should be making' (to paraphrase one manufacturer), although NHTSA recognizes that carry-back and trading are used more frequently when standards increase in stringency more rapidly. Given these dynamics, and given also the fact that the agency has yet to resolve some of the analytical challenges associated with simulating use of these flexibilities, the agency has decided to support this proposal with a conservative analysis that sets aside the potential that manufactures would depend widely on borrowing and trading—not to mention that, for purposes of determining maximum feasible CAFE standards, statute prohibits NHTSA from considering the trading, transferring, or availability of credits (*see* 49 U.S.C. 32902(h)). While compliance costs in real life may be somewhat different from what is modeled in the rulemaking record as a result of this decision, that is broadly true no matter what, and the agency does not believe that the difference would be so great that it would change the policy outcome. Furthermore, a manufacturer employing a trading strategy would presumably do so because it represents a lower-cost compliance option. Thus, the estimates derived from this modeling approach are likely to be conservative in this respect, with real-world compliance costs likely being lower.

[69] To avoid making judgments about possible future trading activity, the model simulates trading by combining all manufacturers into a single entity, so that the most cost-effective choices are made for the fleet as a whole.

projections of GDP and related macroeconomic measures, and updated projections of future highway travel. While NHTSA would have made these updates as a matter of course, we note that the ongoing global economic recovery and the ongoing war in Ukraine have impacted major analytical inputs such as fuel prices, GDP, vehicle production and sales, and highway travel. Many inputs remain uncertain, and NHTSA has conducted sensitivity analyses around many inputs to attempt to capture some of that uncertainty. These and other updated analytical inputs are discussed in detail in the Draft TSD and PRIA.

Additionally, E.O. 13990 required the formation of an Interagency Working Group (IWG) on the Social Cost (SC) of GHGs and charged this body with updating estimates of the SCs of carbon, nitrous oxide, and methane (CH_4). As discussed in the TSD, NHTSA has followed DOT's determination that the values developed in the IWG's interim guidance are the most consistent with the best available science and economics and are the most appropriate estimates to use in the analysis of this proposal. Those estimates of costs per ton of emissions (or benefits per ton of emissions reductions) are considerably greater than those applied in the analysis supporting the 2020 final rule. Even still, the estimates NHTSA is now using are not able to fully quantify and monetize a number of important categories of climate damages; because of those omitted damages and other methodological limits, DOT believes its values for SC–GHG are conservative underestimates.

B. What is NHTSA analyzing?

NHTSA is analyzing the effects of different potential CAFE and HDPUV standards on industry, consumers, society, and the world at large. These different potential standards are identified as regulatory alternatives, and amongst the regulatory alternatives, NHTSA identifies which ones the agency is proposing. As in the past several CAFE rulemakings and in the Phase 2 HDPUV rulemaking, NHTSA is proposing to establish attribute-based CAFE and HDPUV standards defined by a mathematical function of vehicle footprint (which has an observable correlation with fuel economy) and a towing-and-hauling-based WF respectively.[70] EPCA, as amended by EISA, expressly requires that CAFE standards for passenger cars and light trucks be based on one or more vehicle attributes related to fuel economy, and be expressed in the form of a mathematical function.[71] The statute gives NHTSA discretion as to how to structure standards for HDPUVs, and NHTSA continues to believe that attribute-based standards expressed as a mathematical function remain appropriate for those vehicles as well, given their similarity in many ways to light trucks. Thus, the proposed standards (and the regulatory alternatives) for passenger cars and light trucks take the form of fuel economy targets expressed as functions of vehicle footprint (the product of vehicle wheelbase and average track width) that are separate for passenger cars and light trucks, and the proposed standards and alternatives for HDPUVs take the form of fuel consumption targets expressed as functions of vehicle WF (which is in turn a function of towing and hauling capabilities).

For passenger cars and light trucks, under the footprint-based standards, the function defines a fuel economy performance target for each unique footprint combination within a car or truck model type. Using the functions, each manufacturer thus will have a CAFE average standard for each year that is almost certainly unique to each of its fleets,[72] based upon the footprint and production volumes of the vehicle models produced by that manufacturer. A manufacturer will have separate footprint-based standards for cars and for trucks, consistent with 49 U.S.C. 32902(b)'s direction that NHTSA must set separate standards for cars and for trucks. The functions are mostly sloped, so that generally, larger vehicles (*i.e.,* vehicles with larger footprints) will be subject to lower mpg targets than smaller vehicles. This is because smaller vehicles are generally more capable of achieving higher levels of fuel economy, mostly because they tend not to have to work as hard (and therefore to require as much energy) to perform their driving task. Although a manufacturer's fleet average standard could be estimated throughout the MY based on the projected production volume of its vehicle fleet (and are estimated as part of EPA's certification process), the standards with which the manufacturer must comply are determined by its final model year (FMY) production figures. A manufacturer's calculation of its fleet average standards, as well as its fleets' average performance at the end of the MY, will thus be based on the production-weighted average target and performance of each model in its fleet.[73]

For passenger cars, consistent with prior rulemakings, NHTSA is proposing to define fuel economy targets as shown in Equation II–1.

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

Equation II-1: Passenger Car Fuel Economy Footprint Target Curve

Where:

TARGET$_{FE}$ is the fuel economy target (in mpg) applicable to a specific vehicle model type with a unique footprint combination,

a is a minimum fuel economy target (in mpg),

b is a maximum fuel economy target (in mpg),

c is the slope (in gallons per mile (or gpm) per square foot) of a line relating fuel

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[70] Vehicle footprint is the vehicle's wheelbase times average track width (or more simply, the length and width beween the vehicle's four wheels). The HDPUV FE towing-and-hauling-based ''WF'' metric is based on a vehicle's payload and towing capabilities, with an added adjustment for 4-wheel drive vehicles.

[71] 49 U.S.C. 32902(a)(3)(A).

[72] EPCA/EISA requires NHTSA and EPA to separate passenger cars into domestic and import passenger car fleets for CAFE compliance purposes (49 U.S.C. 32904(b)), whereas EPA combines all passenger cars into one fleet for GHG compliance purposes.

[73] As discussed in prior rulemakings, a manufacturer may have some vehicle models that exceed their target and some that are below their target. Compliance with a fleet average standard is determined by comparing the fleet average standard (based on the production-weighted average of the target levels for each model) with fleet average performance (based on the production-weighted average of the performance of each model). This is inherent in the statutory structure of CAFE, which requires NHTSA to set *corporate average* standards.

consumption (the inverse of fuel economy) to footprint, and

d is an intercept (in gpm) of the same line.

Here, *MIN* and *MAX* are functions that take the minimum and maximum values, respectively, of the set of included values. For example, *MIN*[40, 35] = 35 and *MAX*(40, 25) = 40, such that *MIN*[*MAX*(40, 25), 35] = 35.

For the Preferred Alternative, this equation is represented graphically as the curves in Figure II–2.

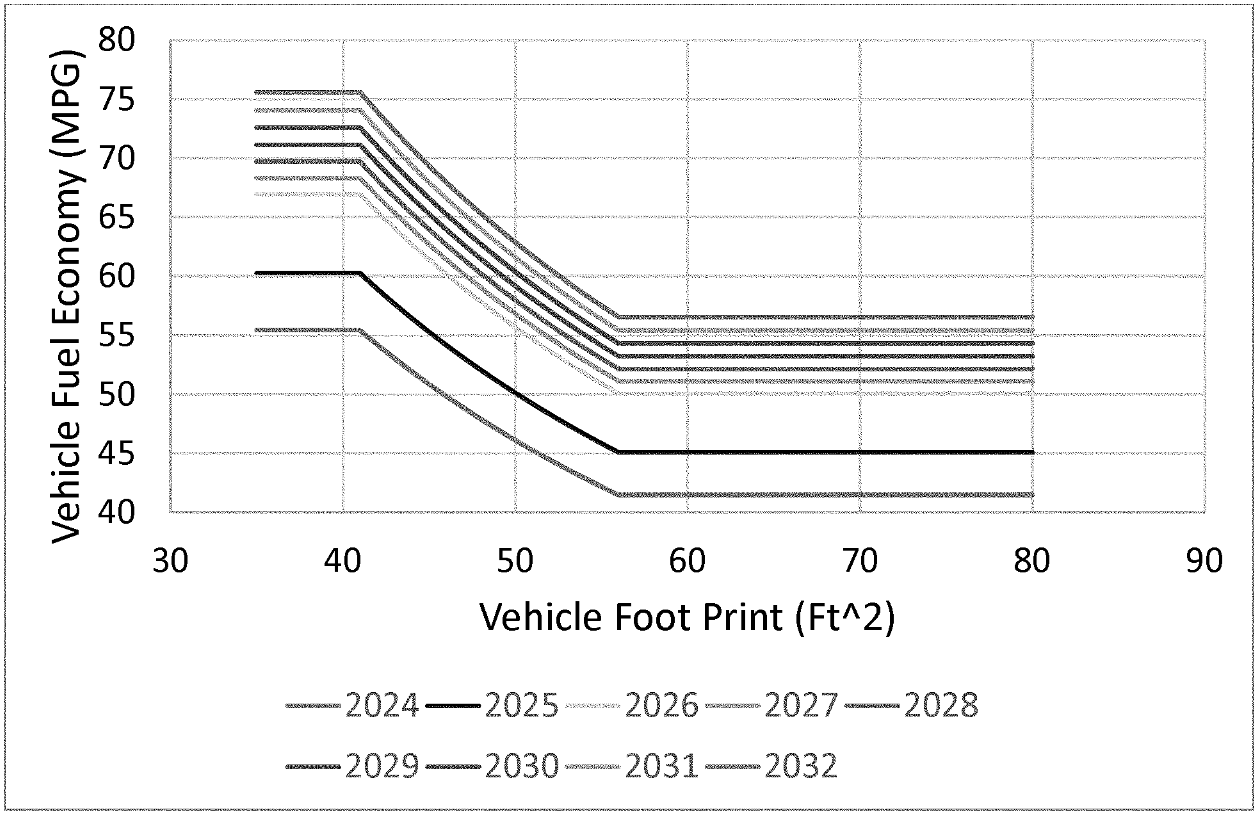

Figure II-2: Preferred Alternative, Fuel Economy Target Curves, Passenger Cars

For light trucks, also consistent with prior rulemakings, NHTSA is proposing to define fuel economy targets as shown in Equation II–2.

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

Equation II-2: Light Truck Fuel Economy Footprint Target Curve

Where:

TARGET$_{FE}$ is the fuel economy target (in mpg) applicable to a specific vehicle model type with a unique footprint combination,

a, b, c, and *d* are as for passenger cars, but taking values specific to light trucks,

e is a second minimum fuel economy target (in mpg),

f is a second maximum fuel economy target (in mpg),

g is the slope (in gpm per square foot) of a second line relating fuel consumption (the inverse of fuel economy) to footprint, and

h is an intercept (in gpm) of the same second line.

For the Preferred Alternative, this equation is represented graphically as the curves in Figure II–3.

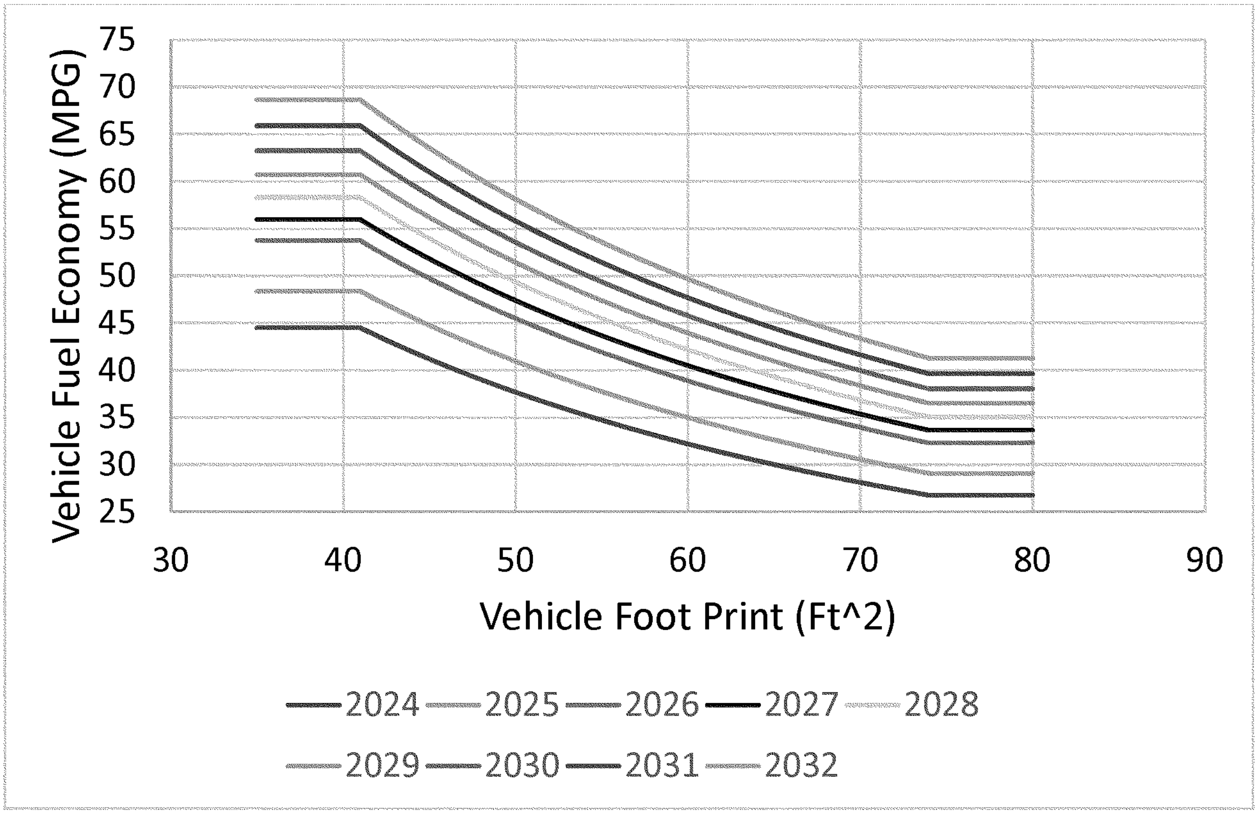

Figure II-3: Preferred Alternative, Fuel Economy Target Curves, Light Trucks

Although the general model of the target function equation is the same for passenger cars and light trucks, and the same for each MY, the parameters of the function equation differ for cars and trucks. The actual parameters for both the Preferred Alternative and the other regulatory alternatives are presented in Section III.

The required CAFE level applicable to a passenger car (either domestic or import) or light truck fleet in a given MY is determined by calculating the production-weighted harmonic average of fuel economy targets applicable to specific vehicle model configurations in the fleet, as shown in Equation II–3.

$$\boldsymbol{CAFE_{required}} = \frac{\sum_i \boldsymbol{PRODUCTION_i}}{\sum_i \frac{\boldsymbol{PRODUCTION_i}}{\boldsymbol{TARGET_{FE,i}}}}$$

Equation II-3: Calculation for Required CAFE Level

Where:

$CAFE_{required}$ is the CAFE level the fleet is required to achieve,

i refers to specific vehicle model/configurations in the fleet,

$PRODUCTION_i$ is the number of model configuration i produced for sale in the U.S., and

$TARGET_{FE,\,i}$ is the fuel economy target (as defined above) for model configuration i.

For HDPUVs, NHTSA has previously set attribute-based standards, but used a work-based metric as the attribute rather than footprint. Work-based measurements such as payload and towing capability are key among the parameters that characterize differences in the design of these vehicles, as well as differences in how the vehicles will be used. Since NHTSA has been regulating HDPUVs, these standards have been based on a WF attribute that combines the vehicle's payload and towing capabilities, with an added adjustment for 4-wheel drive vehicles. Again, while NHTSA is not required by statute to set HDPUV standards that are attribute-based and that are described by a mathematical function, NHTSA continues to believe that doing so is reasonable and appropriate for this segment of vehicles, consistent with prior HDPUV standard-setting rulemakings. NHTSA proposes to continue using the work-based attribute and gradually increasing stringency (which for HDPUVs means that standards appear to *decline,* as compared to passenger car and light truck standards where increasing stringency means that standards appear to *increase.* This is because HDPUV standards are based on fuel *consumption,* which is the inverse of fuel *economy,*[74] the metric that NHTSA

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[74] For additional information, see the National Academies of Sciences, Engineering, and Medicine. 2011. Assessment of Fuel Economy Technologies for Light-Duty Vehicles. Washington, DC. The National Academies Press. Available at: *https://nap.nationalacademies.org/catalog/12924/assessment-of-fuel-economy-technologies-for-light-duty-vehicles.* (Accessed: May 31, 2023). Fuel economy is a measure of how far a vehicle will travel with a gallon (or unit) of fuel and is expressed

is statutorily required to use when setting standards for light-duty vehicle (LDV) fuel use). NHTSA proposes to define HDPUV fuel efficiency targets as shown in Equation II–4.

$$\boldsymbol{Subconfiguration\ Target\ Standard\ (gallons\ per\ 100\ miles) = [c \times (WF)] + d}$$

Equation II-4: HDPUV Fuel Efficiency Work Factor Target Curve

Where:

WF = Work Factor = [0.75 × (*Payload Capacity* + *Xwd*)] + [0.25 × *Towing Capacity*]

Where:

Xwd = 4wd adjustment = 500 lbs. if the vehicle group is equipped with 4WD and all-wheel drive, otherwise equals 0 lbs. for 2wd

Payload Capacity = GVWR (lbs.) − Curb Weight (lbs.) (for each vehicle group)

Towing Capacity = GCWR[75] (lbs.) − GVWR (lbs.) (for each vehicle group)

For the Preferred Alternative, this equation is represented graphically as the curves in Figure II–4 and Figure II–5.

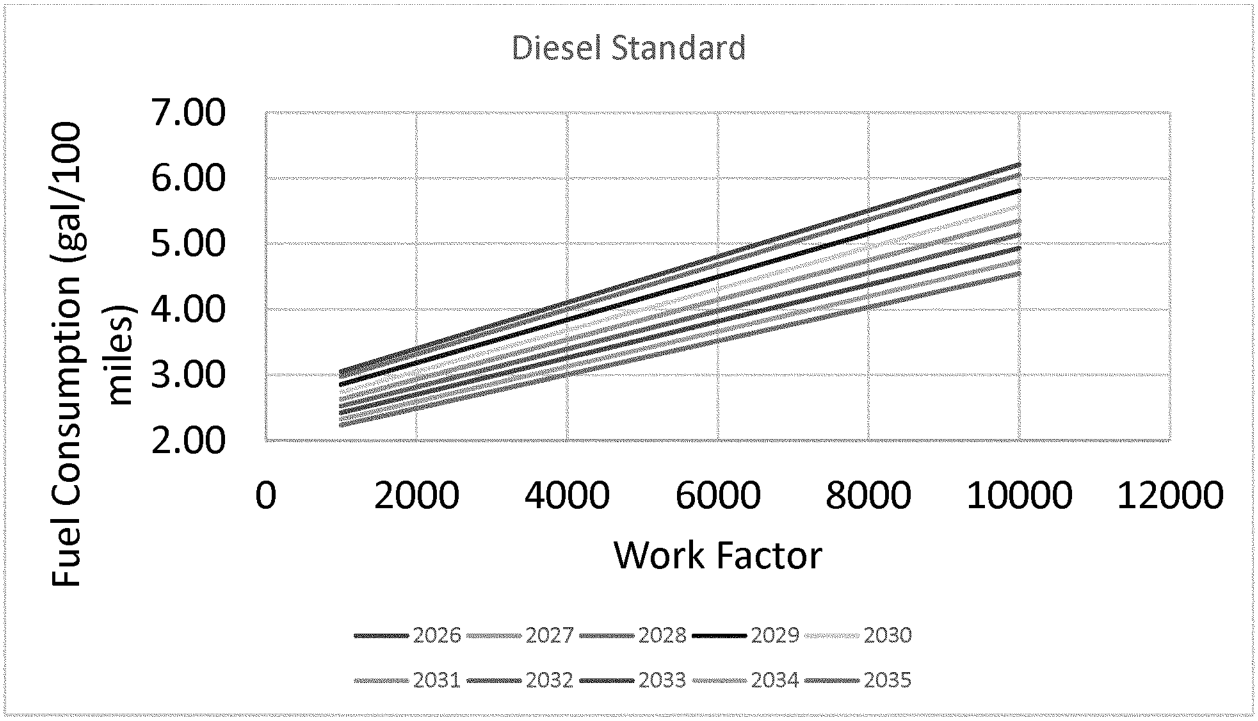

Figure II-4: Preferred Alternative, Fuel Efficiency Target Curves, HDPUVs – CI (Diesel)

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in mpg. Fuel consumption is the inverse of fuel economy. It is the amount of fuel consumed in driving a given distance. Fuel consumption is a fundamental engineering measure that is directly related to fuel consumed per 100 miles and is useful because it can be employed as a direct measure of volumetric fuel savings.

[75] Gross Combined Weight Rating.

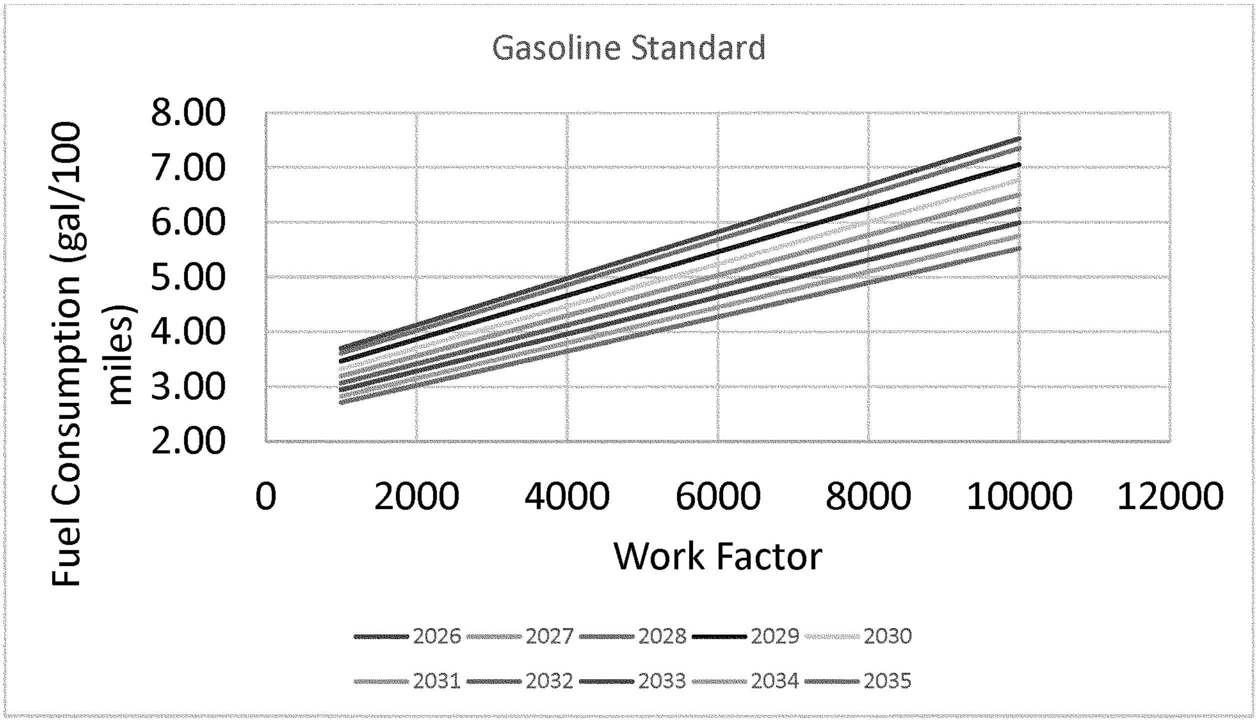

Figure II-5: Preferred Alternative, Fuel Efficiency Target Curves, HDPUVs – Spark Ignition (Gasoline)

Similar to the standards for passenger cars and light trucks, NHTSA (and EPA) have historically set HDPUV standards such that each manufacturer's fleet average standard is based on production volume-weighting of target standards for all vehicles, which are based on each vehicle's WF as explained above. Thus, for HDPUVs, the required fuel efficiency level applicable in a given MY is determined by calculating the production-weighted harmonic average of subconfiguration targets applicable to specific vehicle model configurations in the fleet, as shown in Equation II–5.

$$Fleet\ Average\ Standard = \frac{\sum[Subconfiguration\ Target\ Standard_i\ \times\ Volume_i]}{\sum[Volume_i]}$$

Equation II-5: HDPUV Fuel Efficiency Work Factor Target Curve

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Where:

Subconfiguration Target Standard$_i$ = fuel consumption standard for each group of vehicles with the same payload, towing capacity, and drive configuration (gallons per 100 miles), and

Volume$_i$ = production volume of each unique subconfiguration of a model type based upon payload, towing capacity, and drive configuration.

Chapter 1 of the Draft TSD contains a detailed description of the use of attribute-based standards, generally, for passenger cars, light trucks, and HDPUVs, and explains the specific decision, in past rules and for the current proposal, to continue to use vehicle footprint as the attribute over which to vary passenger car and light truck stringency, and WF as the attribute over which to vary HDPUV stringency. That chapter also discusses the policy and approach in selecting the specific mathematical functions. NHTSA refers readers to the Draft TSD for a full discussion of these topics and seeks comment on that discussion.

C. What inputs does the compliance analysis require?

The first step in our analysis of the effects of different levels of fuel economy standards is the compliance simulation. When we say, ''compliance simulation'' throughout this rulemaking, we mean the CAFE Model's simulation of how vehicle manufacturers could comply with different levels of CAFE standards by adding fuel-economy-improving technology to an existing fleet of vehicles.[76] At the most basic level, a model is a set of equations, algorithms,[77] or other calculations that are used to make predictions about a

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[76] When we use the phase ''the model'' throughout this section, we are referring to the CAFE Model. Any other model will be specifically named.

[77] See Merriam-websiter, ''algorithm.'' Broadly, an algorithm is a step-by-step procedure for solving a problem or accomplishing some end. More specifically, an algorithm is a procedure for solving a mathematical problem (as of finding the greatest common divisor) in a finite number of steps that frequently involves repetition of an operation.

complex system, such as the environmental impact of a particular industry or activity. A model may consider various inputs, such as emissions data, technology costs, or other relevant factors, and use those inputs to generate output predictions.

One important note about models is that a model is only as good as the data and assumptions that go into it. We attempt to ensure that the technology inputs and assumptions that go into the CAFE Model to project the effects of different levels of CAFE standards are based on sound science and reliable data, and that our reasons for using those inputs and assumptions are transparent and understandable to stakeholders. This section and the following section discuss at a high level how we generate the technology inputs and assumptions that the CAFE Model uses for the compliance simulation.[78] The Draft Technical Support Document, CAFE Model Documentation, CAFE Analysis Autonomie Model Documentation,[79] and other technical reports supporting this proposal discuss our technology inputs and assumptions in more detail.

We incorporate technology inputs and assumptions either directly in the CAFE Model or in the CAFE Model's various input files. The heart of the CAFE Model's decisions about how to apply technologies to manufacturer's vehicles to project how the manufacturer could meet CAFE standards is the compliance simulation algorithm. The compliance simulation algorithm is several equations that direct the model to apply fuel economy improving technologies to vehicles in a way that estimates how manufacturers might apply those technologies to their vehicles in the real world. The compliance simulation algorithm projects a cost-effective pathway for manufacturers to comply with different levels of CAFE standards, considering the technology present on manufacturer's vehicles now, and what technology could be applied to their vehicles in the future. Embedded directly in the CAFE Model is the universe of technology options that the model can consider and some rules about the order in which it can consider those options and estimates of how effective fuel economy improving technology is on different types of vehicles, like on a sedan or a pickup truck.

Technology inputs and assumptions are also located in all four of the CAFE Model's input files. The Market Data Input file is a Microsoft Excel file that characterizes the baseline automotive fleet used as the starting point for the analysis. There is one Excel row describing each vehicle model and model configuration manufactured in the United States in a MY (or years), and input and assumption data that links that vehicle to technology, economic, environmental, and safety effects. Next, the Technologies Input File identifies approximately six dozen technologies we use in the analysis, uses phase-in caps to identify when and how widely each technology can be applied to specific types of vehicles, provides most of the technology costs (only battery costs for electrified vehicles are provided in a separate file), and provides some of the inputs involved in estimating impacts on vehicle fuel consumption and weight. The Scenarios Input File provides the coefficient values defining the standards for each regulatory alternative,[80] and other relevant information applicable to modeling each regulatory scenario. This information includes, for example, the estimated value of select tax credits from the IRA, which provide Federal technology incentives for electrified vehicles, and the PEF, which is a value that the Secretary of Energy determines under EPCA that applies to EV fuel economy values.[81] Finally, the Parameters Input File contains mainly economic and environmental data, as well as data about how fuel economy credits and California's Zero Emissions Vehicle program credits are simulated in the model.

We generate these technology inputs and assumptions in several ways, including by and through evaluating data submitted by vehicle manufacturers pursuant to their CAFE reporting obligations; consolidating public data on vehicle models from manufacturer websites, press materials, marketing brochures, and other publicly available information; collaborative research, testing, and modeling with other Federal agencies, like the DOE's ANL; research, testing, and modeling with independent organizations, like IAV GmbH Ingenieurgesellschaft Auto und Verkehr (IAV), Southwest Research Institute (SwRI), NAS and FEV North America; determining that work done for prior rules is still relevant and applicable; considering feedback from stakeholders on prior rules and in meetings conducted before the commencement of this rule; and using our own engineering judgment. When we say, ''engineering judgment'' throughout this rulemaking, we are referring to decisions made by a team of engineers and analysts. This judgment is based on their experience working in the automotive industry and other relevant fields, and assessment of all the data sources described above. Most importantly, we use engineering judgment to assess how best to represent vehicle manufacturer's potential responses to different levels of CAFE standards within the boundaries of our modeling tools, as ''a model is meant to simplify reality in order to make it tractable.'' [82] In other words, we use engineering judgment to concentrate potential technology inputs and assumptions from millions of discrete data points from hundreds of sources to three datasets integrated in the CAFE Model and four input files. How the CAFE Model decides to apply technology, *i.e.,* the compliance simulation algorithm, has also been developed using engineering judgment, considering some of the same factors that manufacturers consider when they add technology to vehicles in the real world.

While upon first read this discussion may seem oversimplified, we believe that there is value in all stakeholders being able to understand how the analysis uses different sets of technology inputs and assumptions and how those inputs and assumptions are based on real-world factors. This is so that all stakeholders have the appropriate context to better comment on the specific technology inputs and assumptions discussed later and in detail in all of the associated technical documentation.

1. Technology Options and Pathways

We begin the compliance analysis by defining the range of fuel economy improving technologies that the CAFE Model could add to a manufacturer's vehicles in the United States

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[78] As explained throughout this section, our inputs are a specific number or datapoint used by the model, and our assumptions are based on judgment after careful consideration of available evidence. An assumption can be an underlying reason for the *use* of a specific datapoint, function, or modeling process. For example, an input might be the fuel economy value of the Ford Mustang, whereas the assumption is that the Ford Mustang's fuel economy value reported in Ford's CAFE compliance data should be used in our modeling.

[79] The ANL report is titled ''Vehicle Simulation Process to Support the Analysis for MY 2027 and Beyond CAFE and MY 2030 and Beyond HDPUV FE Standards;'' however, for ease of use and consistency with the Draft TSD, it is referred to as ''CAFE Analysis Autonomie Documentation.''

[80] The coefficient values are defined in Draft TSD Chapter 1.2.1 for both the CAFE and HDPUV FE standards.

[81] *See* 49 U.S.C. 32904(a)(2), 88 FR 21525 (April 11, 2023).

[82] *Chem. Mfrs. Ass'n* v. *E.P.A.,* 28 F.3d 1259, 1264–65 (D.C. Cir. 1994) (citing Milton Friedman, The Methodology of Positive Economics, in Essays in Positive Economics 3, 14–15 (1953)).

market.[83] [84] [85] These are technologies that we believe are representative of what vehicle manufacturers currently use on their vehicles, and that vehicle manufacturers could use on their vehicles in the timeframe of the standards (MYs 2027 and beyond for the LD analysis and MYs 2030 and beyond for the HDPUV analysis). The technology options include basic and advanced engines, transmissions, electrification, and road load technologies, which include mass reduction (MR), aerodynamic improvement (AERO), and tire rolling resistance (ROLL) reduction technologies. Note that while EPCA/EISA constrains our ability to consider the possibility that manufacturers would comply with CAFE standards by implementing some electrification technologies when making decisions about the level of CAFE standards that is maximum feasible, there are several reasons why we must accurately model the range of available electrification technologies. These are discussed in more detail in Section II.D and in Section V.

We require several data elements to add a technology to the range of options that the CAFE Model can consider; those elements include a broadly applicable technology definition, estimates of how effective that technology is at improving a vehicle's fuel economy value on a range of vehicles (*e.g.,* sedan through pickup truck, or HD pickup truck and HD van), and the cost to apply that technology on a range of vehicles. Each technology we select is designed to be representative of a wide range of specific technology applications used in the automotive industry. For example, in MY 2022, eleven vehicle brands under five vehicle manufacturers [86] used what we call a ''downsized turbocharged engine with cylinder deactivation.'' While we might expect brands owned by the same manufacturer to use similar technology on their engines, among those five manufacturers, the engine systems will be very different. Some manufacturers may also have been making those engines longer than others, meaning that they have had more time to make the system more efficient while also making it cheaper, as they make gains learning the development improvement and production process. If we chose to model the best performing, cheapest engine and applied that technology across vehicles made by all automotive manufacturers, we would likely be underestimating the cost and underestimating the technology required for the entire automotive industry to achieve higher levels of CAFE standards. The reverse would be true if we selected a system that was less efficient and more expensive. So, in reality, some vehicle manufacturers' systems will perform better and cost less than our modeled systems and some will perform worse and cost more. However, selecting representative technology definitions for our analysis will ensure that, on balance, we capture a reasonable level of costs and benefits that would result from any manufacturer applying the technology.

We have been refining the LD technology options since first developing the CAFE Model in the early 2000s. ''Refining'' means both adding and removing technology options depending on technology availability now and projected future availability in the United States market, while balancing a reasonable amount of modeling and analysis complexity. Since the last analysis we have reduced the number of LD ICE technology options but have refined the options, so they better reflect the diversity of engines in the current fleet. Our technology options also reflect an increase in diversity for hybridization and electrification options, though we utilize these options in a manner that is consistent with statutory constraints. In addition to better representing the current fleet, this reflects consistent feedback from vehicle manufacturers who have told us that they will reduce investment in ICEs while increasing investment in hybrid and plug-in BEV options.[87]

Feedback on the past several CAFE rules has also centered thematically on the expected scope of future electrified vehicle technologies. We have received feedback that we cannot consider BEV options and even so, our costs underestimate BEV costs when we do consider them in, for example, the baseline. We have also received comments that we should consider more electrified vehicle options and our costs overestimate future costs. Consistent with our interpretation of EPCA/EISA, discussed further in Section V.D.1, we include several LD electrified technologies to appropriately represent the diversity of current and anticipated future technology options while ensuring our analysis remains consistent with statutory limitations. In addition, this ensures that our analysis can appropriately capture manufacturer decision making about their vehicle fleets for reasons other than CAFE standards (*e.g.,* other regulatory programs and manufacturing decisions).

The technology options also include our judgment about which technologies will not be available in the rulemaking timeframe. There are several reasons why we may have concluded that it was reasonable to exclude a technology from the options we consider. As with past analyses, we did not include technologies unlikely to be feasible in the rulemaking timeframe, engines technologies designed for markets other than the United States market that are required to use unique gasoline,[88] or technologies where there were not appropriate data available for the range of vehicles that we model in the analysis (*i.e.,* technologies that are still in the research and development phase but are not ready for mass market production). Each technology section below and in chapter 3 of the Draft TSD discusses these decisions in detail.

The HDPUV technology options also represent a diverse range of both internal combustion and electrified powertrain technologies. We last used the CAFE Model for analyzing HDPUV standards in the Phase 2 Medium- and Heavy-Duty Greenhouse Gas and Fuel Efficiency joint rules with EPA in 2016.[89] Since issuing that rule, we refined the ICE technology options based on trends on vehicles in the fleet and updated technology cost and effectiveness data. The HDPUV options also reflect more electrification and hybridization options in that real-world fleet. However, the HDPUV technology options are also less diverse than the LD technology options, for several reasons.

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[83] 40 CFR 86.1806–17—Onboard diagnostics.

[84] 40 CFR 86.1818–12—Greenhouse gas emission standards for light-duty vehicles, light-duty trucks, and medium-duty passenger vehicles.

[85] Commission Directive 2001/116/EC—European Union emission regulations for new LDVs—including passenger cars and light commercial vehicles (LCV).

[86] Ford, General Motors (GM), Honda, Stellantis, and VWA represent the following 11 brands: Acura, Alfa Romeo, Audi, Bentley, Buick, Cadillac, Chevrolet, Ford, GMC, Lamborghini, and Porsche.

[87] 87 FR 25781 (May 2, 2022); 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.

[88] In general, most vehicles produced for sale in the United States have been designed to use ''Regular'' gasoline, or 87 octane. See EIA. What is Octane. Available at: *https://www.eia.gov/energyexplained/gasoline/octane-in-depth.php.* (Accessed: May 31, 2023), for more information.

[89] 81 FR 73478 (Oct. 25, 2016); CAFE Compliance and Effects Modeling System. 2016 Final Rule for Model Years 2021–2027 Heavy-Duty Pickups and Vans. Available at: *https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-compliance-and-effects-modeling-system.* (Accessed: May 31, 2023).

The HDPUV fleet is significantly smaller than the LD fleet, with five manufacturers building a little over 30 nameplates in one thousand vehicle model configurations,[90] compared with the almost 20 LDV manufacturers building 369 nameplates in the range of over two thousand configurations. Also, by definition, the HDPUV fleet only includes two vehicle types: HD pickup trucks and work vans.[91] These vehicle types have focused applications, which includes transporting people and moving equipment and supplies. As discussed in more detail below, these vehicles are built with specific technology application, reliability, and durability requirements in order to do work.[92] We believe the range of HDPUV technology options appropriately and reasonably represents the smaller range of technology options available currently and for application in future MYs for the United States market.

Note, however, that for both the LD and HDPUV analyses, the CAFE Model does not dictate or predict the technologies manufacturers must use to comply; rather, the CAFE Model outlines a technology pathway that manufacturers could use to meet the standards cost-effectively. While we estimate the costs and benefits for different levels of CAFE standards estimating technology applications that manufacturers could use in the rulemaking timeframe, it is entirely possible and reasonable that a vehicle manufacturer will use different technology options to meet our standards than the CAFE Model estimates and may even use technologies that we do not include in our analysis. This is because our standards do not mandate the application of any particular technology. Rather, our standards are performance based: manufacturers can and do use a range of compliance solutions that include technology application, shifting sales from one vehicle model or trim level to another,[93] and even paying civil penalties. That said, we are confident that the 75 LD technology options and 30 HDPUV technology options included in the analysis (in particular considering that for each technology option, the analysis includes distinct technology cost and effectiveness values for fourteen different types of vehicles, resulting in about a million different technology effectiveness and cost data points) strike a reasonable balance between the diversity of technology used by an entire industry and simplifying reality in order to make modeling tractable.

Table II–1 and Table II–2 below list most of the technologies that we used for the LD and HDPUV analyses. Each technology has a name that loosely corresponds to its real-world technology equivalent. We abbreviate the name to a short easy signifier for the CAFE Model to read. We organize those technologies into groups based on technology type: basic and advanced engines, transmissions, electrification, and road load technologies, which include MR, aerodynamic improvement, and low rolling resistance tire technologies.

TABLE II–1—LIGHT DUTY VEHICLE TECHNOLOGY OPTIONS[94]

Technology name	Abbreviation	Technology group
Single Overhead Camshaft Engine with VVT	SOHC	Basic Engines.
Double Overhead Camshaft Engine with VVT	DOHC	Basic Engines.
Variable Valve Lift	VVL	Basic Engines.
Stoichiometric Gasoline Direct Injection	SGDI	Basic Engines.
Cylinder Deactivation	DEAC	Basic Engines.
Turbocharged Engine	TURBO0	Advanced Engines.
Turbocharged Engine with Cooled Exhaust Gas Recirculation	TURBOE	Advanced Engines.
Turbocharged Engine with Cylinder Deactivation	TURBOD	Advanced Engines.
Advanced Turbocharged Engine, Level 1	TURBO1	Advanced Engines.
Advanced Turbocharged Engine, Level 2	TURBO2	Advanced Engines.
DOHC Engine with Advanced Cylinder Deactivation	ADEACD	Advanced Engines.
SOHC Engine with Advanced Cylinder Deactivation	ADEACS	Advanced Engines.
High Compression Ratio Engine	HCR	Advanced Engines.
High Compression Ratio Engine with Cooled Exhaust Gas Recirculation	HCRE	Advanced Engines.
High Compression Ratio Engine with Cylinder Deactivation	HCRD	Advanced Engines.
Variable Compression Ratio Engine	VCR	Advanced Engines.
Variable Turbo Geometry Engine	VTG	Advanced Engines.
Variable Turbo Geometry Engine with eBoost	VTGE	Advanced Engines.
Turbocharged Engine with Advanced Cylinder Deactivation	TURBOAD	Advanced Engines.
Advanced Diesel Engine	ADSL	Advanced Engines.
Advanced Diesel Engine with Cylinder Deactivation	DSLI	Advanced Engines.
Compressed Natural Gas Engine	CNG	Advanced Engines.
5-Speed Automatic Transmission	AT5	Transmissions.
6-Speed Automatic Transmission	AT6	Transmissions.
7-Speed Automatic Transmission with Level 2 high efficiency gearbox (HEG)	AT7L2	Transmissions.
8-Speed Automatic Transmission	AT8	Transmissions.
8-Speed Automatic Transmission with Level 2 HEG	AT8L2	Transmissions.
8-Speed Automatic Transmission with Level 3 HEG	AT8L3	Transmissions.
9-Speed Automatic Transmission with Level 2 HEG	AT9L2	Transmissions.
10-Speed Automatic Transmission with Level 2 HEG	AT10L2	Transmissions.
10-Speed Automatic Transmission with Level 3 HEG	AT10L3	Transmissions.
6-Speed Dual Clutch Transmission	DCT6	Transmissions.

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[90] In this example, a HDPUV "nameplate" could be the "Sprinter 2500", as in the Mercedes-Benz Sprinter 2500. The vehicle model configurations are each unique variants of the Sprinter 2500 that have an individual row in our Market Data Input File, which are divided generally based on compliance fuel consumption value and WF.

[91] For this proposal, vehicles were divided between the LD and HDPUV fleets solely on their gross vehicle weight rating (GVWR) being above or below 8,500 lbs. We will revisit the distribution of vehicles in the final rule to include the the distinction for MDPVs.

[92] "Work" includes hauling, towing, carrying cargo, or transporting people, animals, or equipment.

[93] Manufacturers could increase their production of one type of vehicle that has higher fuel economy level, like the hybrid version of a conventional vehicle model, to meet the standards. For example, Ford has conventional, hybrid, and electric versions of its F–150 pickup truck, and Toyota has conventional, hybrid, and plug-in hybrid versions of its RAV4 sport utility vehicle.

[94] A detailed discussion of all the technologies listed in the table can be found in TSD Chapter 3.

Table II–1—Light Duty Vehicle Technology Options [94]—Continued

Technology name	Abbreviation	Technology group
8-Speed Dual Clutch Transmission	DCT8	Transmissions.
Continuously Variable Transmission	CVT	Transmissions.
Continuously Variable Transmission with Level 2 HEG	CVTL2	Transmissions.
Conventional Powertrain (Non-Electric)	CONV	Electrification.
12V Micro-Hybrid Start-Stop System	SS12V	Electrification.
48V Belt Mounted Integrated Starter/Generator	BISG	Electrification.
Parallel Strong Hybrid/Electric Vehicle with DOHC Engine	P2D	Electrification.
Parallel Strong Hybrid/Electric Vehicle with DOHC+SGDI Engine	P2SGDID	Electrification.
Parallel Strong Hybrid/Electric Vehicle with SOHC Engine	P2S	Electrification.
Parallel Strong Hybrid/Electric Vehicle with SOHC+SGDI Engine	P2SGDIS	Electrification.
Parallel Strong Hybrid Electric Vehicle with TURBO0 Engine	P2TRB0	Electrification.
Parallel Strong Hybrid Electric Vehicle with TURBOE Engine	P2TRBE	Electrification.
Parallel Strong Hybrid Electric Vehicle with TURBO1 Engine	P2TRB1	Electrification.
Parallel Strong Hybrid Electric Vehicle with TURBO2 Engine	P2TRB2	Electrification.
Parallel Strong Hybrid Electric Vehicle with HCR Engine	P2HCR	Electrification.
Parallel Strong Hybrid Electric Vehicle with HCRE Engine	P2HCRE	Electrification.
Power Split Strong Hybrid/Electric Vehicle with Full Time Atkinson Engine	SHEVPS	Electrification.
Plug-in Hybrid Vehicle with TURBO1 Engine and 20 miles of electric range	PHEV20T	Electrification.
Plug-in Hybrid Vehicle with TURBO1 Engine and 50 miles of electric range	PHEV50T	Electrification.
Plug-in Hybrid Vehicle with HCR Engine and 20 miles of electric range	PHEV20H	Electrification.
Plug-in Hybrid Vehicle with HCR Engine and 50 miles of electric range	PHEV50H	Electrification.
Plug-in Hybrid Vehicle with Full Time Atkinson Engine and 20 miles of electric range	PHEV20PS	Electrification.
Plug-in Hybrid Vehicle with Full Time Atkinson Engine and 50 miles of electric range	PHEV50PS	Electrification.
Battery Electric Vehicle with 200 miles of range	BEV1	Electrification.
Battery Electric Vehicle with 250 miles of range	BEV2	Electrification.
Battery Electric Vehicle with 300 miles of range	BEV3	Electrification.
Battery Electric Vehicle with 350 miles of range	BEV4	Electrification.
Fuel Cell Vehicle	FCV	Electrification.
Baseline Tire Rolling Resistance	ROLL0	Rolling Resistance.
Tire Rolling Resistance, 10% Improvement	ROLL10	Rolling Resistance.
Tire Rolling Resistance, 20% Improvement	ROLL20	Rolling Resistance.
Tire Rolling Resistance, 30% Improvement	ROLL30	Rolling Resistance.
Baseline Aerodynamic Drag Technology	AERO0	Aerodynamic Drag.
Aerodynamic Drag, 5% Drag Coefficient Reduction	AERO5	Aerodynamic Drag.
Aerodynamic Drag, 10% Drag Coefficient Reduction	AERO10	Aerodynamic Drag.
Aerodynamic Drag, 15% Drag Coefficient Reduction	AERO15	Aerodynamic Drag.
Aerodynamic Drag, 20% Drag Coefficient Reduction	AERO20	Aerodynamic Drag.
Baseline Mass Reduction Technology	MR0	Mass Reduction.
Mass Reduction—5.0% of Glider	MR1	Mass Reduction.
Mass Reduction—7.5% of Glider	MR2	Mass Reduction.
Mass Reduction—10.0% of Glider	MR3	Mass Reduction.
Mass Reduction—15.0% of Glider	MR4	Mass Reduction.
Mass Reduction—20.0% of Glider	MR5	Mass Reduction.

Table II–2—Heavy-Duty Pickup Truck and Van Technology Options [95]

Technology name	Abbreviation	Technology group
Single Overhead Camshaft Engine with VVT	SOHC	Basic Engines.
Double Overhead Camshaft Engine with VVT	DOHC	Basic Engines.
Stoichiometric Gasoline Direct Injection	SGDI	Basic Engines.
Cylinder Deactivation	DEAC	Basic Engines.
Turbocharged Engine	TURBO0	Advanced Engines.
Advanced Diesel Engine	ADSL	Advanced Engines.
Advanced Diesel Engine with Improvements	DSLI	Advanced Engines.
5-Speed Automatic Transmission	AT5	Transmissions.
6-Speed Automatic Transmission	AT6	Transmissions.
8-Speed Automatic Transmission	AT8	Transmissions.
9-Speed Automatic Transmission with Level 2 HEG	AT9L2	Transmissions.
10-Speed Automatic Transmission with Level 2 HEG	AT10L2	Transmissions.
Conventional Powertrain (Non-Electric)	CONV	Electrification.
12V Micro-Hybrid Start-Stop System	SS12V	Electrification.
Belt Mounted Integrated Starter/Generator	BISG	Electrification.
Parallel Strong Hybrid/Electric Vehicle with SOHC Engine	P2S (P2D, P2TRB0)	Electrification.
Plug-in Hybrid Vehicle with Basic Engine and 50 miles of electric range	PHEV50H (PHEV50T)	Electrification.
Battery Electric Vehicle with 150 miles of range (for van classes) or 200 miles of range (for pickup classes).	BEV1	Electrification.
Battery Electric Vehicle with 250 miles of range (for van classes) or 300 miles of range (for pickup classes).	BEV2	Electrification.

TABLE II–2—HEAVY-DUTY PICKUP TRUCK AND VAN TECHNOLOGY OPTIONS [95]—Continued

Technology name	Abbreviation	Technology group
Fuel Cell Vehicle	FCV	Electrification.
Baseline Tire Rolling Resistance	ROLL0	Rolling Resistance.
Tire Rolling Resistance, 10% Improvement	ROLL10	Rolling Resistance.
Tire Rolling Resistance, 20% Improvement	ROLL20	Rolling Resistance.
Baseline Aerodynamic Drag Technology	AERO0	Aerodynamic Drag.
Aerodynamic Drag, 10% Drag Coefficient Reduction	AERO10	Aerodynamic Drag.
Aerodynamic Drag, 20% Drag Coefficient Reduction	AERO20	Aerodynamic Drag.
Baseline Mass Reduction Technology	MR0	Mass Reduction.
Mass Reduction—1.4% of Glider	MR1	Mass Reduction.
Mass Reduction—13.0% of Glider	MR2	Mass Reduction.

We then organize the groups into pathways. The pathways instruct the CAFE Model how and in what order to apply technology. In other words, the pathways define technologies that are mutually exclusive (*i.e.,* that cannot be applied at the same time), and define the direction in which vehicles can advance as the model evaluates which technologies to apply. Figure II–6 shows the LD and HDPUV technology pathways used in this analysis. In general, the paths are tied to ease of implementation of additional technology and how closely related the technologies are.

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[95] A detailed discussion of all the technologies listed in the table can be found in TSD Chapter 3.

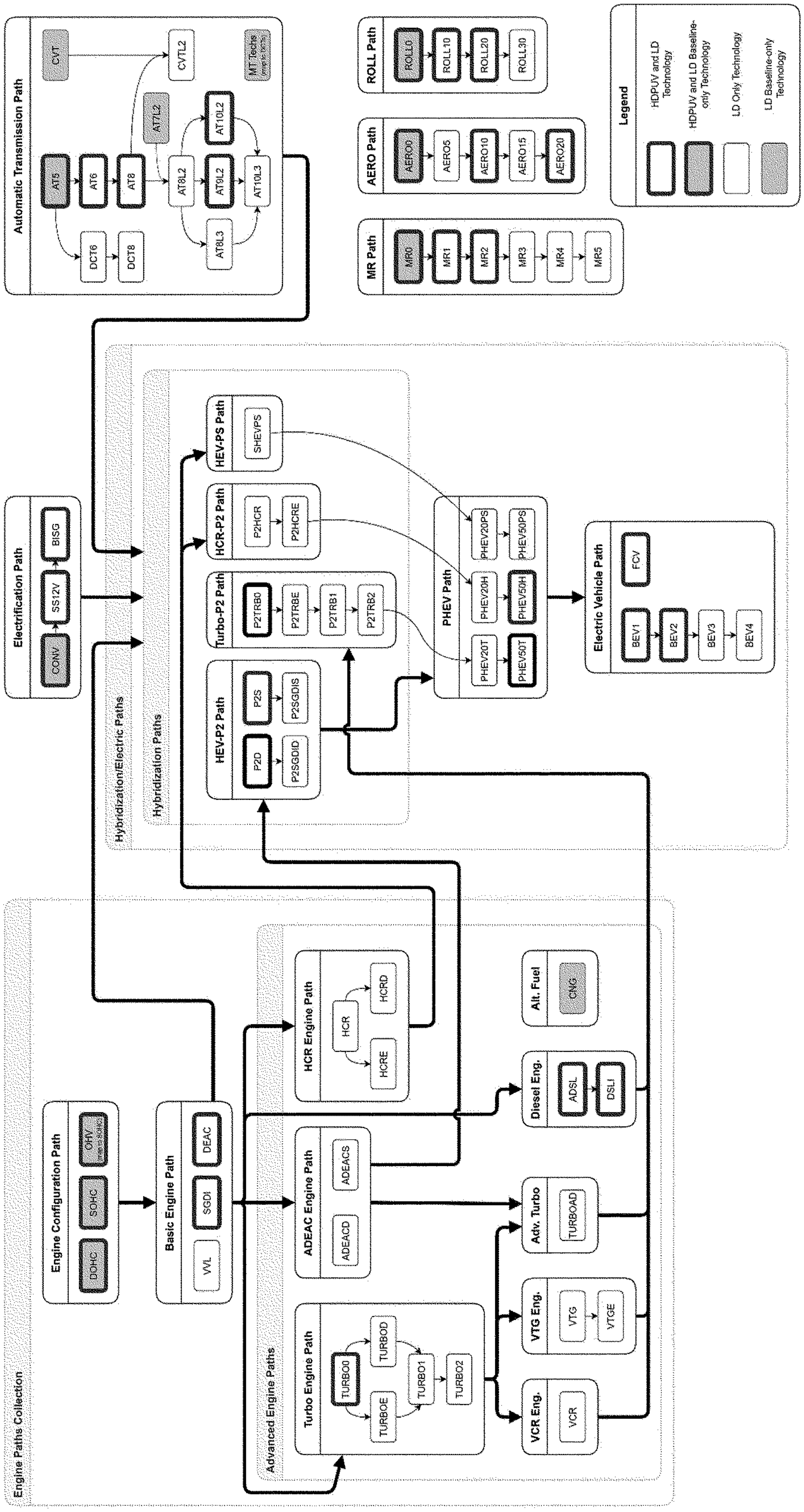

Figure II-6: CAFE Model Technology Pathways

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As an example, our "Turbo Engine Path" consists of five different engine technologies that employ different levels of turbocharging technology. A turbocharger is essentially a small turbine that is driven by exhaust gases produced by the engine. As these gases flow through the turbocharger, they spin the turbine, which in turn spins a compressor that pushes more air into an engine's cylinder. Having more air in the engine's cylinder allows the engine to burn more fuel, which then creates more power, without needing a physically larger engine. In our analysis, an engine that uses a turbocharger ''downsizes,'' or becomes smaller. The smaller engine can use less fuel to do the same amount of work as the engine did before it used a turbocharger and was downsized. Allowing basic engines to be downsized and turbocharged instead of just turbocharged keeps the vehicle's utility and performance constant so that we can measure the costs and benefits of different levels of fuel economy improvements, rather than the change in different vehicle attributes. This concept is discussed further, below.

Grouping technologies on pathways also tells the model how to evaluate technologies; continuing this example, a vehicle can only have one engine, so if a vehicle has one of the Turbo engines the model will evaluate which more advanced Turbo technology to apply. Or, if it is more cost-effective to go beyond the Turbo pathway, the model will evaluate whether to apply more advanced engine technologies and hybridization path technology.

Then, the arrows between technologies instruct the model on the order in which to evaluate technologies on a pathway. This ensures that a vehicle that uses a more fuel-efficient technology cannot downgrade to a less efficient option or that a vehicle would switch to technology that was significantly technically different. As an example, if a vehicle in the compliance simulation begins with a TURBOD engine—a turbocharged engine with cylinder deactivation—it cannot adopt a TURBO0 engine. Similarly, this vehicle with a TURBOD engine cannot adopt an ADEACD engine.[96] The model follows instructions pursuant to the direction of arrows between technology groups and between technologies on the same pathway.

We also consider two categories of technology that we could not simulate as part of the CAFE Model's technology pathways. ''Off-cycle'' and air conditioning (AC) efficiency technologies improve vehicle fuel economy, but the benefit of those technologies cannot be captured using the fuel economy test methods that we must use under EPCA/EISA.[97] As an example, manufacturers can claim a benefit for technology like active seat ventilation and solar reflective surface coatings that make the cabin of a vehicle more comfortable for the occupants, who then do not have to use other less efficient accessories like heat or AC. Instead of including off-cycle and AC efficiency technologies in the technology pathways, we include the improvement as a defined benefit that gets applied to a manufacturer's entire fleet instead of to individual vehicles. The defined benefit that each manufacturer receives in the analysis for using off-cycle and AC efficiency technology on their vehicles is located in the Market Data Input file. See Chapter 3.7 of the Draft TSD for more discussion in how off-cycle and AC efficiency technologies are developed and modeled.

To illustrate, throughout this section we will follow the hypothetical vehicle mentioned above that begins the compliance simulation with a TURBOD engine. Our hypothetical vehicle, Generic Motors' Ravine Runner F Series, is a roomy, top of the line sport utility vehicle (SUV). The Ravine Runner F Series starts the compliance simulation with technologies from most technology pathways; specifically, after looking at Generic Motors' website and marketing materials, we determined that it has technology that loosely fits within the following technologies that we consider in the CAFE Model: it has a turbocharged engine with cylinder deactivation, a fairly advanced 10-speed automatic transmission, a 12V start-stop system, the least advanced tire technology, a fairly aerodynamic vehicle body, and it employs a fairly advanced level of MR. We track the technologies on each vehicle using a ''technology key'', which is the string of technology abbreviations for each vehicle. Again, the vehicle technologies and their abbreviations that we consider in this analysis are shown in Table II–1 and Table II–2 above. The technology key for the Ravine Runner F Series is ''TURBOD; AT10L2, SS12V; ROLL0; AERO5; MR3.''

2. Defining the Technology Baseline

The Market Data Input File is one of four Excel input files that the CAFE Model uses for compliance and effects simulation. The Market Data Input file's ''Vehicles'' tab (or worksheet) houses one of the most significant compilations of technology inputs and assumptions in the analysis, which is a characterization of a baseline fleet of vehicles to which the CAFE Model adds fuel-economy-improving technology. We call this fleet the ''baseline fleet'' or the ''analysis fleet.'' The baseline fleet includes a number of inputs necessary for the model to add fuel economy improving technology to each vehicle for the compliance analysis and to calculate the resulting impacts for the effects analysis.

There is one Microsoft Excel file row for each vehicle model, for LD with the same certification fuel economy value and vehicle footprint, and for HDPUV with the same certification fuel consumption and WF. This means that vehicle models with different configurations that affect the vehicle's certification fuel economy or fuel consumption value—for example, our Ravine Runner example vehicle comes in three different configurations, the Ravine Runner FWD, Ravine Runner AWD, and Ravine Runner F Series—will be separated into three rows in the Vehicles tab. In each row we also designate a vehicle's engine, transmission, and platform codes.[98] Vehicles that have the same engine, transmission, or platform code are deemed to ''share'' that component in the CAFE Model. Parts sharing helps manufacturers achieve economies of scale, deploy capital efficiently, and make the most of shared research and development expenses, while still presenting a wide array of consumer choices to the market. The CAFE Model was developed to treat vehicles, platforms, engines, and transmissions as separate entities, which allows the modeling system to concurrently evaluate technology improvements on multiple vehicles that may share a

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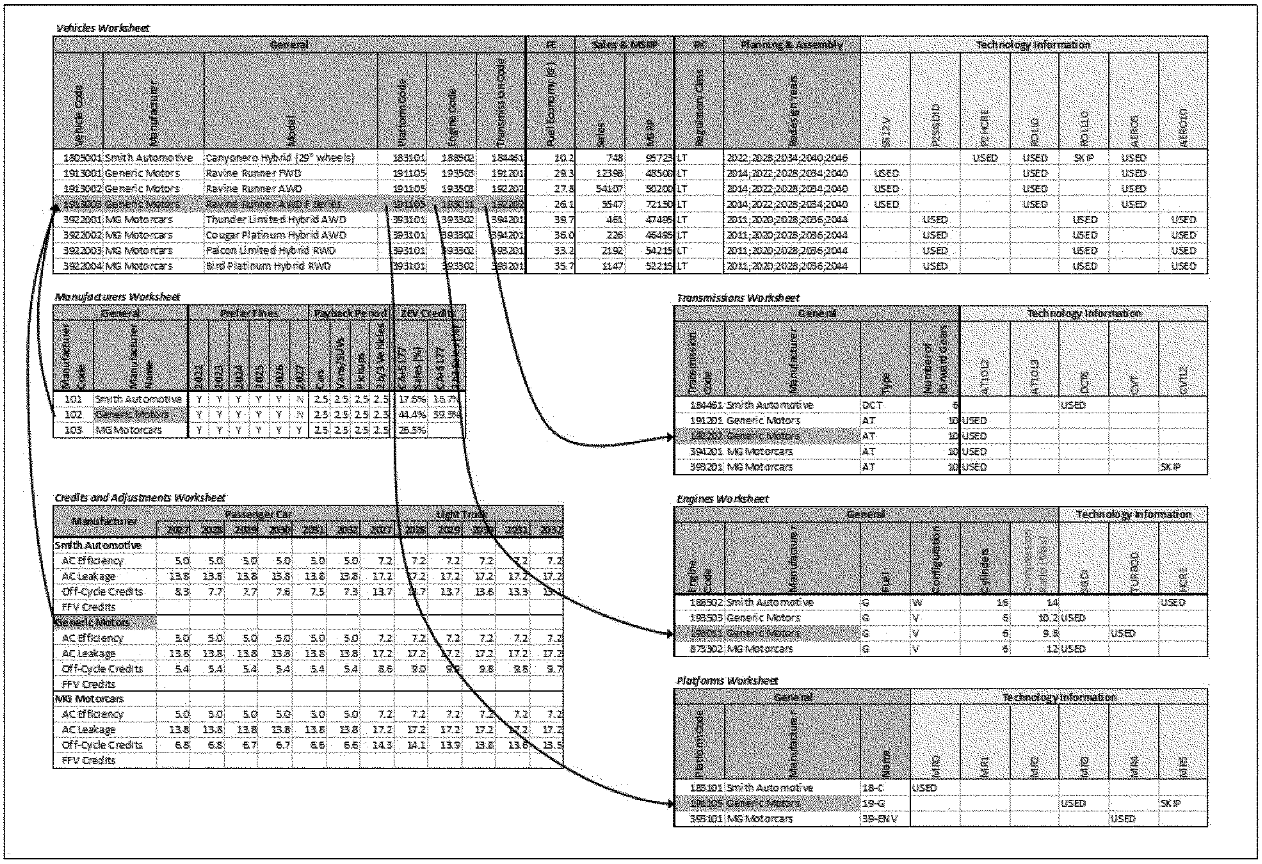
[96] An engine could potentially be changed from TURBO0 to TURBO2 without redesigning the engine block or requiring significantly different expertise to design and implement. A change to ADEACD would likely require a different engine block that might not be possible to fit in the engine bay of the vehicle without a complete redesign and different technical expertise requiring years of research and development. This consideration which would strand capital and break parts sharing is why the advanced engine paths restrict most movement between them.

[97] *See* 49 U.S.C. 32904(c) (''Testing and calculation procedures. . . . the Administrator shall use the same procedures for passenger automobiles the Administrator used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle), or procedures that give comparable results.'').

[98] Each numeric engine, transmission, or platform code designates important information about that vehicle's technology; for example, a vehicle's six-digit Transmission Code includes information about the manufacturer, the vehicle's drive configuration (*i.e.,* front-wheel drive, all-wheel drive, four-wheel drive, or rear-wheel drive), transmission type, number of gears (*e.g.,* a 6-speed transmission has six gears), and the transmission variant.

common component. Sharing also enables realistic propagation, or ''inheriting,'' of previously applied technologies from an upgraded component down to the vehicle ''users'' of that component that have not yet realized the benefits of the upgrade. For additional information about the initial state of the fleet and technology evaluation and inheriting within the CAFE Model, please see Section 2.1 and Section 4.4 of the Draft CAFE Model Documentation.

Figure II–7 below shows how we separate the different configurations of the Ravine Runner. We can see by the Platform Codes that these Ravine Runners all share the same platform, but only the Ravine Runner FWD and Ravine Runner AWD share an engine. Even so, all three certification fuel economy values are different, which is common of vehicles that differ in drive type (drive type meaning whether the vehicle has all-wheel drive (AWD), four-wheel drive (4WD), front-wheel drive (FWD), or rear-wheel drive). While it would certainly be easier to aggregate vehicles by model, ensuring that we capture model variants with different fuel economy values improves the accuracy of our analysis and the potential that our estimated costs and benefits from different levels of standards are appropriate. We include information about other vehicle technologies at the farthest right side of the Vehicles tab, and in the ''Engines'', ''Transmissions'', and ''Platforms'' worksheets, as discussed further below.



Vehicles Worksheet

General						FE	Sales & MSRP		RC	Planning & Assembly	Technology Information						
Vehicle Code	Manufacturer	Model	Platform Code	Engine Code	Transmission Code	Fuel Economy (B.)	Sales	MSRP	Regulatory Class	Redesign Years	SS12V	P2SGDID	P2HCRE	ROLLD	ROLL10	AERO5	AERO10
1805001	Smith Automotive	Canyonero Hybrid (29" wheels)	183101	188502	184461	10.2	748	95723	LT	2022;2028;2034;2040;2046			USED	USED	SKIP	USED	
1913001	Generic Motors	Ravine Runner FWD	191105	193503	191201	29.3	12398	48500	LT	2014;2022;2028;2034;2040	USED			USED		USED	
1913002	Generic Motors	Ravine Runner AWD	191105	193503	192202	27.8	54107	50200	LT	2014;2022;2028;2034;2040	USED			USED		USED	
1913003	Generic Motors	Ravine Runner AWD F Series	191105	193011	192202	26.1	5547	72150	LT	2014;2022;2028;2034;2040	USED			USED		USED	
3922001	MG Motorcars	Thunder Limited Hybrid AWD	393101	393302	394201	39.7	461	47495	LT	2011;2020;2028;2036;2044		USED			USED		USED
3922002	MG Motorcars	Cougar Platinum Hybrid AWD	393101	393302	394201	36.0	226	46495	LT	2011;2020;2028;2036;2044		USED			USED		USED
3922003	MG Motorcars	Falcon Limited Hybrid RWD	393101	393302	393201	33.2	2192	54215	LT	2011;2020;2028;2036;2044		USED			USED		USED
3922004	MG Motorcars	Bird Platinum Hybrid RWD	393101	393302	393201	35.7	1147	52215	LT	2011;2020;2028;2036;2044		USED			USED		USED

Manufacturers Worksheet

General		Prefer Fines						Payback Period				ZEV Credits	
Manufacturer Code	Manufacturer Name	2022	2023	2024	2025	2026	2027	Cars	Vans/SUVs	Pickups	2b/3 Vehicles	CA+S177 Sales (%)	CA+S177 2b3 Sales (%)
101	Smith Automotive	Y	Y	Y	Y	Y	N	2.5	2.5	2.5	2.5	17.6%	16.7%
102	Generic Motors	Y	Y	Y	Y	Y	N	2.5	2.5	2.5	2.5	44.4%	39.5%
103	MG Motorcars	Y	Y	Y	Y	Y	Y	2.5	2.5	2.5	2.5	26.5%	

Credits and Adjustments Worksheet

Manufacturer	Passenger Car						Light Truck					
	2027	2028	2029	2030	2031	2032	2027	2028	2029	2030	2031	2032
Smith Automotive												
AC Efficiency	5.0	5.0	5.0	5.0	5.0	5.0	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	13.8	13.8	13.8	13.8	13.8	13.8	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle Credits	8.3	7.7	7.7	7.6	7.5	7.3	13.7	13.7	13.7	13.6	13.3	13.1
FFV Credits												
Generic Motors												
AC Efficiency	5.0	5.0	5.0	5.0	5.0	5.0	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	13.8	13.8	13.8	13.8	13.8	13.8	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle Credits	5.4	5.4	5.4	5.4	5.4	5.4	8.6	9.0	9.9	9.8	9.6	9.7
FFV Credits												
MG Motorcars												
AC Efficiency	5.0	5.0	5.0	5.0	5.0	5.0	7.2	7.2	7.2	7.2	7.2	7.2
AC Leakage	13.8	13.8	13.8	13.8	13.8	13.8	17.2	17.2	17.2	17.2	17.2	17.2
Off-Cycle Credits	6.8	6.8	6.7	6.7	6.6	6.6	14.3	14.1	13.9	13.8	13.6	13.5
FFV Credits												

Transmissions Worksheet

General				Technology Information				
Transmission Code	Manufacturer	Type	Number of Forward Gears	AT10L2	AT10L3	DCT6	CVT	CVTL2
184461	Smith Automotive	DCT	6			USED		
191201	Generic Motors	AT	10	USED				
192202	Generic Motors	AT	10	USED				
394201	MG Motorcars	AT	10	USED				
393201	MG Motorcars	AT	10	USED				SKIP

Engines Worksheet

General						Technology Information		
Engine Code	Manufacturer	Fuel	Configuration	Cylinders	Compression Ratio (Max)	SGDI	TURBOD	HCRE
188502	Smith Automotive	G	W	16	14			USED
193503	Generic Motors	G	V	6	10.2	USED		
193011	Generic Motors	G	V	6	9.8		USED	
873302	MG Motorcars	G	V	6	12	USED		

Platforms Worksheet

General			Technology Information					
Platform Code	Manufacturer	Name	MR0	MR1	MR2	MR3	MR4	MR5
183101	Smith Automotive	18-C	USED					
191105	Generic Motors	19-G				USED		SKIP
393101	MG Motorcars	39-ENV					USED	

Figure II-7: Generic Motors' Ravine Runner F Series in the Market Data Input File[99]

Moving from left to right on the Vehicles tab, after including general information about vehicles and their compliance fuel economy value, we include sales and manufacturer's suggested retail price (MSRP) data, regulatory class information (*i.e.,* domestic passenger car, import passenger car, light truck, MDPV, HD pickup truck, or HD van), and information about how we classify vehicles for the effectiveness and safety analyses. Each of these data points is important to different parts of the compliance and effects analysis, so that the CAFE Model can accurately average the technologies required across a manufacturer's regulatory class for each class to meet its CAFE standard, or the impacts of higher fuel economy standards on vehicle sales. In addition, we include columns indicating if a vehicle is a ''ZEV Candidate,'' which means that the vehicle could be made into a zero emissions vehicle (ZEV) at its first redesign opportunity in order to simulate a manufacturer's compliance with California's ACC, ACC II, or ACT program, which is discussed further below. Next, we include vehicle information necessary for applying different types of technology; for example, designating a vehicle's body style means that we can appropriately apply aerodynamic technology, and designating starting curb weight values means that we can more accurately apply MR technology. Importantly, this section also includes vehicle footprint data (because we set footprint-based standards).

We also set product design cycles, which are the years when the CAFE Model can apply different technologies

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[99] Note that not all data columns are shown in this example for brevity.

to vehicles. Manufacturers often introduce fuel saving technologies at a ''redesign'' of their product or adopt technologies at ''refreshes'' in between product redesigns. As an example, the redesigned third generation Chevrolet Silverado was released for the 2019 MY, and featured a new platform, updated drivetrain, increased towing capacity, reduced weight, improved safety and expanded trim levels, to name a few improvements. For MY 2022, the Chevrolet Silverado received a refresh (or facelift as it is commonly called), with an updated interior, infotainment, and front-end appearance.[100]

During modeling, all improvements from technology application are initially realized on a component and then propagated (or inherited) down to the vehicles that share that component. As such, new component-level technologies are initially evaluated and applied to a platform, engine, or transmission during their respective redesign or refresh years. Any vehicles that share the same redesign and/or refresh schedule as the component apply these technology improvements during the same MY. The rest of the vehicles inherit technologies from the component during their refresh or redesign year (for engine- and transmission-level technologies), or during a redesign year only (for platform-level technologies). Please see Section 4.4 of the Draft CAFE Model Documentation for additional information about technology evaluation and inheriting within the CAFE Model.

The CAFE Model also considers the potential safety effect of MR technologies and crash compatibility of different vehicle types. MR technologies lower the vehicle's curb weight, which may change crash compatibility and safety, depending on the type of vehicle. We assign each vehicle in the Market Data Input File a ''safety class'' that best aligns with the CAFE Model's analysis of vehicle mass, size, and safety, and include the vehicle's baseline curb weight.[101]

The CAFE Model includes procedures to consider the direct labor impacts of manufacturers' response to CAFE regulations, considering the assembly location of vehicles, engines, and transmissions, the percent U.S. content (that reflects percent U.S. and Canada content), and the dealership employment associated with new vehicle sales. Baseline labor information, by vehicle, is included in the Market Data Input File. Sales volumes included in and adapted from the market data also influence total estimated direct labor projected in the analysis. See Chapter 6.2.5 of the Draft TSD for further discussion of the labor utilization analysis.

Then we assign the CAFE Model's range of technologies to individual vehicles. This initial linkage of vehicle technologies is how the CAFE Model knows how to advance a vehicle down each technology pathway. Assigning CAFE Model technologies to individual vehicles is dependent on the mix of information we have about any particular vehicle and trends about how a manufacturer has added technology to that vehicle in the past, equations and models that translate real-world technologies to their counterparts in our analysis, and our engineering judgment.

As discussed further below, we use information directly from manufacturers to populate some fields in the Market Data Input file, like vehicle horsepower ratings and vehicle weight. We also use manufacturer data as an input to various other models that calculate how a manufacturer's real-world technology equates to a technology level in our model. For example, we calculate MR, aerodynamic drag reduction, and ROLL baseline levels by looking at industry-wide trends and calculating—through models or equations—levels of improvement for each technology. The models and algorithms that we use are described further below and in detail in Chapter 3 of the Draft TSD. Other fields, like vehicle refresh and redesign years, are projected forward based on historic trends.

Let us return to the Ravine Runner F Series with the technology key ''TURBOD; AT10L2, SS12V; ROLL0; AERO5; MR3.'' Generic Motor's publicly available spec sheet for the Ravine Runner F Series says that the Ravine Runner F Series uses Generic Motor's Turbo V6 engine with proprietary Adaptive Cylinder Management Engine (ACME) technology. ACME improves fuel economy and lowers emissions by operating the engine using only three of the engine's cylinders in most conditions and using all six engine cylinders when more power is required. Generic Motors uses this engine in several of their vehicles, and the specifications of the engine can be found in the Engines Tab of the Market Data Input File, under a six-digit engine code.[102]

This is a relatively easy engine to assign based on publicly available specification sheets, but some technologies are much more difficult to assign. Manufacturers use different trade names or terms for different technology, and the way that we assign the technology in our analysis may not necessarily line up with how a manufacturer describes the technology. We must use some engineering judgment to determine how discrete technologies in the market best fit the technology options that we consider in our analysis. We discuss factors that we use to assign each vehicle technology in the individual technology subsections below.

In addition to the Vehicles Tab that houses the baseline fleet, the Market Data input file includes information that affects how the CAFE Model might apply technology to vehicles in the compliance simulation. Specifically, the Market Data Input file's ''Manufacturers'' tab includes a list of vehicle manufacturers considered in the analysis and several pieces of information about their economic and compliance behavior. First, we determine if a manufacturer ''prefers fines,'' meaning that historically in the LD fleet, we have observed this manufacturer paying civil penalties for failure to meet CAFE standards.[103] We might designate a manufacturer as not preferring fines if, for example, they have told us that paying civil penalties would be a violation of provisions in their corporate charter. For this analysis, we assume that all manufacturers are willing to pay fines in MYs 2022–2026, and that in MY 2027 and beyond, only the manufacturers that have historically paid fines would continue to pay fines. We seek comment on these fine payment preference assumptions. Note however that, as further discussed below in regard to the CAFE Model's compliance simulation algorithm, the model will still apply technologies for these manufacturers if it is cost-effective to do so, defined by several variables discussed below in Section II.C.6.

Next, we designate a ''payback period'' for each manufacturer. The payback period represents an assumption that consumers are willing to buy vehicles with more fuel economy

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[100] GM Authority. 2022 Chevy Silverado. Available at: *https://gmauthority.com/blog/gm/chevrolet/silverado/2022-chevrolet-silverado/.* (Accessed May 31, 2023).

[101] Vehicle curb weight is the weight of the vehicle with all fluids and components but without the drivers, passengers, and cargo.

[102] Like the Transmission Codes discussed above, the Engine Codes include information identifying the manufacturer, engine displacement (*i.e.,* how many liters the engine is), whether the engine is naturally aspirated or force inducted (*e.g.,* turbocharged), and whether the engine has any other unique attributes.

[103] *See* 49 U.S.C. 32912.

technology because the fuel economy technology will save them money on gas in the long run. For the past several CAFE Model analyses we have assumed that in the absence of CAFE or other regulatory standards, manufacturers would apply technology that ''pays for itself''—by saving the consumer money on fuel—in 2.5 years. While the amount of technology that consumers are willing to pay for is subject to much debate, we assume a 2.5-year payback period based on what manufacturers have told us they do, and on estimates in the available literature. This is discussed in detail in Section II.E below, and in the Draft TSD and PRIA.

We also designate in the Market Data Input file the percentage of each manufacturer's sales that must meet CAA section 177 requirements in certain states. Section 209(a) of the CAA generally preempts states from adopting emission control standards for new motor vehicles; however, Congress created an exemption program in section 209(b) that allows the State of California to seek a waiver of preemption. EPA must grant the waiver unless the Agency makes one of three statutory findings.[104] Under CAA section 177, other States can adopt and enforce standards identical those approved under California's section 209(b) waiver.

Finally, we include estimated CAFE compliance credit banks for each manufacturer in several years through 2021, which is the year before the compliance simulation begins. The CAFE Model does not explicitly simulate credit trading between and among vehicle manufacturers, but we estimate how manufacturers might use compliance credits in early MYs. This reflects manufacturers' tendency to use regulatory credits rather than to apply technology.[105]

Before we begin building the Market Data Input file for any analysis, we must consider what MY vehicles will comprise the baseline fleet. There is an inherent time delay in the data we can use for any particular analysis because we must set LD CAFE standards at least 18 months in advance of a MY if the CAFE standards increase,[106] and HDPUV fuel efficiency standards at least 4 full MYs in advance if the standards increase.[107] In addition to the requirement to set standards at least 18 months in advance of a MY, we must propose standards with enough time to allow the public to comment on the proposed standards and meaningfully evaluate that feedback and incorporate it into the final rule in accordance with the APA.[108] This means that the most recent data we have available to generate the baseline fleet necessarily falls behind the MY fleets of vehicles for which we generate standards. We have historically and intend again to update the data we use for the baseline fleet for the final rule if we receive more recent, high-quality data in time to use it for the final rule.

Using recent data for the baseline is more likely to reflect the current vehicle fleet than older data. Recent data will inherently include manufacturer's decisions on what fuel-economy-improving technology to apply, mix shifts in response to consumer preferences (*e.g.,* more recent data reflects manufacturer and consumer preference towards larger vehicles),[109] and industry sales volumes that incorporate substantive macroeconomic events (*e.g.,* the impact of the Coronavirus disease of 2019 (COVID) or microchip shortages). We considered that using a baseline fleet year that has been impacted by these transitory shocks may not represent trends in future years; however, on balance, we believe that updating to using the most complete set of available fleet data provides the most accurate baseline for the CAFE Model to calculate compliance and effects of different levels of future fuel economy standards. Also, using recent data decreases the likelihood that the CAFE Model selects compliance pathways for future standards that affect vehicles already built-in previous MYs.[110]

At the time we start building the baseline fleet, data that we receive from vehicle manufacturers in accordance with EPCA/EISA,[111] and our CAFE compliance regulations [112] in advance of or during an ongoing MY, offers the best snapshot of vehicles for sale in the US in a MY. These pre-model year (PMY) and mid-model year (MMY) reports include information about individual vehicles at the vehicle configuration level. We use the vehicle configuration, certification fuel economy, sales, regulatory class, and some additional technology data from these reports as the starting point to build a ''row'' (*i.e.,* a vehicle configuration, with all necessary information about the vehicle) in the Market Data Input File's Vehicle's Tab. Additional technology data come from publicly available information, including vehicle specification sheets, manufacturer press releases, owner's manuals, and websites. We also generate some assumptions in the Market Data Input file for data fields where there is limited data, like refresh and redesign cycles for future MYs, and technology levels for certain road load reduction technologies like MR and aerodynamic drag reduction.

For this analysis, the LD baseline fleet consists of every vehicle model in MY 2022 in mostly every configuration that has a different compliance fuel economy value, which results in a little over 2,000 individual rows in the Vehicles Tab of the Market Data Input file. The HDPUV fleet consists of vehicles produced in between MYs 2014 and 2022, which results in a little over 1100 individual rows in the HDPUV Market Data Input file. We used a combination of MY data for that fleet because of data availability, but the resulting dataset is a robust amalgamation that provides a reasonable starting point for the much smaller fleet.

The next section discusses how our analysis evaluates how adding additional fuel-economy-improving technology to a vehicle in the baseline fleet will improve that vehicle's fuel economy value. Put another way, the next section answers the question, how do we estimate how effective any given technology is at improving a vehicle's fuel economy value?

3. Technology Effectiveness Values

How does the CAFE Model know how effective any particular technology is at improving a vehicle's fuel economy value? Accurate technology effectiveness estimates require information about: (1) the vehicle type and size; (2) the other technologies on the vehicle and/or being added to the

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[104] *See* 87 FR 14332 (March 14, 2022). (''The CAA section 209(b) waiver is limited ''to any State which has adopted standards . . . for the control of emissions from new motor vehicles or new motor vehicle engines prior to March 30, 1966,'' and California is the only State that had standards in place before that date.'').

[105] Note, this is just an observation about manufacturers' tendency to use regulatory credits rather than to apply technology; in accordance with 49 U.S.C. 32902(h), the CAFE Model does not simulate a manufacturer's potential credit use during the years for which we are setting new CAFE standards.

[106] 49 U.S.C. 32902(a).

[107] 49 U.S.C. 32902(k)(3)(A).

[108] 5 U.S.C. 553.

[109] See the 2022 EPA Automotive Trends Report at pg. 14–19.

[110] For example, in this analysis the CAFE Model must apply technology to the MY 2022 fleet from MYs 2023–2026 for the compliance simulation that begins in MY 2027 (for the light-duty fleet), and from MYs 2023–2029 for the compliance simulation that begins in MY 2030 (for the HDPUV fleet). While manufacturers have already built MY 2022 and later vehicles, the most current, complete dataset with regulatory fuel economy test results to build the analysis fleet at the time of writing remains MY 2022 data for the light-duty fleet, and a range of MYs between 2014 and 2022 for the HDPUV fleet.

[111] 49 U.S.C. 32907(a)(2).

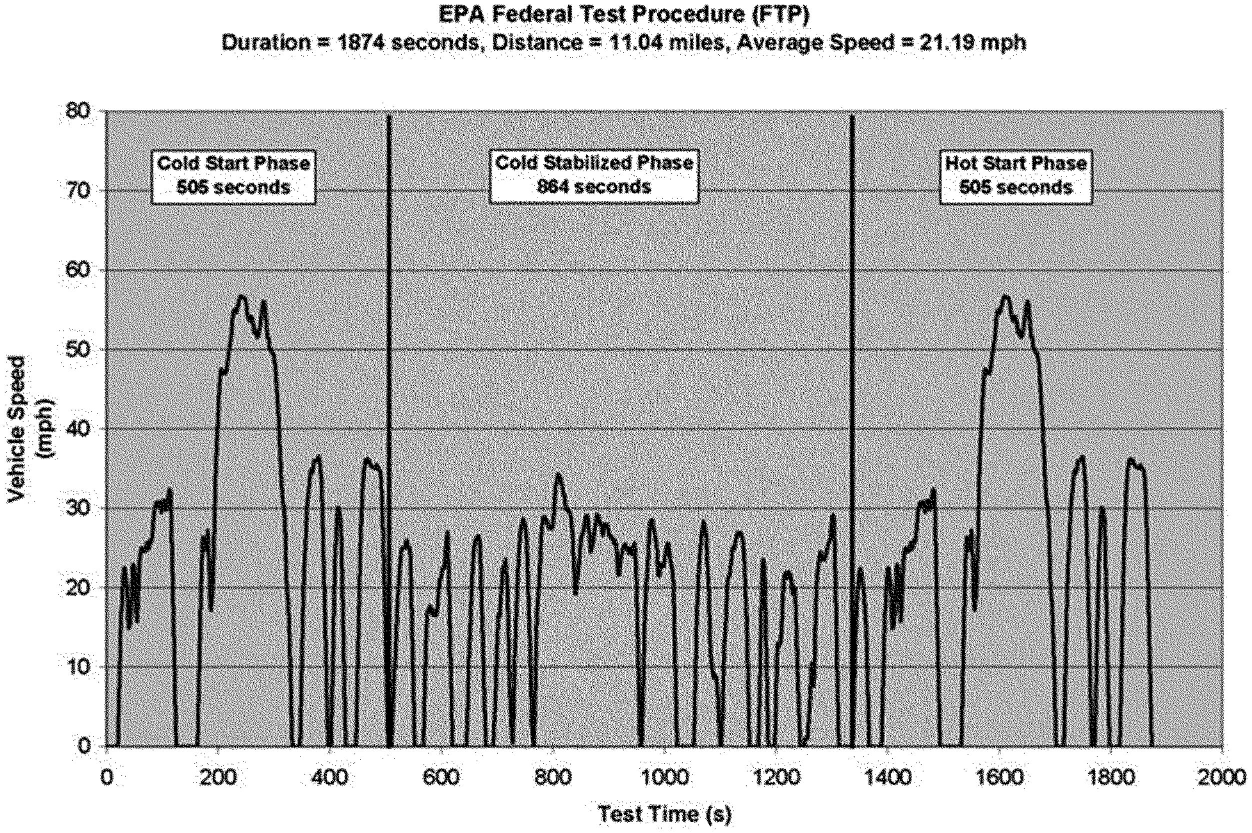
[112] 49 CFR part 537.

vehicle at the same time; and (3) and how the vehicle is driven. Any oversimplification of these complex factors could make the effectiveness estimates less accurate.

To build a database of technology effectiveness estimates that includes these factors, we partner with the DOE's ANL. ANL has developed and maintains a physics-based full-vehicle modeling and simulation tool called Autonomie that generates technology effectiveness estimates for the CAFE Model.

What is physics-based full-vehicle modeling and simulation? A model is a mathematical representation of a system, and simulation is the behavior of that mathematical representation over time. In Autonomie, the model is a mathematical representation of an entire vehicle, including its individual technologies such as the engine and transmission, overall vehicle characteristics such as mass and aerodynamic drag, and the environmental conditions, such as ambient temperature and barometric pressure.

We simulate a vehicle model's behavior over the "two-cycle" tests that are used to measure vehicle fuel economy.[113] For readers unfamiliar with this process, measuring a vehicle's fuel economy on the two-cycle tests is like running a car on a treadmill following a program—or more specifically, two programs. The "programs" are the "urban cycle," or Federal Test Procedure (abbreviated as "FTP"), and the "highway cycle," or Highway Fuel Economy Test (abbreviated as "HFET"). Figure II–8 below shows the FTP "program"; the vehicle meets certain speeds at certain times during the test, or in technical terms, the vehicle must follow the designated "speed trace." The FTP is meant roughly to simulate stop and go city driving, and the HFET is meant roughly to simulate steady flowing highway driving at about 50 miles per hour (mph). We also use the Society of Automotive Engineers (SAE) recommended practices to simulate hybridized and EV drive cycles,[114] which involves the test cycles mentioned above and additional test cycles to measure battery energy consumption and range.


EPA Federal Test Procedure (FTP)

Duration = 1874 seconds, Distance = 11.04 miles, Average Speed = 21.19 mph

Figure II-8: EPA Federal Test Procedure Speed Trace[115]

Measuring every vehicle's fuel economy values using the same test cycles (and in the real world, using sophisticated test and measurement equipment including dynamometers, carefully controlled environmental conditions, and precise procedures) ensures that the fuel economy certification results are repeatable for

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[113] We are statutorily required to use the two-cycle tests to measure vehicle fuel economy in the CAFE program. See 49 U.S.C. 32904(c) ("Testing and calculation procedures. . . . the Administrator shall use the same procedures for passenger automobiles the Administrator used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle), or procedures that give comparable results.").

[114] SAE. Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles, Including Plug-in Hybrid Vehicles. SAE Standard J1711. Rev. Feb 2023.; and SAE. Battery Electric Vehicle Energy Consumption and Range Test Procedure. SAE Standard J1634. Rev. April 2021.

[115] EPA. Emissions Standards Reference Guide. EPA FTP. Available at: *https://www.epa.gov/emission-standards-reference-guide/epa-federal-test-procedure-ftp.* (Accessed: May 31, 2023).

each vehicle model, and comparable among all of the different vehicle models.

Finally, ''physics-based'' simply refers to the mathematical equations underlying the modeling and simulation—the simulated vehicle models and all of the sub-models that make up specific vehicle components and the calculated fuel used on simulated test cycles are calculated mathematical equations that conform to the laws of physics.

Full-vehicle modeling and simulation was initially developed to avoid the costs of designing and testing prototype parts for every new type of technology. For example, Generic Motors can use physics-based computer modeling to determine the fuel economy penalty for adding a 4WD, rugged off-road tire trim level of the Ravine Runner to its lineup. The Ravine Runner, modeled with its new drivetrain and off-road tires, can be simulated on a defined test route and under defined test conditions and compared against the baseline Ravine Runner simulated without the change. Full-vehicle modeling and simulation allows Generic Motors to consider and evaluate different designs and concepts before building a single prototype for any potential technology change.

Full vehicle modeling and simulation is also essential to measuring how all technologies on a vehicle interact. An analysis using single or limited point estimates may assume that, for example, one technology may improve the vehicle's fuel economy by 5% and a second technology may improve the vehicle's fuel economy by 10%, but when both technologies are added to the vehicle together, they achieve a 15% improvement. Single point estimates generally do not provide accurate effectiveness values because they do not capture complex relationships among technologies. Technology effectiveness often differs significantly depending on the vehicle type (*e.g.,* sedan versus pickup truck) and the way in which the technology interacts with other technologies on the vehicle, as different technologies may provide different incremental levels of fuel economy improvement if implemented alone or in combination with other technologies. As stated above, any oversimplification of these complex factors could lead to less accurate technology effectiveness estimates.

In addition, because manufacturers often add several fuel-saving technologies simultaneously when redesigning a vehicle, it is difficult to isolate the effect of adding any one individual technology to the full vehicle system. Modeling and simulation offer the opportunity to isolate the effects of individual technologies by using a single or small number of baseline vehicle configurations and incrementally adding technologies to those baseline configurations. This provides a consistent reference point for the incremental effectiveness estimates for each technology and for combinations of technologies for each vehicle type. Vehicle modeling also reduces the potential for overcounting or undercounting technology effectiveness.

ANL does not build an individual vehicle model for every single vehicle configuration in our LD and HDPUV Market Data Input files. This would be nearly impossible, because Autonomie requires very detailed data on hundreds of different vehicle attributes (like the weight of the vehicle's fuel tank, the weight of the vehicle's transmission housing, the weight of the engine, the vehicle's 0–60 mph time, and so on) to build a vehicle model, and for practical reasons we cannot acquire 4000 vehicles and obtain these measurements every time we promulgate a new rule (and we cannot acquire vehicles that have not yet been built). Rather, ANL builds a discrete number of vehicle models that are representative of large portions of vehicles in the real world. We refer to the vehicle model's type and performance level as the vehicle's ''technology class.'' By assigning each vehicle in the Market Data Input file a ''technology class,'' we can connect it to the Autonomie effectiveness estimate that best represents how effective the technology would be on the vehicle, taking into account vehicle characteristics like type and performance metrics. Because each vehicle technology class has unique characteristics, the effectiveness of technologies and combinations of technologies is different for each technology class.

There are ten technology classes for the LD analysis: small car (SmallCar), small performance car (SmallCarPerf), medium car (MedCar), medium performance car (MedCarPerf), small SUV (SmallSUV), small performance SUV (SmallSUVPerf), medium SUV (MedSUV), medium performance SUV (MedSUVPerf), pickup truck (Pickup), and high towing pickup truck (PickupHT). There are four technology classes for the HDPUV analysis, based on the vehicle's ''weight class.'' An HDPUV that weighs between 8,501 and 10,000 pounds is in ''Class 2b,'' and an HDPUV that weighs between 10,001 and 14,000 pounds is in ''Class 3.'' Our four HDPUV technology classes are Pickup2b, Pickup3, Van2b, and Van3.

We use a two-step process that involves two algorithms to give vehicles a ''fit score'' that determines which vehicles best fit into each technology class. At the first step we determine the vehicle's size, and at the second step we determine the vehicle's performance level. Both algorithms consider several metrics about the individual vehicle and compare that vehicle to other vehicles in the baseline fleet. This process is discussed in detail in Draft TSD Chapter 2.2.

Consider our Ravine Runner F Series, which is a medium-sized performance SUV. The exact same combination of technologies on the Ravine Runner F Series, which is a medium-sized SUV, will operate differently in a compact car or pickup truck, two different vehicle sizes. Our Ravine Runner F Series also achieves slightly better performance metrics than other medium-sized SUVs in the baseline fleet. When we say, ''performance metrics,'' we mean power, acceleration, handing, braking, and so on, but for the performance fit score algorithm, we consider the vehicle's estimated 0–60 mph time compared to a baseline 0–60 mph time for the vehicle's technology class. Accordingly, the ''technology class'' for the Ravine Runner F Series in our analysis is ''MedSUVPerf''.

Table II–3 shows how vehicles in different technology classes that use the exact same fuel economy technology have very different absolute fuel economy values. Note that, as discussed further below, the Autonomie absolute fuel economy values are not used directly in the CAFE Model; we calculate the ratio between two Autonomie absolute fuel economy values (one for each technology key for a specific technology class) and apply that ratio to a baseline fleet vehicle's starting fuel economy value.

TABLE II–3—EXAMPLES OF TECHNOLOGY CLASS DIFFERENCES

Technology class and technology key	Autonomie absolute fuel economy value (mpg)
MedSUVPerf TURBOD; AT10L2, SS12V; ROLL0; AERO5; MR3	30.8
MedSUV TURBOD; AT10L2, SS12V; ROLL0; AERO5; MR3	34.9
CompactPerf TURBOD; AT10L2, SS12V; ROLL0; AERO5; MR3	42.2
Pickup TURBOD; AT10L2, SS12V; ROLL0; AERO5; MR3	29.7

Let us also return to the concept of what we call technology synergies. Again, depending on the technology, when two technologies are added to the vehicle together, they may not result in an additive fuel economy improvement. This is an important concept to understand because in Section II.D, below, we present technology effectiveness estimates for every single combination of technology that could be applied to a vehicle. In some cases, technology effectiveness estimates show that a combined technology has a different effectiveness estimate than if the individual technologies were added together individually. However, this is expected and not an error. Continuing our example from above, turbocharging technology and DEAC technology both improve fuel economy by reducing the engine displacement, and accordingly burning less fuel. Turbocharging allows a larger naturally aspirated engine to be reduced in size or displacement while still doing the same amount of work, and its fuel efficiency improvements are in part due to the reduced displacement. DEAC effectively makes a larger engine smaller by essentially turning off cylinders, but the engine is able to perform the same amount of work when needed. Therefore, a manufacturer upgrading to an engine that uses both a turbocharger and DEAC technology, like the TURBOD engine in our example above, may not see a significant fuel economy improvement from that specific combination of technologies. Table II–4 shows a vehicle's fuel economy value when using the baseline DEAC technology and when using the baseline turbocharging technology, compared to our vehicle that uses both of those technologies combined with a TURBOD engine.

TABLE II–4—EXAMPLE OF TECHNOLOGY SYNERGIES

MedSUVPerf technology key	Autonomie absolute fuel economy value (mpg)
DOHC; SGDI; AT10L2; SS12V; ROLL0; AERO5; MR3	28.6
DOHC; SGDI; DEAC; AT10L2; SS12V; ROLL0; AERO5; MR3	29.1
TURBO0; AT10L2; SS12V; ROLL0; AERO5; MR3	30.7
TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR3	30.8

As expected, the percent improvement in Table II–4 between the first and second rows is 1.7% and between the third and fourth rows is 0.3%, even though the only difference within the two sets of technology keys is the DEAC technology (note that we only compare technology keys within the same technology class). This is because there are complex interactions between all fuel economy improving technologies. We model these individual technologies and groups of technologies to reduce the uncertainty and improve the accuracy of the CAFE Model outputs.

Some technology synergies that we will discuss in Section II.D include advanced engine and hybrid powertrain technology synergies. As an example, we do not see a particularly high effectiveness improvement from applying advanced engines to existing parallel strong hybrid (*i.e.,* P2) architectures.[116] In this instance, the P2 powertrain improves fuel economy, in part, by allowing the engine to spend more time operating at efficient engine speed and load conditions. This reduces the advantage of adding advanced engine technologies, which also improve fuel economy, by broadening the range of speed and load conditions for the engine to operate at high efficiency. This redundancy in fuel savings mechanism results in a lower effectiveness when the technologies are added to each other. Again, we intend and expect that different combinations of technologies will provide different effectiveness improvements on different vehicle types. This is something we can only see using full vehicle modeling and simulation.

Just as our CAFE Model analysis requires a large set of technology inputs and assumptions, the Autonomie modeling uses a large set of technology inputs and assumptions. Figure II–9 below shows the suite of fuel consumption input data used in the Autonomie modeling to generate the fuel consumption input data we use in the CAFE Model.

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[116] A parallel strong hybrid powertrain is fundamentally similar to a conventional powertrain but adds one electric motor to improve efficiency. Section II.C.1, Technology Options and Pathways, shows all of the parallel strong hybrid powertrain options we model in this analysis.

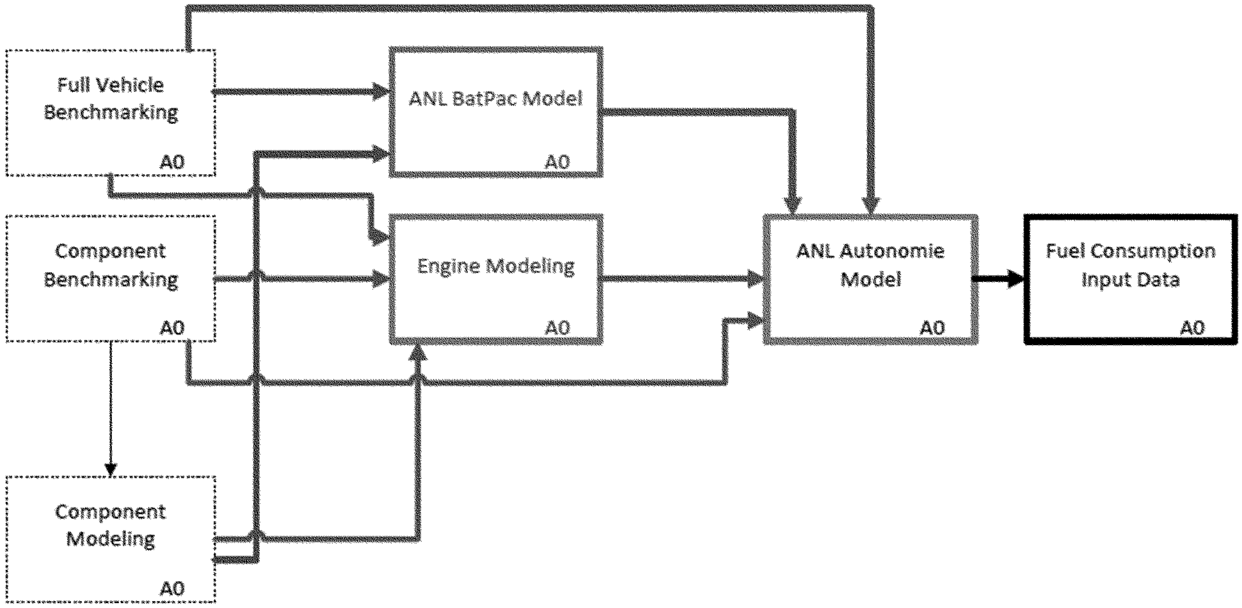

Figure II-9: Fuel Consumption Input Data Used in the Autonomie Modeling

What are each of these inputs? For full vehicle benchmarking, vehicles are instrumented with sensors and tested both on the road and on chassis dynamometers (*i.e.,* the car treadmills used to calculate vehicle's fuel economy values) under different conditions and duty cycles. Some examples of full vehicle benchmarking we did in conjunction with our partners at ANL in anticipation of this rule include benchmarking a 2019 Chevy Silverado, a 2021 Toyota Rav4 Prime, a 2022 Hyundai Sonata Hybrid, a 2020 Tesla Model 3, and a 2020 Chevy Bolt. We produced a report for each vehicle benchmarked, and those are available in the docket and on our website. As discussed further below, that full vehicle benchmarking data is used as inputs to the engine modeling and Autonomie full vehicle simulation modeling. Component benchmarking is like full vehicle benchmarking, but instead of testing a full vehicle, we instrument a single production component or prototype component with sensors and test it on a similar duty cycle as a full vehicle. Examples of components we benchmark are engines, transmissions, axles, electric motors, and batteries. Component benchmarking data are used as an input to component modeling, where a production or prototype component is changed in fit, form and/or function and modeled in the same scenario. As an example, we might model a decrease in the size of holes in fuel injectors to see the fuel atomization impact or see how it affects the fuel spray angle.

We use a range of models to do the component modeling for our analysis. As shown in Figure II–9, battery pack modeling using ANL's BatPaC Model and engine modeling are two of the most significant component models used to generate data for the Autonomie modeling. We discuss BatPaC in detail in Section II.D, but briefly, BatPaC is the battery pack modeling tool we use to estimate the cost of vehicle battery packs, based on the materials chemistry, battery design, and manufacturing design of the plants manufacturing the battery packs.

Engine modeling is used to generate engine fuel map models that define the fuel consumption rate for an engine equipped with specific technologies when operating over a variety of engine load and engine speed conditions. Some performance metrics we capture in engine modeling include power, torque, airflow, volumetric efficiency, fuel consumption, turbocharger performance and matching, pumping losses, and more. Each engine map model has been developed ensuring the engine will still operate under real-world constraints using a suite of other models. Some examples of these models that ensure the engine map models capture real-world operating constraints include simulating heat release through a predictive combustion model, knock characteristics through a kinetic fit knock model,[117] and using physics-based heat flow and friction models, among others. We simulate these constraints using data gathered from component benchmarking, engineering, and physics.

The engine map models are developed by creating a base, or root, engine map and then modifying that root map, incrementally, to isolate the effects of the added technologies. The LD engine maps, developed by IAV using their GT-Power modeling tool and the HDPUV engine maps, developed by SwRI using their GT-Power modeling tool, are based on real-world engine designs. One important feature of both the LD and HDPUV engine maps is that they were both developed using a knock model. As noted above, a knock model ensures that any engine size or specification that we model in the analysis does not result in engine knock, which could damage engine components in a real-world vehicle. Although the same engine map models are used for all vehicle technology classes, the effectiveness varies based on the characteristics of each class. For example, as discussed above, a compact car with a turbocharged engine will

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[117] Engine knock occurs when combustion of some of the air/fuel mixture in the cylinder does not result from propagation of the flame front ignited by the spark plug, but one or more pockets of air/fuel mixture explodes outside of the envelope of the normal combustion front. Engine knock can result in unsteady operation and damage to the engine.

have a different effectiveness value than a pickup truck with the same engine technology type. The engine map model development and specifications are discussed further in Chapter 3 of the Draft TSD.

ANL also compiles a database of vehicle attributes and characteristics that are reasonably representative of the vehicles in that technology class to build the vehicle models. Relevant vehicle attributes may include a vehicle's fuel efficiency, emissions, horsepower, 0–60 mph acceleration time, and stopping distance, among others, while vehicle characteristics may include whether the vehicle has all-wheel-drive, 18-inch wheels, summer tires, and so on. ANL identified representative vehicle attributes and characteristics for both the LD and HDPUV fleets from publicly available information and automotive benchmarking databases such as A2Mac1,[118] ANL's Downloadable Dynamometer Database (D^3),[119] EPA compliance and fuel economy data,[120] EPA's guidance on the cold start penalty on 2-cycle tests,[121] the 21st Century Truck Partnership,[122] [123] [124] and industry partnerships.[125] The resulting vehicle technology class baseline assumptions and characteristics database consists of over 100 different attributes like vehicle height and width and weights for individual vehicle parts.

ANL then assigns ''reference'' technologies to each vehicle model. The reference technologies are the technologies on the first step of each CAFE Model technology pathway, and they closely (but do not exactly) correlate to the technology abbreviations that we use in the CAFE Model. As an example, the first Autonomie vehicle model in the ''MedSUVPerf'' technology class starts out with the least advanced engine, which is ''DOHC'' (a dual overhead cam engine) in the CAFE Model, or ''eng01'' in the Autonomie modeling. The vehicle has the least advanced transmission, AT5, the least advanced MR level, MR0, the least advanced aerodynamic body style, AERO0, and the least advanced ROLL level, ROLL0. The first vehicle model is also defined by initial vehicle attributes and characteristics that consist of data from the suite of sources mentioned above. Again, these attributes are meant to reasonably represent the average of vehicle attributes found on vehicles in a certain technology class.

Then, just as a vehicle manufacturer tests its vehicles to ensure they meet specific performance metrics, Autonomie ensures that the built vehicle model meets its performance metrics. We include quantitative performance metrics in our Autonomie modeling to ensure that the vehicle models can meet real-world performance metrics that consumers observe and that are important for vehicle utility and customer satisfaction. The four performance metrics that we use in the Autonomie modeling for light duty vehicles are low-speed acceleration (the time required to accelerate from 0–60 mph), high-speed passing acceleration (the time required to accelerate from 50–80 mph), gradeability (the ability of the vehicle to maintain constant 65 mph speed on a six percent upgrade), and towing capacity for light duty pickup trucks. We have been using these performance metrics for the last several CAFE Model analyses, and vehicle manufacturers have repeatedly agreed that these performance metrics are representative of the metrics considered in the automotive industry.[126] ANL simulates the vehicle model driving the two-cycle tests (*i.e.,* running its treadmill ''programs'') to ensure that it meets its applicable performance metrics (*e.g.,* our MedSUVPerf does not have to meet the towing capacity performance metric because it is not a pickup truck). For HDPUVs, Autonomie examines sustainable maximum speed at 6 percent grade, start/launch capability on grade, and maximum sustainable grade at highway cruising speed, before examining towing capability to look for the maximum possible vehicle weight over 40 mph in gradeability. This process ensures that the vehicle can satisfy the gradeability requirement (over 40 mph) with additional payload mass to the curb weight. These metrics are based on commonly used metrics in the automotive industry, including SAE J2807 tow requirements.[127] Additional details about how we size light duty and HDPUV powertrains in Autonomie to meet defined performance metrics can be found in the CAFE Analysis Autonomie Documentation.

If the vehicle model does not initially meet one of the performance metrics, then Autonomie's powertrain sizing algorithm increases the vehicle's engine power. The increase in power is achieved by increasing engine displacement (which is the measure of the volume of all cylinders in an engine), which might involve an increase in the number of engine cylinders, which may lead to an increase in the engine weight. This iterative process then determines if the baseline vehicle with increased engine power and corresponding updated engine weight meets the required performance metrics. The powertrain sizing algorithm stops once all the baseline vehicle's performance requirements are met.

Some technologies require extra steps for performance optimization before the

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[118] A2Mac1: Automotive Benchmarking. (Proprietary data). Available at: *https://www.a2mac1.com.* (Accessed: May 31, 2023). A2Mac1 is subscription-based benchmarking service that conducts vehicle and component teardown analyses. Annually, A2Mac1 removes individual components from production vehicles such as oil pans, electric machines, engines, transmissions, among the many other components. These components are weighed and documented for key specifications which is then available to their subscribers.

[119] Downloadable Dynamometer Database (D^3). Argonne National Laboratory, Energy Systems Division. Available at: *https://www.anl.gov/es/downloadable-dynamometer-database.* (Accessed: May 31, 2023).

[120] Data on Cars used for Testing Fuel Economy. EPA Compliance and Fuel Economy Data. Available at: *https://www.epa.gov/compliance-and-fuel-economy-data/data-cars-used-testing-fuel-economy.* (Accessed: May 31, 2023).

[121] EPA PD TSD at 2–265–2–266.

[122] DOE. 2019. 21st Century Truck Partnership Research Blueprint. Available at: *https://www.energy.gov/sites/default/files/2019/02/f59/21CTPResearchBlueprint2019_FINAL.pdf.* (Accessed: May, 31, 2023).

[123] Office of Energy Efficiency & Renewable Energy. 2023. 21st Century Truck Partnership. Available at: *https://www.energy.gov/eere/vehicles/21st-century-truck-partnership.* (Accessed: May 31, 2023).

[124] National Academies of Sciences, Engineering, and Medicine. 2015. Review of the 21st Century Truck Partnership, Third Report. Washington, DC: The National Academies Press. Available at: *https://nap.nationalacademies.org/21784/.* (Accessed: May 31, 2023).

[125] North American Council for Freight Efficiency. Research and analysis. *https://www.nacfe.org/research/overview/.* (Accessed: May 31, 2023).

[126] See, *e.g.,* NHTSA–2021–0053–1492, at 134 (''Vehicle design parameters are never static. With each new generation of a vehicle, manufacturers seek to improve vehicle utility, performance, and other characteristics based on research of customer expectations and desires, and to add innovative features that improve the customer experience. The Agencies have historically sought to maintain the performance characteristics of vehicles modeled with fuel economy-improving technologies. Auto Innovators encourages the Agencies to maintain a performance-neutral approach to the analysis, to the extent possible. Auto Innovators appreciates that the Agencies continue to consider highspeed acceleration, gradeability, towing, range, traction, and interior room (including headroom) in the analysis when sizing powertrains and evaluating pathways for road-load reductions. All of these parameters should be considered separately, not just in combination. (For example, we do not support an approach where various acceleration times are added together to create a single ''performance'' statistic. Manufacturers must provide all types of performance, not just one or two to the detriment of others.)'').

[127] See SAE J2807, Performance Requirements for Determining Tow-Vehicle Gross Combination Weight Rating and Trailer Weight Rating, available at *https://www.sae.org/standards/content/j2807_202002/.*

vehicle models are ready for simulation. Specifically, the sizing and optimization process is more complex for the electrified vehicles (*e.g.,* hybrid electric vehicle (HEVs) and plug-in hybrid electric vehicles (PHEVs) compared to vehicles with only ICEs, as discussed further in the Draft TSD. As an example, a PHEV powertrain that can travel a certain number of miles on its battery energy alone (referred to as all-electric range (AER), or as performing in electric-only mode) is also sized to ensure that it can meet the performance requirements of the SAE standardized drive cycles mentioned above in electric-only mode.

Every time a vehicle model in Autonomie adopts a new technology, the vehicle weight is updated to reflect the weight of the new technology. For some technologies, the direct weight change is easy to assess. For example, when a vehicle is updated to a higher geared transmission, the weight of the original transmission is replaced with the corresponding transmission weight (*e.g.,* the weight of a vehicle moving from a 6-speed automatic (AT6) to an 8-speed automatic (AT8) transmission is updated based on the 8-speed transmission weight). For other technologies, like engine technologies, calculating the updated vehicle weight is more complex. As discussed earlier, modeling a change in engine technology involves both the new technology adoption and a change in power (because the reduction in vehicle weight leads to lower engine loads, and a resized engine). When a vehicle adopts new engine technology, the associated weight change to the vehicle is accounted for based on a regression analysis of engine weight versus power.[128]

In addition to using performance metrics that are commonly used by automotive manufacturers, we instruct Autonomie to mimic real-world manufacturer decisions by only resizing engines at specific periods in the analysis and in specific ways. When a vehicle manufacturer is making decisions about how to change a vehicle model to add fuel economy improving technology, the manufacturer could entirely ''redesign'' the vehicle, or the manufacturer could ''refresh'' the vehicle with relatively more minor technology changes. We discuss how our modeling captures vehicle refreshes and redesigns in more detail below, but for now there are some simple yet important concepts to understand. First, most changes to a vehicle's engine happen when the vehicle is redesigned and not refreshed, as incorporating a new engine in a vehicle is a 10- to 15-year endeavor at a cost of $750 million to $1 billion.[129] But, manufacturers will use that same basic engine, with only minor changes, across multiple vehicle models. We model engine ''inheriting'' from one vehicle to another in both the Autonomie modeling and the CAFE Model. During a vehicle ''refresh'', one vehicle may inherit an already redesigned engine from another vehicle that shares the same platform. In the Autonomie modeling, when a new vehicle adopts fuel saving technologies that are inherited, the engine is not resized (*i.e.,* the properties from the reference vehicle are used directly). While this may result in a small change in vehicle performance, manufacturers have repeatedly and consistently told us that the high costs for redesign and the increased manufacturing complexity that would result from resizing engines for small technology changes preclude them from doing so. In addition, when a manufacturer applies MR technology (*i.e.,* makes the vehicle lighter), the vehicle can use a less powerful engine because there is less weight to move. However, Autonomie will only use a resized engine at certain MR application levels, as a representation of how manufacturers update their engine technologies. Again, this is intended to reflect manufacturer's comments that it would be unreasonable and unaffordable to resize powertrains for every unique combination of technologies. We have determined that our rules about performance neutrality and technology inheritance result in a fleet that is essentially performance neutral.

Why is it important to ensure that the vehicle models in our analysis maintain consistent performance levels? The answer involves how we measure the costs and benefits of different levels of fuel economy standards. In our analysis, we want to capture the costs and benefits of vehicle manufacturers applying fuel-economy-improving technologies to their vehicles. If we modeled increases or decreases in performance because of fuel economy improving technology—for example, say a manufacturer that adds a turbocharger to their engine without downsizing the engine, and then directs all of the additional engine work to additional vehicle horsepower instead of vehicle fuel economy improvements—that increase in performance has a monetized benefit attached to it that is not specifically due to our fuel economy standards. By ensuring that our vehicle modeling remains performance neutral, we can better ensure that we are reasonably capturing the costs and benefits due only to potential changes in the fuel economy standards.

As with past rules, we have analyzed the change in low speed acceleration (0–60 mph) time for four scenarios: (1) MY 2022 under the no action scenario (*i.e.,* No-Action Alternative), (2) MY 2022 under the Preferred Alternative, (3) MY 2032 under the no action scenario, and (4) MY 2032 under the Preferred Alternative.[130] Using the MY 2022 analysis fleet sales volumes as weights, we calculated the weighted average 0–60 mph acceleration time for the analysis fleet in each of the four above scenarios. We identified that the analysis fleet under no action standards in MY 2032 had a 0.5002 percent worse 0–60 mph acceleration time than under the Preferred Alternative, indicating there is minimal difference in performance between the alternatives.

Autonomie then adopts one single fuel saving technology to the baseline vehicle model, keeping everything else the same except for that one technology and the attributes associated with it. Once one technology is assigned to the vehicle model and the new vehicle model meets its performance metrics, the vehicle model is used as an input to the full vehicle simulation. This means that Autonomie simulates the optimized vehicle models for each technology class driving the test cycles we described above. As an example, the Autonomie modeling could start with 14 initial vehicle models (one for each technology class in the LD and HDPUV analysis). Those 14 initial vehicle models use a baseline 5-speed automatic transmission.[131] ANL then builds 14 new vehicle models; the only difference between the 14 new vehicle models and the first set of vehicle models is that the

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[128] See Merriam-Webster, ''regression analysis'' is the use of mathematical and statistical techniques to estimate one variable from another especially by the application of regression coefficients, regression curves, regression equations, or regression lines to empirical data. In this case, we are estimating engine weight by looking at the relationship between engine weight and engine power.

[129] 2015 NAS Report, at 256. It's likely that manufacturers have made improvements in the product lifetime and development cycles for engines since this NAS report and the report that the NAS relied on, but we do not have data on how much. We believe that it is still reasonable to conclude that generating an all new engine or transmission design with little to no carryover from the previous generation would be a notable investment.

[130] The baseline reference for both the No-Action Alternative and the Preferred Alternative is MY 2022 fleet performance.

[131] Note that although both the LD and HDPUV analyses include a 5-speed automatic transmission, the characteristics of those transmissions differ between the two analyses.

new vehicle models have a 6-speed automatic transmission. Replacing the AT5 with an AT6 would lead either to an increase or decrease in the total weight of the vehicle because each technology class includes different assumptions about transmission weight. ANL then ensures that the new vehicle models with the 6-speed automatic transmission meet their performance metrics. Now we have 28 different vehicle models that can be simulated on the two-cycle tests. This process is repeated for each technology option and for each technology class. This results in fourteen separate datasets, each with over 100,000 results, that include information about a vehicle model made of specific fuel economy improving technology and the fuel economy value that the vehicle model achieved driving its simulated test cycles.

We condense the million or so datapoints from Autonomie into three datasets used in the CAFE Model. These three datasets include (1) the fuel economy value (converted into ‘‘fuel consumption’’, which is the inverse of fuel economy; fuel economy is mpg and fuel consumption is gallons per mile) that each modeled vehicle achieved while driving the test cycles, for every technology combination in every technology class; (2) the fuel economy value for PHEVs driving those test cycles, when those vehicles drive on gasoline-only in order to comply with statutory constraints; and (3) optimized battery costs for each vehicle that adopts some sort of electrified powertrain (this is discussed in more detail below).

Now, how does this information translate into the technology effectiveness data that we use in the CAFE Model? An important feature of this analysis is that the fuel economy improvement from each technology and combinations of technologies should be accurate and relative to a consistent baseline vehicle. We use the absolute fuel economy values from the full vehicle simulations only to determine the relative fuel economy improvement from adding a set of technologies to a vehicle, but not to assign an absolute fuel economy value to any vehicle model or configuration. For this analysis, the baseline absolute fuel economy value for each vehicle in the analysis fleet is based on CAFE compliance data. For subsequent technology changes, we apply the incremental fuel economy improvement values from one or more technologies to the baseline fuel economy value to determine the absolute fuel economy achieved for applying the technology change. Accordingly, when the CAFE Model is assessing how to cost-effectively add technology to a vehicle in order to improve the vehicle's fuel economy value, the CAFE Model calculates the difference in the fuel economy value from an Autonomie modeled vehicle with less technology and an Autonomie modeled vehicle with more technology. The relative difference between the two Autonomie modeled vehicles' fuel economy values is applied to the actual fuel economy value of a vehicle in the CAFE Model's baseline fleet.

Let's return to our Ravine Runner F Series, which has a starting fuel economy value of just over 26 mpg and a starting technology key ‘‘TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR3.’’ The equivalent Autonomie vehicle model has a starting fuel economy value of just over 30.8 mpg and is represented by the technology descriptors Midsize_SUV, Perfo, Micro Hybrid, eng38, AUp, 10, MR3, AERO1, ROLL0. In 2028, the CAFE Model determines that Generic Motors needs to redesign the Ravine Runner F Series to reach Generic Motors' new light truck CAFE standard. The Ravine Runner F Series now has lots of new fuel-economy-improving technology—it is a parallel strong HEV with a TURBOE engine, an integrated 8-speed automatic transmission, 30% improvement in ROLL, 20% aerodynamic drag reduction, and 10% lighter glider (*i.e.,* mass reduction). Its new technology key is now P2TRBE, ROLL30, AERO20, MR3. Table II–5 shows how the incremental fuel economy improvement from the Autonomie simulations is applied to the Ravine Runner F Series' starting fuel economy value.

TABLE II–5—EXAMPLE TRANSLATION FROM THE AUTONOMIE EFFECTIVENESS DATABASE TO THE CAFE MODEL

Model	Starting technology key/technology descriptors	MPG	Ending technology key/technology descriptors	MPG
CAFE Model	TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR3.	26.1	P2TRBE, ROLL30, AERO20, MR3	36.3
Autonomie	Midsize_SUV, Perfo, Micro Hybrid, eng38, AUp, 10, MR3, AERO1, ROLL0.	30.8	Midsize_SUV, Perfo, Par HEV, eng37, AUp 8, MR3, AERO4, ROLL3.	42.9

Note that the fuel economy values we obtain from the Autonomie modeling are based on the city and highway test cycles (*i.e.,* the two-cycle test) described above. This is because we are statutorily required to measure vehicle fuel economy based on the two-cycle test.[132] In 2008, EPA introduced three additional test cycles to bring fuel economy ‘‘label’’ values from two-cycle testing in line with the efficiency values consumers were experiencing in the real world, particularly for hybrids. This is known as 5-cycle testing. Generally, the revised 5-cycle testing values have proven to be a good approximation of what consumers will experience while driving, significantly better than the previous two-cycle test values. Although the compliance modeling uses two-cycle fuel economy values, we use the ‘‘on-road’’ fuel economy values, which are the ratio of 5-cycle to 2-cycle testing values (*i.e.,* the CAFE compliance values to the ‘‘label’’ values)[133] to calculate the value of fuel savings to the consumer in the effects analysis. This is because the 5-cycle test fuel economy values better represent fuel savings that consumers will experience from real-world driving. For more information about these calculations, please see Section 5.3.2 of the CAFE Model Documentation, and our discussion of the effects analysis later in this section.

In sum, we use Autonomie to generate physics-based full vehicle modeling and simulation technology effectiveness estimates. These estimates ensure that

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[132] 49 U.S.C. 32904(c) (EPA ‘‘shall measure fuel economy for each model and calculate average fuel economy for a manufacturer under testing and calculation procedures prescribed by the Administrator. However, except under section 32908 of this title, the Administrator shall use the same procedures for passenger automobiles the Administrator used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle), or procedures that give comparable results.'').

[133] We apply a certain percent difference between the 2-cycle test value and 5-cycle test value to represent the gap in compliance fuel economy and real-world fuel economy.

our modeling captures differences in technology effectiveness due to (1) vehicle size and performance relative to other vehicles in the baseline fleet; (2) other technologies on the vehicle and/or being added to the vehicle at the same time; and (3) and how the vehicle is driven. This modeling approach also comports with the NAS 2015 recommendation to use full vehicle modeling supported by application of lumped improvements at the sub-model level.[134] The approach allows the isolation of technology effects in the analysis supporting an accurate assessment.

In our analysis, ''technology effectiveness values'' are the relative difference between the fuel economy value for one Autonomie vehicle model driving the two-cycle tests, and a second Autonomie vehicle model that uses new technology driving the two-cycle tests. We add the difference between two Autonomie-generated fuel economy values to a vehicle in the Market Data Input file's CAFE compliance fuel economy value. We then calculate the costs and benefits of different levels of fuel economy standards using the incremental improvement required to bring a baseline vehicle model's fuel economy value to a level that contributes to a manufacturer's fleet meeting its CAFE standard.

In the next section, Technology Costs, we describe the process of generating costs for the Technology Costs input file.

4. Technology Costs

We estimate present and future costs for fuel-saving technologies based on a vehicle's technology class and engine size. In the Technologies Input file, there is a separate tab for each technology class that includes unique costs for that class (depending on the technology), and a separate tab for each engine size that also contains unique engine costs for each engine size. These technology cost estimates are based on three main inputs. First, we estimate direct manufacturing costs (DMCs), or the component and labor costs of producing and assembling a vehicle's physical parts and systems. DMCs generally do not include the indirect costs of tools, capital equipment, financing costs, engineering, sales, administrative support or return on investment. We account for these indirect costs via a scalar markup of DMCs, which is termed the RPE. Finally, costs for technologies may change over time as industry streamlines design and manufacturing processes. We estimate potential cost improvements from improvements in the manufacturing process with learning effects (LEs). The retail cost of technology in any future year is estimated to be equal to the product of the DMC, RPE, and LE. Considering the retail cost of equipment, instead of merely DMCs, is important to account for the real-world price effects of a technology, as well as market realities. Each of these technology cost components is described briefly below and in the following individual technology sections, and in detail in Chapters 2 and 3 of the Draft TSD.

DMCs are the component and assembly costs of the physical parts and systems that make up a complete vehicle. We estimate DMCs for individual technologies in several ways. Broadly, we rely in large part on costs estimated by the NHTSA-sponsored 2015 NAS study on the Cost, Effectiveness, and Deployment of Fuel Economy Technologies for LDVs and other NAS studies on fuel economy technologies; BatPaC, a publicly available battery pack modeling software developed and maintained by the DOE's ANL, NHTSA-sponsored teardown studies, and our own analysis of how much advanced MR technology (*i.e.,* carbon fiber) is available for vehicles now and in the future; confidential business information (CBI); and off-cycle and AC efficiency costs from the EPA Proposed Determination TSD.[135] While DMCs for fuel-saving technologies reflect the best estimates available today, technology cost estimates will likely change in the future as technologies are deployed and as production is expanded. For emerging technologies, we use the best information available at the time of the analysis and will continue to update cost assumptions for any future analysis.

Our direct costs include materials, labor, and variable energy costs required to produce and assemble the vehicle; however, direct costs do not include production overhead, corporate overhead, selling costs, or dealer costs, which all contribute to the price consumers ultimately pay for the vehicle. These components of retail prices are illustrated in Table II–6 below.

TABLE II–6—RETAIL PRICE COMPONENTS

Direct Costs	
Manufacturing Cost	Cost of materials, labor, and variable energy needed for production.
Indirect Costs	
	Production Overhead
Warranty	Cost of providing product warranty.
Research and Development	Cost of developing and engineering the product.
Depreciation and amortization	Depreciation and amortization of manufacturing facilities and equipment.
Maintenance, repair, operations	Cost of maintaining and operating manufacturing facilities and equipment.
	Corporate Overhead
General and Administrative	Salaries of nonmanufacturing labor, operations of corporate offices, etc.
Retirement	Cost of pensions for nonmanufacturing labor.
Health Care	Cost of health care for nonmanufacturing labor.
	Selling Costs
Transportation	Cost of transporting manufactured goods.
Marketing	Manufacturer costs of advertising manufactured goods.
	Dealer Costs
Dealer selling expense	Dealer selling and advertising expense.
Dealer profit	Net Income to dealers from sales of new vehicles.

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[134] 2015 NAS report, at 292.

[135] Enviromental Protection Agency. 2016. Proposed Determination on the Appropriateness of the Model Year 2022–2025 Light-Duty Vehicle Greenhouse Gas Emissions Standards under the Midterm Evaluation: Technical Support Document. Assessment and Standards Division, Office of Transportation and Air Quality. Available at: *https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P100Q3L4.pdf.* (Accessed: May 31, 2023).

TABLE II–6—RETAIL PRICE COMPONENTS—Continued

Net income	Net income to manufacturers from production and sales of new vehicles.

To estimate total consumer costs (*i.e.,* both direct and indirect costs), we multiply a technology's DMCs by an indirect cost factor to represent the average price for fuel-saving technologies at retail. The factor that we use is the RPE, and it is the most commonly used to estimate indirect costs of producing a motor vehicle. The RPE markup factor is based on an examination of historical financial data contained in 10–K reports filed by manufacturers with the Securities and Exchange Commission (SEC). It represents the ratio between the retail price of motor vehicles and the direct costs of all activities that manufacturers engage in.

For more than three decades, the retail price of motor vehicles has been, on average, roughly 50 percent above the direct cost expenditures of manufacturers.[136] This ratio has been remarkably consistent, averaging roughly 1.5 with minor variations from year to year over this period. At no point has the RPE markup based on 10–K reports exceeded 1.6 or fallen below 1.4.[137] During this time frame, the average annual increase in real direct costs was 2.5 percent, and the average annual increase in real indirect costs was also 2.5 percent. The RPE averages 1.5 across the lifetime of technologies of all ages, with a lower average in earlier years of a technology's life, and, because of LEs on direct costs, a higher average in later years. Many automotive industry stakeholders have either endorsed the 1.5 markup,[138] or have estimated alternative RPE values. As seen in Table II–7, all estimates range between 1.4 and 2.0, and most are in the 1.4 to 1.7 range.

TABLE II–7—ALTERNATE ESTIMATES OF THE RPE[139]

Author and year	Value, comments
Jack Faucett Associates for EPA, 1985	1.26 initial value, later corrected to 1.7+ by Sierra research.
Vyas et al., 2000	1.5 for outsourced, 2.0 for OEM, electric, and hybrid vehicles.
NRC, 2002	1.4 (corrected to > by Duleep).
McKinsey and Company, 2003	1.7 based on European study.
CARB, 2004	1.4 (derived using the JFA initial 1.26 value, not the corrected 1.7+ value).
Sierra Research for AAA, 2007	2.0 or >, based on Chrysler data.
Duleep, 2008	1.4, 1.56, 1.7 based on integration complexity.
NRC, 2011	1.5 for Tier 1 supplier, 2.0 for OEM.
NRC, 2015	1.5 for OEM.

An RPE of 1.5 does not imply that manufacturers automatically mark up each vehicle by exactly 50 percent. Rather, it means that, over time, the competitive marketplace has resulted in pricing structures that average out to this relationship across the entire industry. Prices for any individual model may be marked up at a higher or lower rate depending on market demand. The consumer who buys a popular vehicle may, in effect, subsidize the installation of a new technology in a less marketable vehicle. But, on average, over time and across the vehicle fleet, the retail price paid by consumers has risen by about $1.50 for each dollar of direct costs incurred by manufacturers. Based on our own evaluation and the widespread use and acceptance of the RPE by automotive industry stakeholders, we have determined that the RPE provides a reasonable indirect cost markup for use in our analysis. A detailed discussion of indirect cost methods and the basis for our use of the RPE to reflect these costs, rather than other indirect cost markup methods, is available in the Final Regulatory Impact Analysis (FRIA) for the 2020 final rule.[140]

Finally, manufacturers make improvements to production processes over time, which often result in lower costs. "Cost learning" reflects the effect of experience and volume on the cost of production, which generally results in better utilization of resources, leading to higher and more efficient production. As manufacturers gain experience through production, they refine production techniques, raw material and component sources, and assembly methods to maximize efficiency and reduce production costs.

We estimated cost learning by considering methods established by T.P. Wright and later expanded upon by J.R. Crawford. Wright, examining aircraft production, found that every doubling of cumulative production of airplanes resulted in decreasing labor hours at a fixed percentage. This fixed percentage is commonly referred to as the progress

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[136] Rogozhin, A. et al. 2009. Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers. EPA. RTI Project Number 0211577.002.004. Triangle Park, N.C.; Spinney, B.C. et al. 1999. Advanced Air Bag Systems Cost, Weight, and Lead Time analysis Summary Report. Contract NO. DTNH22–96–0–12003. Task Orders—001, 003, and 005. Washington, DC.

[137] Based on data from 1972–1997 and 2007. Data were not available for intervening years, but results for 2007 seem to indicate no significant change in the historical trend.

[138] Comment submitted by Chris Nevers, Vice President, Energy & Environment, Alliance of Automobile Manufacturers via *Regulations.gov.* Docket ID No. EPA–HQ–OAR–2018–0283–6186, p. 143. Available at: *https://www.regulations.gov/comment/EPA-HQ-OAR-2018-0283-6186.*

[139] Duleep, K.G. 2008. Analysis of Technology Cost and Retail Price. Presentation to Committee on Assessment of Technologies for Improving LDV Fuel Economy. January 25, 2008, Detroit, MI.; Jack Faucett Associates. 1985. Update of EPA's Motor Vehicle Emission Control Equipment Retail Price Equivalent (RPE) Calculation Formula. September 4, 1985. Chevy Chase, MD; McKinsey & Company. 2003. Preface to the Auto Sector Cases. New Horizons—Multinational Company Investment in Developing Economies. San Francisco, CA.; NRC. 2002. Effectiveness and Impact of Corporate Average Fuel Economy Standards. *The National Academies Press.* Washington, DC; NRC. 2011. Assessment of Fuel Economy Technologies for LDVs. The National Academies Press. Washington, DC; NRC. 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies in LDVs. The National Academies Press. Washington, DC; Sierra Research, Inc. 2007. Study of Industry-Average Mark-Up Factors used to Estimate Changes in Retail Price Equivalent (RPE) for Automotive Fuel Economy and Emissions Control Systems. Sierra Research Inc. Sacramento, CA; Vyas, A. et al. 2000. Comparison of Indirect Cost Multipliers for Vehicle Manufacturing. Center for Transportation Research, ANL, April. Argonne, Ill.

[140] 2020 FRIA, at pp. 354–76. Available at *https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/final_safe_fria_web_version_200701.pdf.* (Accessed: May 31, 2023).

rate or progress ratio, where a lower rate implies faster learning as cumulative production increases. J.R. Crawford expanded upon Wright's learning curve theory to develop a single unit cost model, which estimates the cost of the nth unit produced given the following information is known: (1) cost to produce the first unit; (2) cumulative production of n units; and (3) the progress ratio.

Consistent with Wright's learning curve, most technologies in the CAFE Model use the basic approach by Wright, where we estimate technology cost reductions by applying a fixed percentage to the projected cumulative production of a given fuel economy technology in a given MY.[141] We estimate the cost to produce the first unit of any given technology by identifying the DMC for a technology in a specific MY. As discussed above and in detail below and in Chapter 3 of the Draft TSD, our technology DMCs come from studies, teardown reports, other publicly available data, and feedback from manufacturers and suppliers. Because different studies or cost estimates are based on costs in specific MYs, we identify the ''base'' MYs for each technology where the learning factor is equal to 1.00. Then, we apply a progress ratio to back-calculate the cost of the first unit produced. The majority of technologies in the CAFE Model use a progress ratio (*i.e.,* the slope of the learning curve, or the rate at which cost reductions occur with respect to cumulative production) of approximately 0.89, which is derived from average progress ratios researched in studies funded and/or identified by NHTSA and EPA.[142] Figure II–10 shows how technologies on the MY 2022 Ravine Runner Type F decrease in cost over several years. TURBOD and MR3 are technologies that have existed in vehicles for some time, so they show a gradual sloping learning curve implying that cost reductions from learning is moderate and eventually becomes less steep toward MY2050. Conversely, newer technologies such as, AT10L2, SS12V, and AERO5 show an initial steep learning curve where cost reduction occurs at a high rate. Lastly, ROLL0 exhibits a mostly flat curve implying that this level of rolling resistance technology is very mature and does not incur much cost reduction, if at all, from learning.

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[141] We use statically projected cumulative volume production estimates beause the CAFE Model does not support dynamic projections of cumulative volume at this time.

[142] Simons, J.F. 2017. Cost and weight added by the Federal Motor Vehicle Safety Standards for MY 1968–2012 passenger cars and LTVs. Report No. DOT HS 812 354. NHTSA: Washington, DC 30–33; Argote, L. et al. 1997. The Acquisition and Depreciation of Knowledge in a Manufacturing Organization—Turnover and Plant Productivity. Working Paper. Graduate School of Industrial Administration, Carnegie Mellon University; Benkard, C.L. 2000. Learning and Forgetting—The Dynamics of Aircraft Production. The American Economic Review, Vol. 90(4): pp. 1034–54; Epple, D. et al. 1991. Organizational Learning Curves—A Method for Investigating Intra-Plant Transfer of Knowledge Acquired through Learning by Doing. Organization Science, Vol. *2*(1): pp. 58–70; Epple, D. et al. 1996. An Empirical Investigation of the Microstructure of Knowledge Acquisition and Transfer through Learning by Doing. Operations Research, Vol. 44(1): pp. 77–86; Levitt, S. D. et al. 2013. Toward an Understanding of Learning by Doing—Evidence from an Automobile Assembly Plant. Journal of Political Economy, Vol. 121 (4): pp. 643–81.

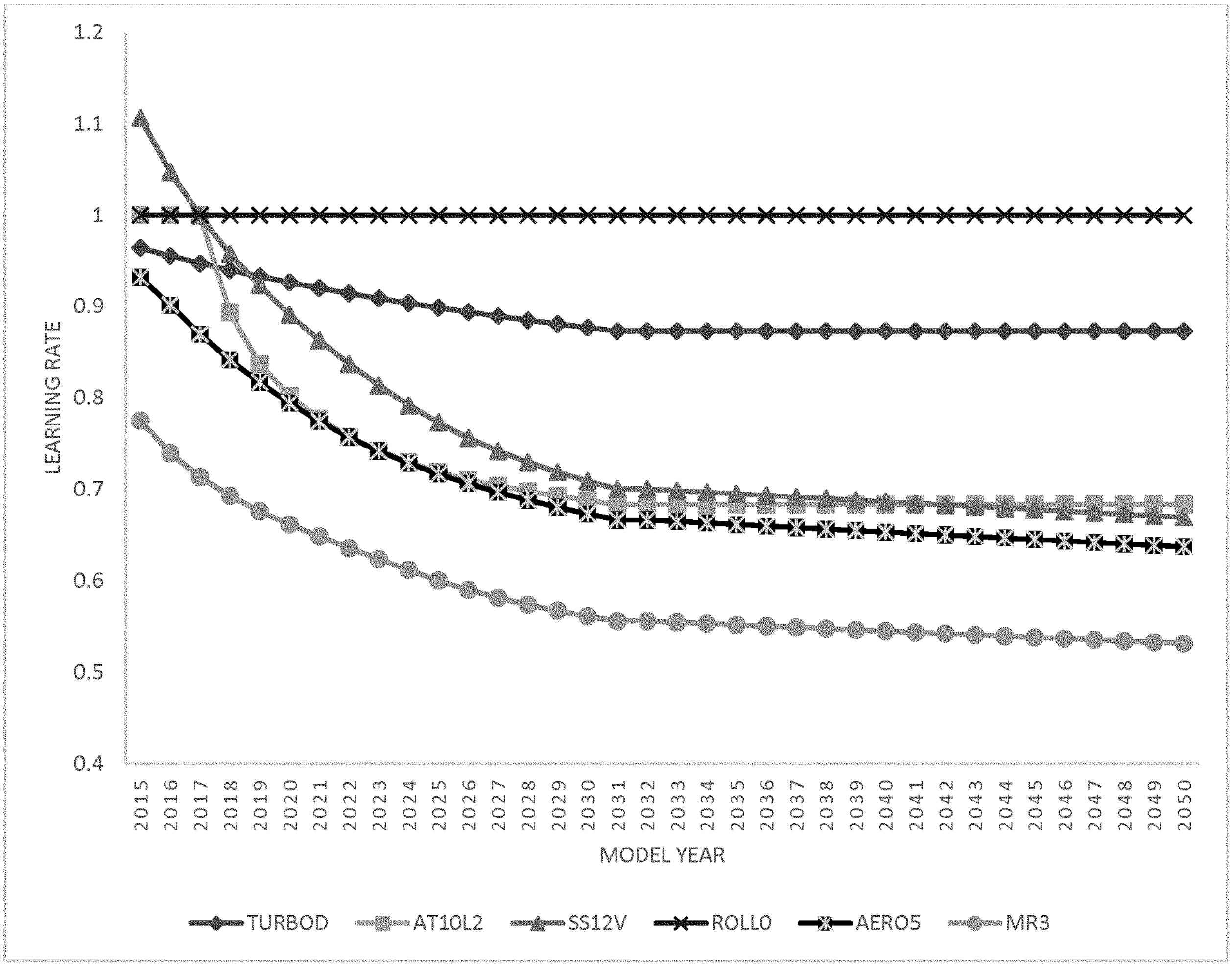

Figure II-10: Learning Curves for Ravine Runner F Series Technologies

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We assign groups of similar technologies or technologies of similar complexity learning curves. While the grouped technologies differ in operating characteristics and design, we chose to group them based on market availability, complexity of technology integration, and production volume of the technologies that can be implemented by manufacturers and suppliers. In general, we consider most base and basic engine and transmission technologies to be mature technologies that will not experience any additional improvements in design or manufacturing. Other basic engine technologies, like VVL, SGDI, and DEAC, do decrease in costs through around MY 2036, because those were introduced into the market more recently. All advanced engine technologies follow the same general pattern of a gradual reduction in costs until MY 2036, when they plateau and remain flat. We expect the cost to decrease as production volumes increase, manufacturing processes are improved, and economies of scale are achieved. We also assigned advanced engine technologies that are based on a singular preceding technology to the same learning curve as that preceding technology. Similarly, the more advanced transmission technologies experience a gradual reduction in costs through MY 2031, when they plateau and remain flat. Lastly, we estimate that the learning curves for road load technologies, with the exception of the most advanced MR level (which decreases at a fairly steep rate through MY 2040, as discussed further below and in Chapter 3.4 of the Draft TSD), will decrease through MY 2036 and then remain flat.

We use the same cost learning rates for both LD and HDPUV technologies. This approach was used in the HDPUV analysis in the Phase 2 Heavy-Duty joint rule with EPA,[143] and we believe that this is an appropriate assumption to continue to use for this analysis. While the powertrains in HDPUVs do have a higher power output than LD powertrains, the designs and technology used will be very similar. Although most HDPUV components will have higher operating loads and provide different effectiveness values than LD components, the overall designs are similar between the technologies. The individual technology design and effectiveness differences between LD and HDPUV technologies are discussed below and in Chapter 3 of the Draft TSD.

For technologies that have been in production for many years, like some engine and transmission technologies, this approach produces reasonable estimates that we can compare against

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[143] See MDHD Phase 2 FRIA at 2–56, noting that gasoline engines used in Class 2b and Class 3 pickup trucks and vans include the engines offered in a manufacturer's light-duty truck counterparts, as well as engines specific to the Class 2b and Class 3 segment, and describing that the the technology definitions are based on those described in the LD analysis, but the effectiveness values are different.

other studies and publicly available data. Generating the learning curve for battery packs for BEVs in future MYs is significantly more complicated, and we discuss how we generated those learning curves in Section II.D and in detail in Chapter 3.3 of the Draft TSD. Our battery pack learning curves recognize that there are many factors that could potentially lower battery pack costs over time outside of the cost reductions due to improvements in manufacturing processes due to knowledge gained through experience in production.

Table II–8 shows how some of the technologies on the MY 2022 Ravine Runner Type F decrease in cost over several years. Note that these costs are specifically applicable to the MedSUVPerf class, and other technology classes may have different costs for the same technologies. These costs are pulled directly from the Technology Costs Input file, meaning that they include the DMC, RPE, and learning.

TABLE II–8—ABSOLUTE COSTS FOR EXAMPLE RAVINE RUNNER TYPE F TECHNOLOGIES

Technology (MedSUVPerf)	CY 2022	CY 2027	CY 2032
TURBOD (8C2B)	$8,924.90	$8,877.31	$8,851.36
AT10L2	2,848.19	2,806.64	2,790.92
SS12V	215.47	191.01	180.28
AERO5	55.30	50.91	48.70

5. Technology Incentives

Similar to the regulations that we are proposing, other government actions have the ability to influence the technology manufacturers apply to their vehicles. For the purposes of this analysis, we incorporate two other government actions into our analysis: state ZEV requirements and Federal tax credits.

a. Simulating the Zero Emissions Vehicle Programs

The California Air Resources Board (CARB) has developed various programs to control emissions of criteria pollutants and GHGs from vehicles sold in California. CARB does so in accordance with Federal CAA; CAA section 209(a) generally preempts states from adopting emission control standards for new motor vehicles,[144] however, Congress created an exemption program in CAA section 209(b) that allows the State of California to seek a waiver of preemption related to adopting or enforcing motor vehicle emissions standards.[145] EPA must grant the waiver unless the Agency makes one of three statutory findings.[146] Under CAA section 177, other States can adopt and enforce standards identical to those approved under California's Section 209(b) waiver.[147] States that do so are sometimes referred to as section 177 states, in reference to section 177 of the CAA Since 1990, CARB has included a Zero-Emission Vehicle (ZEV) program as part of its package of standards that control smog-causing pollutants and GHG emissions from passenger vehicles sold in California,[148] and several states have adopted those ZEV program requirements in accordance with CAA section 177.

There are currently three operative ZEV regulations: ACC I (LD ZEV requirements through MY 2025),[149] ACC II (LD ZEV requirements from MYs 2026–2035),[150] and Advanced Clean Trucks (ACT) (trucks in Classes 2b through 8, for MYs 2024–2035).[151] We include the main provisions of the ACC I, II, and ACT programs in the CAFE Model's analysis of compliance pathways. We are confident that manufacturers will comply with the ZEV programs because they have complied with state ZEV programs in the past and they have made announcements of new ZEVs demonstrating an intent to comply with the requirements going forward. NHTSA models manufacturers' compliance with these programs because accounting for technology improvements that manufacturers would make even in the absence of CAFE standards allows NHTSA to gain a more accurate understanding of the effects of the proposed rulemaking.

This is the third analysis where we have modeled compliance with the ACC program (and now the ACC II and ACT program) requirements in the CAFE Model. While we have in the past received feedback agreeing or disagreeing with the modeling inclusion of the ZEV programs at all, the only past substantive comments on the ZEV program modeling methodology have been requesting the inclusion of more states that have recently signed on to adopt California's standards in our analysis. As noted below, the inclusion or exclusion of states in the analysis depends on which states have signed on to the programs at the time of our analysis. While we are aware of legal challenges to some states' adoption of the ZEV programs, it is beyond the scope of this rulemaking to evaluate the likelihood of success of those challenges. For purposes of our analysis, what is important is predicting, using a reasonable assessment, how the fleet will evolve in the future. The following discussion provides updates to our modeling methodology for the ZEV programs in the analysis.

The ACC I, II, and ACT programs require that increasing levels of manufacturers' sales in California and section 177 states in each MY be ZEVs, specifically BEVs, PHEVs, FCEVs.[152] BEVs, PHEVs, and FCEVs each contribute a different ''value'' towards a manufacturer's annual ZEV requirement, which is a product of the manufacturer's production volume sold in a ZEV state, multiplied by a ''percentage requirement.'' The percentage requirements increase in

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[144] 42 U.S.C. 7543(a).

[145] 42 U.S.C. 7543(b).

[146] See 87 FR 14332 (March 14, 2022). (''The CAA section 209(b) waiver is limited ''to any State which has adopted standards . . . for the control of emissions from new motor vehicles or new motor vehicle engines prior to March 30, 1966,'' and California is the only State that had standards in place before that date.''). NHTSA notes that EPA has not yet granted a waiver of preemption for the ACC II program, and NHTSA does not prejudge EPA's decisionmaking. Nonetheless, NHTSA believes it is reasonable, for reasons discussed in detail below, to consider ZEV sales volumes that manufacturers will produce in response to ACC II as part of our consideration of actions that occur in the absence of fuel economy standards.

[147] 42 U.S.C. 7507.

[148] CARB. Zero-Emission Vehicle Program. Available at: *https://ww2.arb.ca.gov/our-work/programs/zero-emission-vehicle-program/about.* (Accessed: May 31, 2023).

[149] 13 CCR 1962.2.

[150] 13 CCR 1962.4.

[151] CARB. Final Regulation Order: Advanced Clean Trucks Regulation. Available at: *https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2019/act2019/fro2.pdf.* (Accessed: May 31, 2023).

[152] CARB. Final Regulation Order. Available at: *https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/acciifro1962.2.pdf.* (Accessed: May 31, 2023).

each year so that a greater portion of a manufacturer's fleet sold in ZEV states in a particular MY must be ZEVs. For example, a manufacturer selling 100,000 vehicles in California and 10,000 vehicles in Connecticut (both states that have ZEV programs) in MY 2028 must ensure that 51,000 of the California vehicles and 5,100 of the Connecticut vehicles are ZEVs.

At the time of our analysis, sixteen states in addition to California either formally signed on to the ACC II standards or were in the process of adopting them.[153] Although a few states are adopting these requirements in future MYs, we include every state that officially committed to adopting the requirements by the start of December 2022 (regardless of MY start date),[154] which was the time of analysis, as being part of the unified ACC II states group for ease of modeling. We consider all ACC II states together and do not model specific states' years of joining, as states that have recently joined the program have done so within a relatively short span of MYs and represent only a very small percentage of new LDV sales.[155] Similarly, nine states including California have formally adopted the ACT standards at the time of analysis.[156] As other states are currently considering adopting ACT standards, we plan to update this number in the final rule analysis if those states formally adopt it.

It is important to note that not all section 177 states have adopted the ACC II or ACT program components.[157] Furthermore, more states have formally adopted the ACC II program than the ACT program, so the discussion in the following sections will call states that have opted in ''ACC II states'' or ''ACT states.'' Separately, many states signed a memorandum of understanding (MOU) in 2020 to indicate their intent to work collaboratively towards a goal of turning 100% of MD and HD vehicles into ZEVs in the future.[158] For the purposes of CAFE analysis, we include only those states that have formally adopted the ACT in our modeling as ''ACT states''. States that have signed the MOU but not formally adopted the ACT program are referred to as ''MOU states'' and are not included in CAFE modeling. When the term ''ZEV programs'' is used hereafter, it refers to both the ACC II and ACT programs.

Incorporating these programs into the model includes converting vehicles that have been identified as potential ZEV candidates into BEVs at the vehicle's ZEV application year so that a manufacturer's fleet meets its required ZEV credit requirements. We focused on BEVs as ZEV conversions, rather than PHEVs or FCEVs, because, as for 2026–2035, manufacturers cannot earn more than 20% of their ZEV credits through PHEV sales. Similarly, PHEVs receive a smaller number of credits than BEVs and FCEVs since their powertrain still incorporates use of an ICE. We determined that including PHEVs in the ZEV modeling would have introduced unnecessary complication to the modeling and would have provided manufacturers little benefit in the modeled program. In addition, although FCEVs can earn the same number of credits as BEVs, we chose to focus on BEV technology pathways since FCEVs are generally less cost-effective than BEVs and most manufacturers have not been producing them at high volumes.

Total credits are calculated by multiplying the credit value each ZEV receives by the vehicle's volume. In the ACC II program, from 2026 onwards, each full ZEV earns one credit value per vehicle, while partial ZEVs (PHEVs) earn credits based on their AER. In the context of this section, ''full ZEVs'' refers to BEVs and FCEVs, as a PHEV generally receives a smaller number of credits than other ZEVs, as discussed above. Credit targets in the ACT program (referred to as deficits) are calculated by multiplying sales by percentage requirement and weight class multiplier. Each HDPUV full ZEV in the 2b/3 class earns 0.8 credits and each NZEV (called PHEVs in the CAFE Model) earns 0.75 credits.[159]

The CAFE Model is designed to present outcomes at a national scale, so the ZEV programs analysis considers the states as a group as opposed to estimating each state's ZEV credit requirements individually. To capture the appropriate volumes subject to the ACC II and ACT requirements, we calculated each manufacturer's total market share in ACC II or ACT states. We used Polk's National Vehicle Population Profile (NVPP) from January 2022 to calculate these percentages.[160] These data include vehicle characteristics such as powertrain, fuel type, manufacturer, nameplate, and trim level, as well as the state in which each vehicle is sold. At the time of the data snapshot, MY 2021 data from the NVPP contained the most current estimate of new vehicle market shares for most manufacturers, and best represented the registered vehicle population on January 1, 2022. We assumed that new registrations data best approximate new sales given the data options. For MY 2021 vehicles in the latest NVPP, the ACC II State group makes up approximately 38% of the total LD sales in the United States. The ACT state groups comprise approximately 19% of the new Class 2b and 3 vehicle market in the U.S.[161] We based the volumes used for the ZEV credit target calculation on each manufacturer's future assumed market share in ACC II and ACT states. We made this assumption after examining three past years of market share data and determining that the geographic

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[153] California, Colorado, Connecticut, Delaware, Maine, Maryland, Massachusetts, Minnesota, Nevada, New York, New Jersey, New Mexico, Oregon, Rhode Island, Vermont, Virginia, and Washington. See California Air Resource Board. States that have Adopted California's Vehicle Standards under Section 1777 of the Federal Clean Air Act. Available at: *https://ww2.arb.ca.gov/sites/default/files/2022-05/%C2%A7177_states_05132022_NADA_sales_r2_ac.pdf.* (Accessed: May 31, 2023).

[154] See States that have Adopted California's Vehicle Standards under Section 177 of the Federal Clean Air Act, May 13, 2022, *https://ww2.arb.ca.gov/sites/default/files/2022-05/%C2%A7177_states_05132022_NADA_sales_r2_ac.pdf; https://governor.nc.gov/eo-faq/open.* We consider these to be states that have passed laws or have progressed sufficiently in the process of adopting requirements. States indicating interest or that still need to vote on adopting these provisions are not counted in this group.

[155] *Id.*

[156] California, Connecticut, Massachusetts, New Jersey, New York, North Carolina, Oregon, Vermont and Washington. We include Connecticut as their House passed the legislation instructing their Department of Energy and Environmental Protection to adopt ACT. See *https://www.electrictrucksnow.com/states; https://vermontbiz.com/news/2022/november/24/vermont-adopts-rules-cleaner-cars-and-trucks; https://deq.nc.gov/about/divisions/air-quality/motor-vehicles-and-air-quality/advanced-clean-trucks; https://www.cga.ct.gov/2022/fc/pdf/2022HB-05039-R000465-FC.pdf.*

[157] At the time of writing, Pennsylvania has adopted the Low-emission Vehicle standards, but not the ZEV (now ACC II) portion. See Pennsylvania Department of Environmental Protection. Clean Vehicle Program. Available at: *https://www.dep.pa.gov/Business/Air/BAQ/Automobiles/Pages/CleanVehicleProgram.aspx.* (Accessed: May 31, 2023).

[158] Northeast States for Coordinated Air Use Management (NESCAUM). Multi-State Medium and Heavy-Duty Zero Emission Vehicle Memorandum of Understanding. July 13, 2020. Available at: *https://www.nescaum.org/documents/mhdv-zev-mou-20220329.pdf/.* (Accessed: May 31, 2023).

[159] CARB. Final Regulation Order: Advanced Clean Trucks Regulation. Available at: *https://www.cga.ct.gov/2022/fc/pdf/2022HB-05039-R000465-FC.pdf.* (Accessed: May 31, 2023).

[160] National Vehicle Population Profile (NVPP). 2022. Includes content supplied by IHS Markit. Copyright R.L. Polk & Co., 2022. All rights reserved. Available at: *https://repository.duke.edu/catalog/caad9781-5438-4d65-b908-bf7d97a80b3a.* (Accessed: May 31, 2023).

[161] We consulted with Polk and determined that their NVPP data set that included vehicles in the 2b/3 weight class provided the most fulsome dataset at the time of analysis, recognizing that the 2b/3 weight class includes both 2b/3 HD pickups and vans and other classes within 2b/3 segment. While we determined that this dataset was the best option for the analysis, it does not contain all Class 3 pickups and vans sold in the United States.

distribution of manufacturers' market shares remained fairly constant. We welcome comment on the assumptions described in this paragraph.

We calculated total credits required for ACC II and ACT compliance by multiplying the percentages from each program's ZEV requirement schedule by the ACC II or ACT state volumes.[162] For the first set of ACC requirements covering 2022 (the first modeled year in our analysis) through 2025, the percentage requirements start at 14.5% and ramp up in increments to 22 percent by 2025.[163] For ACC II, the percentage requirements start at 35% in MY 2026 and ramp up to 100% in MY 2035 and subsequent years.[164] For ACT Class 2b–3 Group vehicles (equivalent to HDPUVs in our analysis), the percentage requirements start at 5% in MY 2024 and increase to 55% in MYs 2035 and beyond.[165] We then multiply the resulting national sales volume predictions by manufacturer by each manufacturer's total market share in the ACC II or ACT states to capture the appropriate volumes in the ZEV credits calculation. Required credits by manufacturer, per year, are determined within the CAFE Model by multiplying the ACC II state volumes by CARB's ZEV credit percentage requirement for each program respectively.

To ensure that the ACC II and ACT credit requirements are met in the baseline in each modeling scenario, we add ZEV candidate vehicles to the baseline. We flag ZEV candidates in the 'vehicles' worksheet in the Market Data Input File, which is described above and in detail in Draft TSD Chapter 2.2. Although we identify the ZEV candidates in the Market Data Input File, the actual conversion from non-ZEV to ZEV vehicles occurs within the CAFE Model. The CAFE Model converts a vehicle to a ZEV during the specified ZEV application year.

We flag ZEV candidates in two ways: using reference vehicles with ICE powertrains or using PHEVs already in the existing fleet. When using ICE powertrains as reference vehicles, we create a duplicate row (which we refer to as the ZEV candidate row) in the Market Data Input File's Vehicles tab for the ZEV version of the original vehicle, designated with a unique vehicle code. The ZEV candidate row specifies the relevant electrification technology level of the ZEV candidate vehicle (*e.g.,* BEV1, BEV2, and so on), the year that the electrification technology is applied,[166] and zeroes out the candidate vehicle's sales volume. We identify all ICE vehicles with varying levels of technology up to and including strong hybrid electric vehicles (SHEVs) with rows that have 100 sales or more as ZEV candidates. The CAFE Model moves the sales volume from the reference vehicle row to the ZEV candidate row on an as-needed basis, considering the MY's ZEV credit requirements. When using existing PHEVs within the fleet as a starting point for identifying ZEV candidates, we base our determination of ZEV application years for each model based on expectations of manufacturers' future EV offerings. The entire sales volume for that PHEV model row is converted to BEV on the application year. This approach allows for only the needed additional sales volumes to flip to ZEVs, based on the ACC II and ACT targets, and keeps us from overestimating ZEVs in future years.

We identify LD ZEV candidates by duplicating every row with 100 or more sales that is not a PHEV, BEV, or FCEV. We refer to the original rows as 'reference vehicles.' Although PHEVs are all ZEV candidates, we do not duplicate those rows as we focus the CAFE Model's simulation of the ACC II and ACT programs on BEVs. However, any PHEVs already in the analysis fleet or made by the model will still receive the appropriate ZEV credits. While flagging the ZEV candidates, we identified each one as a BEV1, BEV2, BEV3, and BEV4 (BEV technology types based on range), based partly on their price, market segment, and vehicle features. For instance, we assumed luxury cars would have longer ranges than economy cars. We also assigned AWD/4WD variants of vehicles shorter BEV ranges when appropriate. See Draft TSD Chapter 3.3 for more detailed information on electrification options for this analysis. The CAFE Model assigns credit values per vehicle depending on whether the vehicle is a ZEV in a MY prior to 2026 or after, due to the change in value after the update of the standards from ACC II.

We follow a similar process in assigning HDPUV ZEV candidates as in assigning LD ZEV candidates. We duplicate every van row with 100 or more sales and duplicate every pickup truck row with 100 or more sales provided the vehicle model has a WF less than 7,500 and a diesel- or gasoline-based range lower than 500 miles based on their rated fuel economy and fuel tank size. This is consistent with our treatment of HDPUVs in the CAFE technology pathways, which is discussed below in Section II.D and in Draft TSD Chapter 3. Note that the model can still apply PHEV technology to HDPUVs. When identifying ZEV candidates, we assign each candidate as either a BEV1 or a BEV2 based on their price, market segment, and other vehicle attributes.

The CAFE Model brings manufacturers into compliance with ACC II and ACT first in the baseline, solving for the technology compliance pathway used to meet increasing ZEV standards.

We did not include two provisions of the ZEV regulations in our modeling. First, while the ACC II Program includes compliance options for providing reduced-price ZEVs to community mobility programs and for selling used ZEVs (known as ''environmental justice vehicle values''), these are focused on a more local level than we could reasonably represent in the CAFE Model. The data for this part of the program are also not available from real world application. Second, CARB allows for some banking of ZEV credits and credit pooling.[167] We did not assume compliance with ZEV requirements through banking of credits when simulating the program in the CAFE Model and focus instead on simulating manufacturer's compliance fully through the production of new ZEVs. In past rules, we assumed 80% compliance through vehicle requirements and the remaining 20% with banked credits.[168] Due to the complicated nature of accounting for the entire credit program, and after conversations with CARB, we have decided not to incorporate banked credits into the ZEV modeling at this time. Based on guidance from CARB and assessment of CARB's responses to manufacturer comments, we expect impacts of banked credit provisions on overall volumes to be small.[169]

Draft TSD Chapter 2.3 includes more information about the process we use to

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[162] Note that the ACT credit target calculation differs slightly from the ACC II calculation because it includes a vehicle class-specific weight modifier.

[163] 13 CCR 1962.2(b).

[164] 13 CCR 1962.4(c)(1)(B).

[165] 13 CCR 1963.1(b).

[166] The model turns all ZEV candidates into BEVs in 2023, so sales volumes can be shifted from the reference vehicle row to the ZEV candidate row as necessary.

[167] CARB. Final Regulation Order: Section 1962.4, Title 13, California Code of Regulations. Available at: *https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/acciifro1962.2.pdf.* (Acessed: May 31, 2023).

[168] CAFE TSD 2024–2026. Pg. 129.

[169] CARB. Final Statement of Resons for Rulemaking, Including Summary of Comments and Agency Response. Appendix C: Summary of Comments to ZEV Regulation and Agency Response. Available at: *https://ww2.arb.ca.gov/sites/default/files/barcu/regact/2022/accii/fsorappc.pdf.* (Accessed: May 31, 2023).

simulate ACC II and ACT program compliance in this analysis.

b. IRA Tax Credits

The IRA included several new and expanded tax credits intended to encourage the adoption of clean vehicles.[170] NHTSA models two of the IRA provisions in this analysis. The first is the Advanced Manufacturing Production Tax Credit (AMPC). This provision 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).[171] The second provision modeled is the Clean Vehicle Tax Credit (CVC),[172] which provides up to $7,500 toward the purchase of clean vehicles with critical minerals and battery components manufactured in North America.[173] The credits are currently in effect and are scheduled to sunset by 2032.[174] Since the CAFE Model forecasts by model years, and MYs typically are released in the preceding CYs, NHTSA applies the credits to MYs 2024–2033 in the analysis for both LDVs and HDPUVs.

Interactions between producers and consumers in the marketplace tend to ensure that subsidies like the AMPC and the CVC, regardless of whether they are initially paid to producers or consumers, are ultimately shared between the two groups. For this analysis, the agency assumes that manufacturers and consumers will each capture half of the dollar value of the AMPC and CVC. The agency assumes that manufacturers' shares of both credits will offset part of the cost to supply models that are eligible for the credits—PHEVs, BEVs, and FCVs. The subsidies reduce the costs of eligible vehicles and increase their attractiveness to buyers (however, in the LD fleet, the tax credits do not alter the penetration rate of BEVs in the regulatory alternatives).[175] Because the AMPC credit scales with battery capacity, NHTSA staff determined average battery energy capacity by powertrain (*e.g.,* PHEV, BEV, FCV) for passenger cars, light trucks, and HDPUVs based on ANL simulation outputs. For a more detailed discussion of these assumptions, see Draft TSD Chapter 2.3.2.

The CAFE Model's approach to analyzing the effects of the CVC includes another restriction. The CAFE Model accounts for the MSRP restrictions of the CVC by assuming that it cannot be applied to cars with an MSRP above $55,000 or other vehicles with an MSRP above $80,000, since these are ineligible for the incentive. NHTSA recognizes that manufacturers may be unable to comply immediately with the CVC's domestic component and critical mineral sourcing requirements, and that domestic production may ramp-up over the coming years. To reflect this ramp-up, the model phases-in the tax credit. See Chapter 2.5.2 of the Draft TSD for details.

NHTSA is unable to explicitly represent all of the requirements of the CVC. For example, NHTSA cannot capture the income restrictions of the CVC in its analysis because the CAFE Model does not account for purchasers' income. We do not have reliable data on the income levels of consumers purchasing specific models. However, the agency's procedure for modeling MSRP restrictions partially captures the CVC income thresholds indirectly, insofar as high-income buyers are more likely to purchase luxury vehicles that exceed the CVC's MSRP caps.

Nor does NHTSA's analysis explicitly represent the tax credits' accompanying restrictions on the location of final assembly and battery production or the origin of critical minerals. While it is unlikely that all PHEVs, BEVs and FCEVs sold in the United States at any point will meet both the critical mineral and battery component requirements, we do not have a reliable method or source to estimate where production is likely to occur during future MYs, particularly as manufacturers respond to the provisions of the IRA.[176] Instead, we make the simplifying assumption for modeling purposes that all PHEVs, BEVs, and FCEVs produced and sold during the time frame that tax credits are offered will be eligible for those credits subject to the MSRP restrictions discussed above.

To account for these limitations, we assume that the average credit value for the CVC across all PHEV, BEV, and FCEV sales in a given year will never reach its full $7,500 value for all vehicles, and instead assume a maximum average credit value of $5,000. We believe this assumption is also supported by the fact that some manufacturers may have optimized their supply chains and relocating component production to the United States could increase their costs of production, the price to the consumer, or both; and the CVC is a non-refundable tax credit, which means if the credit is claimed by the consumer, their tax liability must be at least $7,500 for the credit to reach its full value.

We seek comment on our methodology for modeling the CVC and AMPC. The agency has also included several sensitivity cases testing different passthrough amounts and maximum credit values. If commenters believe the agency should be modeling additional components of either of the tax credits, the agency requests commenters identify both potential data sources and methodologies.

There are several other provisions of the IRA related to clean vehicles that are excluded from the analysis. The Previously-owned Clean Vehicle credit provides a tax credit for the first resale of a clean vehicle by a qualified dealership.[177] The agency excluded this tax credit because we do not track resale prices in the model, nor do we have a method of distinguishing between dealership and person-to-person sales. Furthermore, this credit is only relevant to our analysis to the extent it may reduce scrappage rates of eligible vehicles, which is outside the capabilities of the model to forecast at this time.

The Commercial Clean Vehicle credit (Commercial Credit) provides commercial entities an alternative to the CVC.[178] The value of the Commercial Credit for vehicles covered by this proposal is the cost differential between a qualified vehicle and a comparable non-qualified vehicle but is capped at $7,500. The Commercial Credit has

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[170] Public Law No: 117–169.

[171] 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. Two other provisions of the AMPC are not modeled at this time; (i) a credit equal to 10 percent of the manufacturing cost of electrode active materials, (ii) a credit equal to 10 percent of the manufacturing cost of critical minerals for battery production. 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.

[172] 26 U.S.C 30D.

[173] There are vehicle price and consumer income limitations on the CVC, as well. See 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).

[174] The AMPC has a phase-out beginning in CY 2030.

[175] In Table 9–4 of the PRIA, both the reference case (labeled ''RC'') and the no tax credit case (''No EV tax credits'') show a 32.3% penetration rate for BEVs in the baseline and preferred alternative.

[176] Note that the labor component of this analysis makes certain assumptions about the location of vehicle production. However, we do not make assumptions about how our standards will alter the origination of components and vehicles. Instead, we assume the porportion of hours spent in the United States to produce a component or assemble a vehicle remains constant, but the quantity of components and vehicles assembled will alter.

[177] 26 U.S.C. 25E.

[178] 26 U.S.C. 45W.

none of the origination and MSRP requirements of the CVC. At the time NHTSA was developing its approach to modeling the IRA tax credits and coordinating with EPA, the Treasury Department had yet to release its guidance on the Commercial Credit and NHTSA was uncertain if vehicles leased to consumers would qualify for the credit or how the incremental value of commercial clean vehicles would be calculated. As such, NHTSA felt that if leased vehicles were ineligible for the Commercial Credit or that the incremental approach could lead to a significant amount of vehicles receiving less than the maximum credit, that the value of the Commercial Credit would be subsumed by our approach to modeling the CVC given we allow all vehicles to qualify for the CVC.

Since then, the Treasury Department has clarified that leased vehicles qualify for the Commercial Credit and that the credit will be calculated based off of the DOE's *Incremental Purchase Cost Methodology and Results for Clean Vehicles* report for at least CY 2023 rather than having the taxpayer estimate the actual cost differential.[179] To the extent that our modeling of the CVC misses vehicles that may qualify for a higher credit through the Commercial Credit, our decision to not model the Commercial Credit may understate the impacts of the IRA.

Given these updates, EPA modified their approach to modeling the IRA tax credits prior to finalizing their Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles proposal.[180] EPA elected to model the CVC and Commercial Credit jointly, which resulted in a quicker phase-in schedule with a higher maximum average credit value than that used in NHTSA's analysis.

NHTSA is considering incorporating EPA's revised approach for modeling the CVC and Commercial Credit jointly for the final rule to account for the guidance issued by the Treasury Department. Under this approach, NHTSA could retain the same basic mechanisms employed to model the CVC but would modify the phase-in and maximum average credit to account for the possibility that the Commercial Credit is available and offers a higher tax benefit than the CVC. NHTSA seeks comment on whether it should adopt this approach, and, if so, specifically requests commenters help identify what would be an appropriate maximum average credit, phase-in schedule, and elasticity share between producers and consumers for this approach. EPA and NHTSA will continue to monitor developments with the IRA tax credits and consult with each other on how best to implement the credits for the analyses supporting their respective final rules.

Finally, the Qualifying Advanced Energy Project credit (48C) provides manufacturers an amount equal to 30 percent of the qualified investment, including building or retooling plants for BEVs, PHEVs, or FCEVs.[181] The agency excluded this tax credit for several reasons. The credit requires Treasury's pre-approval and the total amount of credits awarded under this provision may not exceed $10 billion.[182] Furthermore, the AMPC cannot be claimed for any battery cell or module produced from a project that claimed a Qualifying Advanced Energy Project credit. For the sake of simplicity, we assume that manufacturers will chose the AMPC over the Qualified Advanced Energy Project credit. We also do not model other Federal programs that incentivize the production or purchase of clean vehicles and their infrastructure, such as the IRA § 50142 Advanced Technology Vehicle Manufacturing Loan Program, IRA § 50143 Domestic Manufacturing Conversion Grants, IRA § 70002 USPS Clean Fleets, or IRA § 13404 Alternative Fuel Vehicle Refueling Property Credit. These credits and grants incentivize clean vehicles through avenues the CAFE Model is currently unable to consider as they typically affect a smaller subset of the vehicle market and may influence purchasing decisions through means other than price, *e.g.,* through expanded charging networks.

We do not model individual state tax credit or rebate programs. Unlike ZEV requirements which are uniform across states that adopt them, state clean vehicle tax credits and rebates vary from jurisdiction to jurisdiction and are subject to more uncertainty than their Federal counterparts.[183] Tracking sales by jurisdiction and modeling each program's individual compliance program would require significant revisions to the CAFE Model and likely provide minimal changes in the net outputs of the analysis.

We seek comment on our decision to exclude these credits. Excluding these credits may overstate the projected cost to consumers of certain vehicles. If commenters feel that we should include any of these credits in the final rule, the agency requests commenters address the limitations noted above and provide data sources to assist with modeling the credit.

6. Technology Applicability Equations and Rules

How does the CAFE Model decide how to apply technology to the baseline fleet of vehicles? We described above that the CAFE Model projects cost-effective ways that vehicle manufacturers could comply with CAFE standards, subject to limits that ensure that the model reasonably replicates manufacturer's decisions in the real-world. This section describes the equations the CAFE Model uses to determine how to apply technology to vehicles, including whether technologies are cost-effective, and why we believe the CAFE Model's calculation of potential compliance pathways reasonably represents manufacturers' decision-making. This section also gives a high-level overview of real-world limitations that vehicle manufacturers face when designing and manufacturing vehicles, and how we include those in the technology inputs and assumptions in the analysis.

The CAFE Model begins by looking at a manufacturer's fleet in a given MY and determining whether the fleet meets its CAFE standard. If the fleet does not meet its standard, the model begins the process of applying technology to vehicles. We described above how vehicle manufacturers use the same or similar engines, transmissions, and platforms across multiple vehicle models, and we track vehicle models that share technology by assigning Engine, Transmission, and Platform Codes to vehicles in the analysis fleet. As an example, the Ford 10R80 10-speed transmission is currently used in the following Ford Motor Company vehicles: 2017-present Ford F–150, 2018-present Ford Mustang, 2018-present Ford Expedition/Lincoln Navigator, 2019-present Ford Ranger,

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[179] See responses to Q2–Q4 of Internal Revenue Service Fact Sheet Topic G-Frequently Asked Questions About Qualified Commercial Clean Vehicles Credits. Avaliable at: *https://www.irs.gov/newsroom/topic-g-frequently-asked-questions-about-qualified-commercial-clean-vehicles-credit.* (Accessed: May 31, 2023).

[180] See U.S. EPA. Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles Draft Regulatory Impact Analysis., EPA–420–D–23–003 (April 2023), Chapter 2.6.8 and 2.5.2.1.4. **Federal Register**, Vol. 88, No. 87, Friday, May 5, 2023.

[181] 26 U.S.C. 48C.

[182] Public Law 117–169, section 13502.

[183] States have additional mechanisms to amend or remove tax incentives or rebates. Sometimes, even after these programs are enacted, uncertainty persists, see *e.g.* Farah, N. 2023. The Untimely Death of America's 'Most Equitable' EV Rebate. Last Revised: 01/30/2023. Available at: *https://www.eenews.net/articles/the-untimely-death-of-americas-most-equitable-ev-rebate/.* (Accessed: May 31, 2023)

2020-present Ford Explorer/Lincoln Aviator, and the 2020-present Ford Transit.[184] The CAFE Model first determines whether any technology should be ''inherited'' from an engine, transmission, or platform that currently uses the technology to a vehicle that is due for a refresh or redesign. Using the Ford 10R80 10-speed transmission analysis as applied to the CAFE Model, the above models would be linked using the same Transmission Code. Even though the vehicles might be eligible for technology applications in different years because each vehicle model is on a different refresh or redesign cycle, each vehicle could potentially inherit the 10R80 10-speed transmission. The model then again evaluates whether the manufacturer's fleet complies with its CAFE standard. If it does not, the model begins the process of evaluating what from our universe of technologies could be applied to the manufacturer's vehicles.

The CAFE Model applies the most cost-effective technology out of all technology options that could potentially be applied. To determine whether a particular technology is cost-effective, the model will calculate the ''effective cost'' of multiple technology options and choose the option that results in the lowest ''effective cost.'' The ''effective cost'' calculation is actually multiple calculations, but we only describe the highest levels of that logic here; interested readers can consult the CAFE Model Documentation for additional information on the calculation of effective cost. Equation II–6 shows the CAFE Model's effective cost calculation for this analysis.

$$EffCost = \frac{TechCost_{Total} - TaxCredits_{Total} - FuelSavings_{Total} - \Delta Fines}{\Delta ComplianceCredits}$$

Equation II-6: CAFE Model Effective Cost Calculation

Where:

$TechCost_{Total}$: the total cost of a candidate technology evaluated on a group of selected vehicles;

$TaxCredits_{Total}$: 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;

$FuelSavings_{Total}$: the value of the reduction in fuel consumption (or, fuel savings) resulting from application of a candidate technology evaluated on a group of selected vehicles;

$\Delta Fines$: the change in manufacturer's fines in the analysis year if the CAFE compliance program is being evaluated, or zero if evaluating compliance with CO_2 standards;

$\Delta ComplianceCredits$: the change in manufacturer's compliance credits in the analysis year, which depending on the compliance program being evaluated, corresponds to the change in CAFE credits (denominated in thousands of gallons) or the change in CO_2 credits (denominated in metric tons); and

$EffCost$: the calculated effective cost attributed to application of a candidate technology evaluated on a group of selected vehicles.

For the effective cost calculation, the CAFE Model considers the total cost of a technology that could be applied to a *group* of connected vehicles, just as a vehicle manufacturer might consider what new technologies it has that are ready for the market, and which vehicles should and could receive the upgrade. Next, like the technology costs, the CAFE Model calculates the total value of Federal incentives (for this analysis, Federal tax credits) available for a technology that could be applied to a group of vehicles and subtracts that total incentive from the total technology costs. For example, even though we do not consider the fuel economy of LD BEVs in our standard-setting analysis, we do account for the costs of vehicles that manufacturers may build in response to California's ACC I and ACC II program (and in the HDPUV analysis, the ACT program) as part of our evaluation of how the world would look without our regulation, or more simply, the regulatory baseline. If the CAFE Model is evaluating whether to build a BEV outside of the MYs for which NHTSA is setting standards (if the applicable in the modeling scenario), it starts with the total technology cost for a group of BEVs and subtracts the total value of the tax credits that could be applied to that group of vehicles.

The total fuel savings calculation is slightly more complicated. Broadly, when considering total fuel savings from switching from one technology to another, the CAFE Model must calculate the total fuel cost for the vehicle before application of a technology and subtract the total fuel cost for the vehicle after calculation of that technology. The total fuel cost for a given vehicle depends on both the price of gas (or gasoline equivalent fuel) and the number of miles that a vehicle is driven, among other factors. As technology is applied to vehicles in groups, the total fuel cost is then multiplied by the sales volume of a vehicle in a MY to equal total fuel savings. This equation also includes an assumption that consumers are likely to buy vehicles with fuel economy improving technology that pays for itself within 2.5 years, or 30 months. Finally, in the numerator, we subtract the change in a manufacturer's expected fines before and after application of a specific technology. Then, the result from the sequence above is divided by the change in compliance credits, which means a manufacturer's credits earned (expressed as thousands of gallons for the purposes of effective cost calculation) in a compliance category before and after the application of a technology to a group of vehicles.

The effective cost calculation has evolved over successive CAFE Model iterations to become increasingly more complex; however, manufacturers' decision-making regarding what fuel economy improving technology to add to vehicles has also become increasingly more complex. We believe this calculation appropriately captures a number of manufacturers implicit or explicit considerations.

The model accounts explicitly for each MY, applying technologies when vehicles are scheduled to be redesigned or freshened and carrying forward technologies between MYs once they are applied. The CAFE Model accounts explicitly for each MY because manufacturers actually ''carry forward'' most technologies between MYs, tending to concentrate the application of new technology to vehicle redesigns or mid-cycle ''freshenings,'' and design cycles vary widely among manufacturers and specific products. Comments by manufacturers and model peer reviewers strongly support explicit year-by-year simulation. The multi-year planning capability, simulation of ''market-driven overcompliance,'' and

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[184] DOE. 2013. Light-Duty Vehicles Technical Requirements and Gaps for Lightweight and Propulsion Materials. Final Report. Available at: *https://www.energy.gov/eere/vehicles/articles/workshop-reportlight-duty-vehicles-technical-requirements-and-gaps.* (Accessed: May 31, 2023).

EPCA credit mechanisms increase the model's ability to simulate manufacturers' real-world behavior, accounting for the fact that manufacturers will seek out compliance paths for several MYs at a time, while accommodating the year-by-year requirement. This same multi-year planning structure is used to simulate responses to standards defined in grams CO_2/mile and utilizing the set of specific credit provisions defined under EPA's program.

In addition to the model's technology application decisions pursuant to the compliance simulation algorithm, there are also several technology inputs and assumptions that work together to determine which technologies the CAFE Model can apply. The technology pathways, discussed in detail above, are one significant way that we instruct the CAFE Model to apply technology. Again, the pathways define technologies that are mutually exclusive (*i.e.,* that cannot be applied at the same time), and define the direction in which vehicles can advance as the modeling system evaluates specific technologies for application. Then, the arrows between technologies instruct the model on the order in which to evaluate technologies on a pathway, to ensure that a vehicle that uses a more fuel-efficient technology cannot downgrade to a less efficient option.

In addition to technology pathway logic, we have several technology applicability rules that we use to better replicate manufacturers' decision-making. The ''skip'' input—represented in the Market Data Input File as ''SKIP'' in the appropriate technology column corresponding to a specific vehicle model—is particularly important for accurately representing how a manufacturer applies technologies to their vehicles in the real world. This tells the model not to apply a specific technology to a specific vehicle model. SKIP inputs are used to simulate manufacturer decisions with cost-benefit in mind, including (1) parts and process sharing; (2) stranded capital; and (3) performance neutrality.

First, parts sharing includes the concepts of platform, engine, and transmission sharing, which are discussed in detail in Section II.C.2 and Section II.C.3, above. A ''platform'' refers to engineered underpinnings shared on several differentiated vehicle models and configurations. Manufacturers share and standardize components, systems, tooling, and assembly processes within their products (and occasionally with the products of another manufacturer) to manage complexity and costs for development, manufacturing, and assembly. Detailed discussion for this type of SKIP is provided in the ''adoption features'' section for different technologies, if applicable, in Chapter 3 of the Draft TSD.

Similar to vehicle platforms, manufacturers create engines that share parts. For instance, manufacturers may use different piston strokes on a common engine block or bore out common engine block castings with different diameters to create engines with an array of displacements. Head assemblies for different displacement engines may share many components and manufacturing processes across the engine family. Manufacturers may finish crankshafts with the same tools to similar tolerances. Engines on the same architecture may share pistons, connecting rods, and the same engine architecture may include both six- and eight-cylinder engines. One engine family may appear on many vehicles on a platform, and changes to that engine may or may not carry through to all the vehicles. Some engines are shared across a range of different vehicle platforms. Vehicle model/configurations in the analysis fleet that share engines belonging to the same platform are identified as such, and we also may apply a SKIP to a particular engine technology where we know that a manufacturer shares an engine throughout several of their vehicle models, and the engine technology is not appropriate for any of the platforms that share the same engine.

It is important to note that manufacturers define common engines differently. Some manufacturers consider engines as ''common'' if the engines share an architecture, components, or manufacturing processes. Other manufacturers take a narrower definition, and only assume ''common'' engines if the parts in the engine assembly are the same. In some cases, manufacturers designate each engine in each application as a unique powertrain. For example, a manufacturer may have listed two engines separately for a pair that share designs for the engine block, the crank shaft, and the head because the accessory drive components, oil pans, and engine calibrations differ between the two. In practice, many engines share parts, tooling, and assembly resources, and manufacturers often coordinate design updates between two similar engines. We consider engines together (for purposes of coding, discussed in Section II.C.2 above, and for SKIP application) if the engines share a common cylinder count and configuration, displacement, valvetrain, and fuel type, or if the engines only differed slightly in compression ratio (CR), horsepower, and displacement.

Parts sharing also includes the concept of sharing manufacturing lines (the systems, tooling, and assembly processes discussed above), since manufacturers are unlikely to build a new manufacturing line to build a completely new engine. A new engine that is designed to be mass manufactured on an existing production line will have limits in number of parts used, type of parts used, weight, and packaging size due to the weight limits of the pallets, material handling interaction points, and conveyance line design to produce one unit of a product. The restrictions will be reflected in the usage of a SKIP of engine technology that the manufacturing line would not accommodate.

SKIPs also relate to instances of stranded capital when manufacturers amortize research, development, and tooling expenses over many years, especially for engines and transmissions. The traditional production life cycles for transmissions and engines have been a decade or longer. If a manufacturer launches or updates a product with fuel-saving technology, and then later replaces that technology with an unrelated or different fuel-saving technology before the equipment and research and development investments have been fully paid off, there will be unrecouped, or stranded, capital costs. Quantifying stranded capital costs accounts for such lost investments. One design where manufacturers take an iterative redesign approach, as described in a recent SAE paper,[185] is the MacPherson strut suspension. It is a popular low-cost suspension design and manufacturers use it across their fleet.

As we observed previously, manufacturers may be shifting their investment strategies in ways that may alter how stranded capital could be considered. For example, some suppliers sell similar transmissions to multiple manufacturers. Such arrangements allow manufacturers to share in capital expenditures or amortize expenses more quickly. Manufacturers share parts on vehicles around the globe, achieving greater scale and greatly affecting tooling strategies and costs.

As a proxy for stranded capital in recent CAFE analyses, the CAFE Model

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[185] Pilla, S. et al. 2021. Parametric Design Study of McPherson Strut to Stabilizer Bar Link Bracket Weld Fatigue Using Design for Six Sigma and Taguchi Approach. SAE Technical Paper 2021–01–0235. Available at: *https://doi.org/10.4271/2021-01-0235.* (Accessed: May 31, 2023).

has accounted for platform and engine sharing and includes redesign and refresh cycles for significant and less significant vehicle updates. This analysis continues to rely on the CAFE Model's explicit year-by-year accounting for estimated refresh and redesign cycles, and shared vehicle platforms and engines, to moderate the cadence of technology adoption and thereby limit the implied occurrence of stranded capital and the need to account for it explicitly. In addition, confining some manufacturers to specific advanced technology pathways through technology adoption features acts as a proxy to indirectly account for stranded capital. Adoption features specific to each technology, if applied on a manufacturer-by-manufacturer basis, are discussed in each technology section. We will monitor these trends to assess the role of stranded capital moving forward.

Finally, we ensure that our analysis is performance neutral because the goal is to capture the costs and benefits of vehicle manufacturers adding fuel economy improving technology *because* of CAFE standards,[186] and not to inappropriately capture costs and benefits for changing other vehicle attributes that may have a monetary value associated with them.[187] This means that we ''SKIP'' some technologies where we can reasonably assume that the technology would not be able to maintain a performance attribute for the vehicle, and where our simulation over test cycles may not capture the technology limitation.

For example, prior to the development of SAE J2807, manufacturers used internal rating methods for their vehicle towing capacity. Manufacturers switched to the SAE tow rating standard at the next redesign of their respective vehicles so that they could mitigate costs via parts sharing and remain competitive in performance. Usually, the most capable powertrain configuration will also have the highest towing capacity and can be reflected in using this input feature. Separately, we also ensure that the analysis is performance neutral through other inputs and assumptions, like developing our engine maps assuming use with a fuel grade most commonly available to consumers.[188] [189] Those assumptions are discussed throughout this section, and in Chapters 2 and 3 of the Draft TSD. Technology ''phase-in caps'' and the ''phase-in start years'' are defined in the Technology Cost Input file and offer a way to gradually ''phase-in'' technology that is not yet fully mature to the analysis. They apply to the manufacturer's entire estimated production and, for each technology, define a share of production in each MY that, once exceeded, will stop the model from further applying that technology to that manufacturer's fleet in that MY.

The influence of these inputs varies with regulatory stringency and other model inputs. For example, setting the inputs to allow immediate 100 percent penetration of a technology will not guarantee any application of the technology if stringency increases are low and the technology is not at all cost effective. Also, even if these are set to allow only very slow adoption of a technology, other model aspects and inputs may nevertheless force more rapid application than these inputs, alone, would suggest (*e.g.,* because an engine technology propagates quickly due to sharing across multiple vehicles, or because BEV application must increase quickly in response to ZEV requirements). For this analysis, nearly all of these inputs are set at levels that do not limit the simulation at all.

This analysis also applies phase-in caps and corresponding start years to prevent the simulation from showing unlikely rates of applying battery-electric vehicles (BEVs), such as showing that a manufacturer producing very few BEVs in MY 2022 could plausibly replace every product with a 300- or 400-mile BEV by MY 2026. Also, this analysis applies phase-in caps and corresponding start years intended to ensure that the simulation's plausible application of the highest included levels of MR (20 percent reductions of vehicle ''glider'' weight) do not, for example, outpace plausible supply of raw materials and development of entirely new manufacturing facilities.

These model logical structures and inputs act together to produce estimates of ways each manufacturer could potentially shift to new fuel-saving technologies over time, reflecting some measure of protection against rates of change not reflected in, for example, technology cost inputs. This does not mean that every modeled solution would necessarily be economically practicable. Using technology adoption features like phase-in caps and phase-in start years is one mechanism that can be used so that the analysis better represents the potential costs and benefits of technology application in the rulemaking timeframe.

D. Technology Pathways, Effectiveness, and Cost

The previous section discussed, at a high level, how we generate the technology inputs and assumptions used in the CAFE Model. We do this in several ways: by evaluating data

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[186] One example is GM's 2nd generation High Feature V6 engine manufactured at their Romulus, MI plant (*https://www.gm.com/company/facilities/romulusaccessed2/24/2023*). These engines are represented by engine codes 113601, 113602, 113603 and should all be skipped for HCR due to 113603 being a pickup engine on the GMC Canyon and Chevrolet Colorado. DOT staff will add these skips for the final rule.

[187] *See, e.g.,* 87 FR 25887, citing EPA, Consumer Willingness to Pay for Vehicle Attributes: What is the Current State of Knowledge? (2018) (''The agency has previously attempted to model the potential opportunity cost associated with changes in other vehicle attributes in sensitivity analyses. In those other rulemakings, the agency acknowledged that it is extremely difficult to quantify the potential changes to other vehicle attributes. To accurately do so requires extensive projections about which and how much of other attributes will be altered and a detailed accounting of how much value consumers assigned to those attributes. The agency modeled the opportunity cost associated with changes in other vehicle attributes using published empirical estimates of tradeoffs between higher fuel economy and improvements to other attributes, together with estimates of the values buyers attach to those attributes. The agency does not believe this is an appropriate methodology since there is considerable uncertainty in the literature about how much fuel economy consumers are willing to pay for and how consumers value other vehicle attributes. We note, for example, a recent EPA-commissioned study that 'found very little useful consensus' regarding 'estimates of the values of various vehicle attributes,' which ultimately were 'of little use for informing policy decisions.' '').

[188] *See, e.g.,* 85 FR 24386 (''Vehicle manufacturers typically develop their engines and engine control system calibrations based on the fuel available to consumers. In many cases, manufacturers may recommend a fuel grade for best performance and to prevent potential damage. In some cases, manufacturers may require a specific fuel grade for both best performance, to achieve advertised power ratings, and/or to prevent potential engine damage. Consumers, though, may or may not choose to follow the manufacturer's recommendation or requirement for a specific fuel grade for their vehicle. As such, vehicle manufacturers often choose to employ engine control strategies for scenarios where the consumer uses a lower than recommended, or required, fuel octane level, as a way to mitigate potential engine damage over the life of a vehicle. These strategies limit the extent to which some efficiency improving engine technologies can be implemented, such as increased compression ratio and intake system and combustion chamber designs that increase burn rates and rate of in-cylinder pressure rise. If the minimum octane level available in the market were higher (especially the current sub-octane regular grade in the mountain states), vehicle manufacturers might not feel compelled to design vehicles sub-optimally to accommodate such blends.'').

[189] *Id.* at 24390 (''As described in the NPRM and PRIA, the agencies developed engine maps for technologies that are in production today or that are expected to be available in the rulemaking timeframe. The agencies recognize that engines with the same combination of technologies produced by different manufacturers will have differences in Brake-specific fuel consumption and other performance measures, due to differences in the design of engine hardware (*e.g.,* intake runners and head ports, valves, combustion chambers, piston profile, compression ratios, exhaust runners and ports, turbochargers, etc.), control software, and emission calibration. Therefore, the engine maps are intended to represent the levels of performance that can be achieved on average across the industry in the rulemaking timeframe.'').

submitted by vehicle manufacturers; consolidating publicly available data, press materials, marketing brochures, and other information; collaborative research, testing, and modeling with other Federal agencies; research, testing, and modeling with independent organizations; determining that work done for prior rules is still relevant and applicable; considering feedback from stakeholders on prior rules and meetings conducted prior to the commencement of this rulemaking; and using our own engineering judgment.

This section discusses the specific technology pathways, effectiveness, and cost inputs and assumptions used in the compliance analysis. As an example, interested readers learned in the previous section that the starting point for estimating technology costs is an estimate of the DMC—the component and assembly costs of the physical parts and systems that make up a complete vehicle—for any particular technology; in this section, readers will learn that our transmission technology DMCs are based on estimates from the NAS.

After spending over a decade refining the technology pathways, effectiveness, and cost inputs and assumptions used in successive CAFE Model analyses, we have developed guiding principles to ensure that the CAFE Model's compliance analysis results in impacts that we would reasonably expect to see in the real world. These guiding principles are as follows:

Technologies will have complementary or non-complementary interactions with the full vehicle technology system. The fuel economy improvement from any individual technology must be considered in conjunction with the other fuel-economy-improving technologies applied to the vehicle, because technologies added to a vehicle will not result in a simple additive fuel economy improvement from each individual technology. We expect this result in particular from engine and other powertrain technologies that improve fuel economy by allowing the ICE to spend more time operating at efficient engine speed and load conditions, or from engine technologies that both work to reduce the effective displacement of the engine.

The effectiveness of a technology depends on the type of vehicle the technology is being applied to. When we talk about ''vehicle type'' in our analysis, we're referring to our vehicle technology classes—*e.g.,* a small car, a medium performance SUV, or a pickup truck, among other classes. A small car and a medium performance SUV that use the exact same technology will start with very different fuel economy values; so, when the exact same technology is added to both of those vehicles, the technology will provide a different effectiveness improvement on both of those vehicles.

The cost and effectiveness values for each technology should be reasonably representative of what can be achieved across the entire industry. Each technology model employed in the analysis is designed to be representative of a wide range of specific technology applications used in industry. Some vehicle manufacturers' systems may perform better and cost less than our modeled systems and some may perform worse and cost more. However, employing this approach will ensure that, on balance, the analysis captures a reasonable level of costs and benefits that would result from any manufacturer applying the technology.

The baseline for cost and effectiveness values must be identified before assuming that a cost or effectiveness value could be employed for any individual technology. For example, as discussed below, this analysis uses a set of engine map models that were developed by starting with a small number of baseline engine configurations, and then, in a very systematic and controlled process, adding specific well-defined technologies to create a new map for each unique technology combination. Again, providing a consistent reference point to measure incremental technology effectiveness values ensures that we are capturing accurate effectiveness values for each technology combination.

The following sections discuss the engine, transmission, electrification, MR, aerodynamic, ROLL, and other vehicle technologies considered in this analysis. The following sections discuss:

- How we define the technology in the CAFE Model,[190]
- How we assigned the technology to vehicles in the analysis fleet used as a starting point for this analysis,
- Any adoption features applied to the technology, so the analysis better represents manufacturers' real-world decisions,
- The technology effectiveness values, and
- Technology cost.

Please note that the following technology effectiveness sections provide *examples* of the *range* of effectiveness values that a technology could achieve when applied to the entire vehicle system, in conjunction with the other fuel-economy-improving technologies already in use on the vehicle. To see the incremental effectiveness values for any particular vehicle moving from one technology key to a more advanced technology key, see the CAFE Model Fuel Economy Adjustment Files that are installed as part of the CAFE Model Executable File, and not in the input/output folders. Similarly, the technology costs provided in each section are *examples* of absolute costs seen in specific MYs, for specific vehicle classes. Please refer to the Technologies Input File to see all absolute technology costs used in the analysis across all MYs.

For the LD analysis we show two sets of technology effectiveness charts for each technology type, titled ''Unconstrained'' and ''Standard Setting.'' For the Standard Setting charts, effectiveness values reflect the application of 49 U.S.C. 32902(h) considerations to the technologies; for example, PHEV technologies only show the effectiveness achieved when operating in a gasoline only mode (charge sustaining mode). The Unconstrained charts show the effectiveness values modeled for the technologies without the 49 U.S.C; 32902(h) constraints; for example, PHEV technologies show effectiveness for their full dual fuel use functionality. The standard setting values are used during the standard setting years being assessed in this analysis, and the unconstrained values are used for all other years.

1. Engine Paths

ICEs convert chemical energy in fuel to useful mechanical power. The chemical energy is converted to mechanical power by being burned or oxidized inside the engine. The air/fuel mixture entering the engine and burned fuel/exhaust by-products leaving the engine are the working fluids in the engine. The engine power output is a direct result of the work interaction between these fluids and the mechanical components of the engine.[191] The generated mechanical power is used to perform useful work, such as vehicle propulsion. For a complete discussion on fundamentals of engine characteristics, such as torque, torque maps, engine load, power density, brake mean effective pressure (BMEP), combustion cycles, and

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[190] Note, due to the diversity of definitions industry sometimes employs for technology terms, or in describing the specific application of technology, the terms defined here may differ from how the technology is defined in the industry.

[191] Heywood, John B. Internal Combustion Engine Fundamentals. McGraw-Hill Education, 2018. Chapter 1.

components, please refer to *Heywood* 2018.[192]

We classify the extensive variety of both LD and HDPUV vehicle IC engine technologies into discrete Engine Paths. These paths are used to model the most representative characteristics, costs, and performance of the fuel-economy improving engine technologies most likely available during the rulemaking time frame. The paths are intended to be representative of the range of potential performance levels for each engine technology. In general, the paths are tied to ease of implementation of additional technology and how closely related the technologies are. The technology paths for LD and HDPUV can be seen in Figure II–11 and Figure II–12 respectively.

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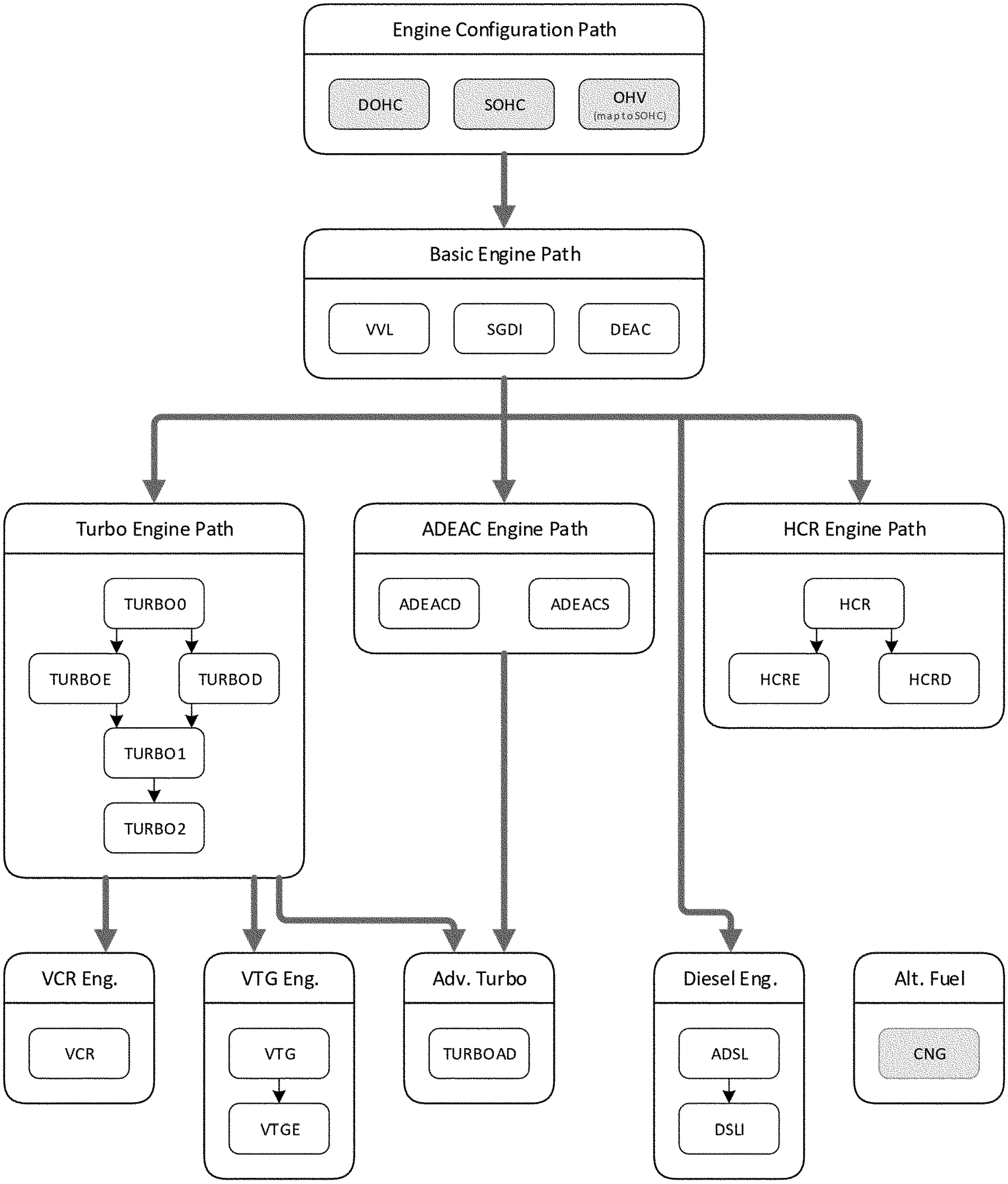

Figure II-11: LD Engine Paths

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[192] Heywood, John B. Internal Combustion Engine Fundamentals. McGraw-Hill Education, 2018.

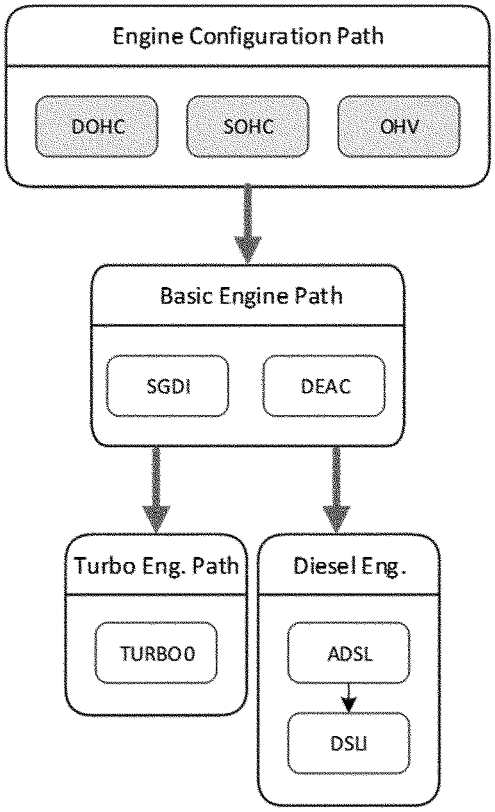

Figure II-12: HDPUV Engine Paths

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The LD Engine Paths have been selected and refined over a period of more than ten years, based on engines in the market, stakeholder comments, and our engineering judgment, subject to the following factors: we included technologies most likely available during the rulemaking time frame and the range of potential performance levels for each technology, and excluded technologies unlikely to be feasible in the rulemaking timeframe, technologies unlikely to be compatible with U.S. fuels, or technologies for which there was not appropriate data available to allow the simulation of effectiveness across all vehicle technology classes in this analysis.

For technologies on the HDPUV Engine Paths, we revisited work done for the HDPUV analysis in the Phase 2 rulemaking. We have updated our HDPUV Engine Paths based on that work, the availability of technology in the HDPUV baseline fleet, and technologies we believe will be available in the rulemaking timeframe. The HDPUV fleet is significantly smaller than the LD fleet with the majority of vehicles being produced by only three manufacturers. These vehicles include work trucks and vans that are focused on transporting people, moving equipment and supplies, and tend to be more focused on a common need than that of vehicles in the LD fleet, which includes everything from sports cars to commuter cars and pickup trucks. The engines options between the two fleets are different in the real world and are accordingly different in the analysis. HDPUVs are work vehicles and their engines must be able to handle the additional work such as higher payloads, towing, and additional stop and go demands. This results in HDPUVs often requiring larger, more robust, and more powerful engines. As a result of the HDPUV's smaller fleet size and narrowed focus, fewer engines and engine technologies are developed or used in this fleet. That said, we believe that the range of technologies between the HDPUV Engine Paths and Electrification/Hybrid/Electrics Path presents a reasonable representation of powertrain options available for HDPUVs now and in the rulemaking time frame.

We begin defining engine technology options by defining potential engine configurations: dual over-head camshaft (DOHC) engines have two camshafts per cylinder head (one operating the intake valves and one operating the exhaust valves), single over-head camshaft (SOHC) engines have a single camshaft, and over-head valve (OHV) engines also have a single camshaft located inside of the engine (south of the valves rather than over-head) connected to a rocker arm that actuates the valves. DOHC and SOHC engine configurations are common in the LD fleet, while OHV engine configurations are more common in the HDPUV fleet.

The next step along the Engine Paths is at the Basic Engine Path technologies. These include variable valve lift (VVL), stoichiometric gasoline direct injection (SGDI), and a basic level of cylinder deactivation (DEAC). VVL dynamically adjusts how far the valve opens and reduces fuel consumption by reducing pumping losses and optimizing airflow over broader range of engine operating conditions. Instead of injecting fuel at lower pressures and before the intake valve, SGDI injects fuel directly into the cylinder at high pressures allowing for more precise fuel delivery while providing a cooling effect and allowing for an increase in the CR and/or more optimal spark timing for improved efficiency. DEAC disables the intake and exhaust valves and turns off fuel injection on select cylinders which effectively, allows the engine to operate temporarily as if it were smaller while also reducing pumping losses to improve efficiency. New for this analysis is that variable valve timing (VVT) technology is integrated in all non-diesel engines, so we do not have a separate box for it on the Basic Engine Path. For the LD analysis, VVL, SGDI, and DEAC can be applied to an engine individually or in combination with each other, and for the HDPUV analysis, SGDI and DEAC can be applied individually or in combination.

Moving beyond the Basic Engine Path technologies are the ''advanced'' engine technologies, which means that applying the technology—both in our analysis and in the real world—would require significant changes to the structure of the engine or an entirely new engine architecture. The advanced engine technologies represent the application of alternate combustion cycles, various applications of forced induction technologies, or advances in cylinder deactivation.

Advanced cylinder deactivation (ADEAC) systems, also known as rolling or dynamic cylinder deactivation systems, allow the engine to vary the percentage of cylinders deactivated and the sequence in which cylinders are deactivated. Depending on the engine's speed and associated torque requirements, an engine might have most cylinders deactivated (*e.g.,* low torque conditions as with slower speed driving) or it might have all cylinders activated (*e.g.,* high torque conditions as with merging onto a highway).[193] An engine operating at low speed/low torque conditions can then save fuel by operating as if it is only a fraction of its total displacement. We model two ADEAC technologies, advanced cylinder deactivation on a single overhead camshaft engine (ADEACS), and advanced cylinder deactivation on a dual overhead camshaft engine (ADEACD).

Forced induction gasoline engines include both supercharged and turbocharged downsized engines, which can pressurize or force more air into an engine's intake manifold when higher power output is needed. The raised pressure results in an increased amount of airflow into the cylinder supporting combustion, increasing the specific power of the engine. The baseline turbocharged downsized technology (TURBO0) engine represents a basic level of forced air induction technology being applied to a DOHC engine. Cooled exhaust gas recirculation (CEGR) systems take engine exhaust gasses and passes them through a heat exchanger to reduce their temperature, and then mixes them with incoming air in the intake manifold. We model the base TURBO0 turbocharged engine with cooled exhausted recirculation (TURBOE), basic cylinder deactivation (TURBOD), and advanced cylinder deactivation (TURBOAD). Walking down the Turbo Engine Path leads to engines that have higher BMEP, which is a function of displacement and power. The higher the BMEP, the higher the engine performance. We model two levels of advanced turbocharging technology (TURBO1 and TURBO2) that run increasingly higher turbocharger boost levels, burning more fuel, and making more power for a given displacement. As discussed above, we pair turbocharging with engine downsizing, meaning that the turbocharged downsized engines in our analysis improve vehicle fuel economy by using less fuel to power the smaller engine while maintaining vehicle performance.

In this analysis, high compression ratio (HCR) engines represent a class of engines that achieve a higher level of fuel efficiency by implementing a high geometric CR with varying degrees of late intake valve closing (LIVC) (*i.e.,* closing the intake valve later than usual) using VVT, and without the use of an electric drive motor.[194] [195] These engines operate on a modified Atkinson cycle allowing for improved fuel efficiency under certain engine load conditions but still offering enough power to not require an electric motor; however, there are limitations on how HCR engines can apply LIVC and the types of vehicles that can use this technology. The way that each individual manufacturer implements a modified Atkinson cycle will be unique, as each manufacturer must balance not only fuel efficiency considerations, but emissions, on-board diagnostics, and safety considerations that includes the vehicle being able to operate responsively to the driver's demand.

We define HCR engines as being naturally aspirated, gasoline, SI, using a geometric CR of 12.5:1 or greater,[196] and able to dynamically apply various levels of LIVC based on load demand. An HCR engine uses less fuel for each engine cycle, which increases fuel economy, but decreases power density (or torque). Generally, during high loads—when more power is needed—the engine will use variable valve actuation to reduce the level of LIVC by closing the intake valve earlier in the compression stroke (leaving more fuel in the compression chamber), increasing the effective CR, reducing over-expansion, and sacrificing efficiency for increased power density.[197] However, there is a limit to how much fuel can remain in the compression chamber of an HCR engine because over-compression of the air-fuel mixture can lead to engine knock.[198] Conversely, at low loads the engine will typically increase the level of LIVC by closing the intake valve later in the compression stroke, reducing the effective CR, increasing the over-expansion, and sacrificing power density for improved efficiency. By closing the intake valve later in the compression stroke (*i.e.,* applying more LIVC), the engine's displacement is effectively reduced, which results in less air and fuel for combustion and a lower power output.[199] Varying LIVC can be used to mitigate, but not eliminate, the low power density issues that can constrain the application of an Atkinson-only engine.

When we say, ''lower power density issues,'' this translates to a low torque density,[200] meaning that the engine cannot create the torque required at necessary speeds to meet load demands. To the extent that a vehicle requires more power in a given condition than an engine with low power density can provide, that engine would experience issues like engine knock for the reasons discussed above, but more importantly, an engine designer would not allow an engine application where the engine has the potential to operate in unsafe conditions in the first place. Instead, a manufacturer could significantly

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[193] See for example, Dynamic Skip Fire, Tula Technology, DSF in real world situations, *https://www.tulatech.com/combustion-engine/.* Our modeled ADEAC system is not based on this specific system, and therefore the effectiveness improvement will be different in our analysis than with this system, however, the theory still applies.

[194] Late intake valve closing (LIVC) is a method manufacturers use to reduce the effective compression ratio and allow the expansion ratio to be greater than the compression ratio resulting in improved fuel economy but reduced power density. Further technical discussion on HCR and Atkinson Engines are discussed in Draft TSD Chapter 3.1.1.2.3.

[195] See the 2015 NAS report, Appendix D, for a short discussion on thermodynamic engine cycles.

[196] Note that even if an engine has a compression ratio of 12.5:1 or greater, it does not necessarily mean it is an HCR engine in our analysis, as discussed below. We look at a number of factors to perform baseline engine assignments.

[197] Variable valve actuation is a general term used to describe any single or combination of VVT, VVL, and variable valve duration used to dynamically alter an engines valvetrain during operation.

[198] Engine knock in spark ignition engines occurs when combustion of some of the air/fuel mixture in the cylinder does not result from propagation of the flame front ignited by the spark plug, but one or more pockets of air/fuel mixture explodes outside of the envelope of the normal combustion front.

[199] Power = (force × displacement)/time.

[200] Torque = radius × force.

increase an engine's displacement (*i.e.,* size) to overcome those low power density issues,[201] or could add an electric motor and battery pack to provide the engine with more power, but a far more effective pathway would be to apply a different type of engine technology, like a downsized, turbocharged engine.[202]

Vehicle manufacturers' intended performance attributes for a vehicle—like payload and towing capability, intention for off-road use, and other attributes that affect frontal area and rolling resistance—dictate whether an HCR engine can be a suitable technology choice for that vehicle.[203] [204] As vehicles require higher payloads and towing capacities,[205] or experience road load increases from larger all-terrain tires or a larger frontal area and less aerodynamic design, or experience driveline losses for AWD and 4WD configurations, more engine torque is required at all engine speeds. Any time more engine torque is required the application of this technology becomes less effective and more limited.[206] For these reasons, to maintain a performance-neutral analysis, and as discussed further below, we limit non-hybrid and non-plug-in-hybrid HCR engine application to certain categories of vehicles.[207] Also for these reasons, HCR engines are not found in the HDPUV baseline fleet nor are they available as an engine option in the HDPUV analysis.

For this analysis, our HCR Engine Path includes three technology options: (1) a baseline Atkinson-enabled engine (HCR) with VVT and SGDI, (2) an Atkinson enabled engine with cooled exhaust gas recirculation (HCRE), and finally, (3) the Atkinson enabled engine with DEAC (HCRD). This updated family of HCR engine map models also reflects our statement in NHTSA's May 2, 2022 final rule that a single engine that employs an HCR, CEGR, *and* DEAC ''is unlikely to be utilized in the rulemaking timeframe based on comments received from the industry leaders in HCR technology application.'' [208]

These three HCR Engine Path technology options (HCR, HCRE, HCRD) should not be confused with the hybrid and plug-in hybrid electric pathway options that also utilize HCR engines in combination with an electrified powertrain (*i.e.,* P2HCR, P2HCRE, PHEV20H, and PHEV50H); those hybridization path options are discussed in Section II.D.3, below. In contrast, Atkinson engines in this analysis (SHEVPS, PHEV20PS, and PHEV50PS) run the Atkinson Cycle full time, but are connected to an electric motor. The full-time Atkinson engines are discussed in Section II.D.3 below.

The Miller cycle is another alternative combustion cycle that uses an extended expansion stroke, similar to the Atkinson cycle, to improve fuel efficiency. Miller cycle-enabled engines have a similar trade-off in power density as Atkinson engines; the lower power density requires a larger volume engine in comparison to an Otto cycle-based turbocharged system for similar applications.[209] To address the impacts of the extended expansion stroke on power density during high load operating conditions, the Miller cycle operates in combination with a forced induction system. In our analysis, the baseline Miller cycle-enabled engine includes the application of variable turbo geometry technology (VTG), or what is also known as a variable-geometry turbocharger. VTG technology allows the turbocharger to adjust key geometric characteristics of the system, thus allowing adjustment of boost profiles and response based on the engine's operating needs. The adjustment of boost profile during operation increases the engine's power density over a broader range of operating conditions and increases the functionality of a Miller cycle-based engine. The use of a variable geometry turbocharger also supports the use of CEGR. The second level of VTG Engine technology in our analysis (VTGE) is an advanced Miller cycle-enabled system that includes the application of at least a 40V-based electronic boost system. An electronic boost system has an electric motor added to assist the turbocharger; the motor assist mitigates turbocharger lag and low boost pressure by providing the extra boost needed to overcome the torque deficit at low engine speeds.

Variable compression ratio (VCR) engines work by changing the length of the piston stroke of the engine to optimize the CR and improve thermal efficiency over the full range of engine operating conditions. Engines that use VCR technology are currently in production as small displacement turbocharged in-line four-cylinder, high BMEP applications.

Diesel engines have several characteristics that result in better fuel efficiency over traditional gasoline engines, including reduced pumping losses due to lack of (or greatly reduced) throttling, high pressure direct injection of fuel, a combustion cycle that operates at a higher CR, and a very lean air/fuel mixture relative to an equivalent-performance gasoline engine. However, diesel technologies require additional systems to control NO_X emissions, such as a NO_X adsorption catalyst system or a urea/ammonia selective catalytic reduction system. We included two

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[201] But see the 2022 EPA Trends Report at 46 (''As vehicles have moved towards engines with a lower number of cylinders, the total engine size, or displacement, is also at an all-time low.''), and the discussion below about why we do not believe manufacturers will increase the displacement of HCR engines to make the necessary power.

[202] See, *e.g.,* Toyota Newsroom. 2024 Toyota Tacoma Makes Debut on the Big Island, Hawaii. May 19, 2023. Available at: *https://pressroom.toyota.com/2024-toyota-tacoma-makes-debut-on-the-big-island-hawaii/.* (Accessed: May 31, 2023). The 2024 Toyota Tacoma comes in 8 ''grades,'' all of which use a turbocharged engine.

[203] Supplemental Comments of Toyota Motor North America, Inc., Notice of Proposed Rulemaking: Safer Affordable Fuel-Efficient Vehicles Rule, Docket ID Numbers: NHTSA–2018–0067 and EPA–HQ–OAR–2018–0283. p.6.

[204] Feng, R. et al. 2016. Investigations of Atkinson Cycle Converted from Conventional Otto Cycle Gasoline Engine. SAE Technical Paper. Available at: *https://www.sae.org/publications/technical-papers/content/2016-01-0680/.* (Accessed: May 31, 2023).

[205] See Tucker, S. 2023. What Is Payload: A Complete Guide, Kelly Blue Book. Last revised: Feb. 2, 2023. Availale at: *https://www.kbb.com/car-advice/payload-guide/#link3.* (Accessed: May 31, 2023). (''Roughly speaking, payload capacity is the amount of weight a vehicle can carry, and towing capacity is the amount of weight it can pull. Automakers often refer to carrying weight in the bed of a truck as hauling to distinguish it from carrying weight in a trailer or towing.'').

[206] Supplemental Comments of Toyota Motor North America, Inc., Notice of Proposed Rulemaking: Safer Affordable Fuel-Efficient Vehicles Rule, Docket ID Numbers: NHTSA–2018–0067 and EPA–HQ–OAR–2018–0283. (''Tacoma has a greater coefficient of drag from a larger frontal area, greater tire rolling resistance from larger tires with a more aggressive tread, and higher driveline losses from 4WD. Similarly, the towing, payload, and off road capability of pick-up trucks necessitate greater emphasis on engine torque and horsepower over fuel economy.

This translates into engine specifications such as a larger displacement and a higher stroke-to-bore ratio. . . . Tacoma's higher road load and more severe utility requirements push engine operation more frequently to the less efficient regions of the engine map and limit the level of Atkinson operation . . . This endeavor is not a simple substitution where the performance of a shared technology is universal. Consideration of specific vehicle requirements during the vehicle design and engineering process determine the best applicable powertrain.'').

[207] To maintain performance neutrality when sizing powertrains and selecting technologies we perform a series of simulations in Automime which are further discussed in the TSD Chapter 2.3.4 and in the CAFE Analysis Autonomie Documentation. The concept of performance neutrality is discussed in detail above in Section II.C.3, Technology Effectiveness Values, and additional reasons why we maintain a performance neutral analysis are discussed in Section II.C.6, Technology Applicability Equations and Rules.

[208] 87 FR 25796 (May 2, 2022).

[209] National Academies of Sciences, Engineering, and Medicine. 2021. Assessment of Technologies for Improving Light-Duty Vehicle Fuel Economy 2025–2035.The National Academies Press: Washington, DC. Section 4. Available at: *https://doi.org/10.17226/26092.* (Accessed: May 31, 2023). [hereinafter 2021 NAS report].

levels of diesel engine technology in both the LD and HDPUV analyses: the baseline diesel engine technology (ADSL) is a turbocharged diesel engine, and the more advanced diesel engine (DSLI) adds DEAC to the ADSL engine technology. The diesel engine maps are new for this analysis. The LD diesel engine maps and HD van engine maps are based on a modern 3.0L turbo-diesel engine, and the HDPUV pickup truck engine maps are based on a larger 6.7L turbo-diesel engine.

Finally, compressed natural gas (CNG) systems are ICEs that run on natural gas as a fuel source. The fuel storage and supply systems for these engines differ tremendously from gasoline, diesel, and flex fuel vehicles.[210] The CNG engine option has been included in past analyses; however, the LD and HDPUV baseline fleets do not include any dedicated CNG vehicles. As with the last analyses, CNG engines are included as a baseline-only technology and are not applied to any vehicle that did not already include a CNG engine.

The first step in assigning engine technologies to vehicles in the LD and HDPUV baseline fleets is to use data for each manufacturer to determine which vehicle platforms share engines. Within each manufacturer's fleet, we develop and assign unique engine codes based on configuration, technologies applied, displacement, CR, and power output. While the process for engine assignments is the same between the LD and HDPUV analyses, engine codes are not shared between the two fleets, and engine technologies are not shared between the fleets, for the reasons discussed above. We also assign engine technology classes, which are codes that identify engine architecture (*e.g.,* how many cylinders the engine has, whether it is a DOHC or SOHC, and so on) to accurately account for engine costs in the analysis.

When we assign engine technologies to vehicles in the baseline fleets, we must consider the actual technologies on a manufacturer's engine and compare those technologies to the engine technologies in our analysis. We have just over 270 unique engine codes in the LD baseline fleet and just over 20 unique engine codes in the HDPUV fleet, meaning that for both analysis fleets, we must identify the technologies present on those almost 300 unique engines in the real world, and make decisions about which of our approximately 40 engine map models (and therefore engine technology on the technology tree)[211] best represents those real-world engines. When we consider how to best fit each of those 300 engines to our 40 engine technologies and engine map models, we use specific technical elements contained in manufacturer publications, press releases, vehicle benchmarking studies, technical publications, manufacturer's specification sheets, and occasionally CBI (like the specific technologies, displacement, CR, and power mentioned above), and engineering judgment. For example, in the LD analysis, an engine with a 13.0:1 CR is a good indication that an engine would be considered an HCR engine in our analysis, and some engines that achieve a slightly lower CR, *e.g.,* 12.5, may be considered an HCR engine depending on other technology on the engine, like inclusion of SGDI, increased engine displacement compared to other competitors, a high energy spark system, and/or reduction of engine parasitic losses through variable or electric oil and water pumps. Importantly, we never assign engine technologies based on one factor alone; we use data and engineering judgment to assign complex real-world engines to their corresponding engine technologies in the analysis. We believe that our initial characterization of the fleet's engine technologies reasonably captures the current state of the market while maintaining a reasonable amount of analytical complexity. Also, as a reminder, in addition to the 40 engine map models used in the Engine Paths Collection, we have over 20 additional potential powertrain technology assignments available in the Hybrid/Electric Paths Collection.

Engine technology adoption in the model is defined through a combination of technology path logic, refresh and redesign cycles, phase-in capacity limits,[212] and SKIP logic. How does technology path logic define technology adoption? Once an engine design moves to the advanced engine tree it is not allowed to move to alternate advanced engine trees. For example, any LD basic engine can adopt one of the TURBO engine technologies, but vehicles that have turbocharged engines in the baseline fleet will stay on the Turbo Engine Path to prevent unrealistic engine technology change in the short timeframe considered in the rulemaking analysis. This represents the concept of stranded capital, which as discussed above, is when manufacturers amortize research, development, and tooling expenses over many years. Besides technology path logic, which applies to all manufacturers and technologies, we place additional constraints on the adoption of VCR and HCR technologies.

Basic and turbocharged engines in the LD analysis can adopt a VCR engine if the engine is currently manufactured by a manufacturer or partnered manufacturer that has already implemented the technology. VCR technology requires a complete redesign of the engine, and in the analysis fleet, only two models have incorporated this technology. VCR engines are complex, costly by design, and address many of the same efficiency losses as mainstream technologies like turbocharged downsized engines, making it unlikely that a manufacturer that has already started down an incongruent technology path would adopt VCR technology. Because of these issues, we limited adoption of the VCR engine technology to original equipment manufacturers (OEMs) that have already employed the technology and their partners. We do not believe any other manufacturers will invest to develop and market this technology in their fleet in the rulemaking time frame.

HCR engines are subject to three limitations. This is because, as we have recognized in past analyses,[213] HCR engines excel in lower power applications for lower load conditions, such as driving around a city or steady state highway driving without large payloads. Thus, their adoption is more limited than some other technologies.

First, we do not allow vehicles with 405 or more horsepower, and (to simulate parts sharing) vehicles that share engines with vehicles with 405 or more horsepower, to adopt HCR engines due to their prescribed power needs being more demanding and likely not supported by the lower power density found in HCR-based engines.[214] Because

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[210] Flexible fuel vehicles (FLEX) are designed to run on gasoline or gasoline-ethanol blends of up to 85 percent ethanol.

[211] We assign each engine code technology that most closely corresponds to an engine map; for most technologies, one box on the technology tree corresponds to one engine map that corresponds to one engine code.

[212] Although we did apply phase-in caps for this analysis, as discussed in Chapter 3.1.1 of the Draft TSD, those phase-in caps are not binding because the model has several other less advanced technologies available to apply first at a lower cost, as well as the redesign schedules. As discussed in Draft TSD Chapter 2.2, 100 percent of the analysis fleet will not redesign by 2023, which is the last year that phase-in caps could apply to the engine technologies discussed in this section. Please see the Draft TSD for more information on engine phase-in caps.

[213] The discussions at 83 FR 43038 (Aug. 24, 2018), 85 FR 24383 (April 30, 2020), 86 FR 49568 and 49661 (September 3, 2021), and 87 FR 25786 and 25790 (May 2, 2022) are incorporated herein by reference.

[214] Heywood, John B. Internal Combustion Engine Fundamentals. McGraw-Hill Education, 2018. Chapter 5.

LIVC essentially reduces the engine's displacement, to make more power and keep the same levels of LIVC, manufacturers would need to increase the displacement of the engine to make the necessary power. We do not believe manufacturers will increase the displacement of their engines to accommodate HCR technology adoption. This bears out in industry trends: total engine size (or displacement) is at an all-time low, and trends show that industry focus on turbocharged downsized engine packages are leading to their much higher market penetration.[215] Separately, as seen in the baseline fleet, manufacturers generally use HCR engines in applications where the vehicle's power requirements fall significantly below our horsepower threshold. In fact, the horsepower average for the sales weighted average of vehicles in the baseline analysis fleet that use HCR Engine Path technologies is 179 hp, demonstrating that HCR engine use has indeed been limited to lower-hp applications, and well below our 405 hp threshold. In fringe cases where a vehicle classified as having higher load requirements does have an HCR engine, it is coupled to a hybrid system.[216]

Secondly, to maintain a performance-neutral analysis,[217] we exclude pickup trucks and (to simulate parts sharing)[218] vehicles that share engines with pickup trucks from receiving HCR engines that are not accompanied by an electrified powertrain. In other words, pickup trucks and vehicles that share engines with pickup trucks can receive HCR-based engine technologies in the Hybridization Paths Collection of technologies. We exclude pickup trucks and vehicles that share engines with pickup trucks from receiving HCR engines that are not accompanied by an electrified powertrain because these often-heavier vehicles have higher low speed torque needs, higher base road loads, increased payload and towing requirements,[219] and have powertrains that are sized and tuned to perform this additional work above what passenger cars are required to conduct. Again, vehicle manufacturers' intended performance attributes for a vehicle—like payload and towing capability, intention for off-road use, and other attributes that affect frontal area and rolling resistance—dictate whether an HCR engine can be a suitable technology choice for that vehicle.[220] [221] For example, road loads are comprised of aerodynamic loads which include frontal area vehicle design along with rolling resistance that attribute to higher engine loads as vehicle speed increases.[222] We assume that a manufacturer intending to apply HCR technology to their pickup truck or vehicle that shares an engine with a pickup truck would do so in combination with an electric system to assist with the vehicle's load needs, and indeed the only manufacturer that has an HCR-like engine (in terms of how we model HCR engines in this analysis) in its pickup truck in the baseline fleet has done so.

Finally, we restrict HCR engine application for some manufacturers that are heavily performance-focused and have demonstrated a significant commitment to power dense technologies such as turbocharged downsizing.[223] When we say, ''significant commitment to power dense technologies,'' we mean that their fleets use near 100% turbocharged downsized engines. This means that no vehicle manufactured by these manufacturers can receive an HCR engine. Again, we implement this adoption feature to avoid an unquantified amount of stranded capital that would be realized if these manufacturers switched from one technology to another.

Note, however, that these adoption features only apply to vehicles that receive HCR engines that are not accompanied by an electrified powertrain. A P2 hybrid system that uses an HCR engine overcomes the low-speed torque needs using the electric motor and thus has no restrictions or SKIPs applied.

How effective an engine technology is at improving a vehicle's fuel economy depends on several factors such as the vehicle's technology class and any additional technology that is being added or removed from the vehicle in conjunction with the new engine technology, as discussed in Section II.C, above. The Autonomie model's full vehicle simulation results provide most of the effectiveness values that we use as inputs to the CAFE Model. For a full discussion of the Autonomie modeling see Chapter 2.4 of the Draft TSD and the CAFE Analysis Autonomie Documentation. The Autonomie modeling uses engine map models as the primary inputs for simulating the effects of different engine technologies.

Engine maps provide a three-dimensional representation of engine performance characteristics at each engine speed and load point across the operating range of the engine. Engine maps have the appearance of topographical maps, typically with engine speed on the horizontal axis and engine torque, power, or BMEP on the vertical axis. A third engine characteristic, such as brake-specific fuel consumption (BSFC), is displayed

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[215] See 2022 EPA Trends Report at 46, 72.

[216] See the Market Data Input File. As an example, the reported total system horsepower for the Ford Maverick HEV is also 191hp, well below our 405hp threshold. See also the Lexus LC/LS 500h: the Lexus LC/LS 500h also uses premium fuel to reach this performance level.

[217] As discussed in detail in Section II.C.3 and II.C.6 above, we maintain a performance-neutral analysis to capture only the costs and benefits of manufacturers adding fuel-economy-improving technology to their vehicles in response to CAFE standards.

[218] See Section II.C.6.

[219] See Society of Automotive Engineers Surface Vehicle Recommended Practice J2807. Performance Requirements for Determining Tow-Vehicle Gross Combination Weight Rating and Trailer Weight Rating (issued April 2008, revised February 2020); Trevor Reed. SAE J207 Tow Tests—The Standard, Motortrend (Jan 16, 2015). Available at *https://www.motortrend.com/how-to/1502-sae-j2807-tow-tests-the-standard/.* (Accessed: May 31, 2023). When we say ''increased payload and towing requirements,'' we are referring to a literal defined set of requirements that manufacturers follow to ensure the manufacturer's vehicle can meet a set of performance measurements when building a tow-vehicle in order to give consumers the ability to ''cross-shop'' between different manufacturer's vehicles. As discussed in detail above in Section II.C.3 and II.C.6, we maintain a performance neutral analysis to ensure that we are only accounting for the costs and benefits of manufacturers adding technology in response to CAFE standards. This means that we will apply adoption features, like the HCR application restriction, to a vehicle that begins the analysis with specific performance measurements, like a pickup truck, where application of the specific technology would likely not allow the vehicle to meet the manufacturer's baseline performance measurements.

[220] See, *e.g.,* Supplemental Comments of Toyota Motor North America, Inc., Notice of Proposed Rulemaking: Safer Affordable Fuel-Efficient Vehicles Rule, Docket ID Numbers: NHTSA–2018–0067 and EPA–HQ–OAR–2018–0283. p.6.

[221] Supplemental Comments of Toyota Motor North America, Inc., Notice of Proposed Rulemaking: Safer Affordable Fuel-Efficient Vehicles Rule, Docket ID Numbers: NHTSA–2018–0067 and EPA–HQ–OAR–2018–0283. ''Tacoma has a greater coefficient of drag from a larger frontal area, greater tire rolling resistance from larger tires with a more aggressive tread, and higher driveline losses from 4WD. Similarly, the towing, payload, and off road capability of pick-up trucks necessitate greater emphasis on engine torque and horsepower over fuel economy.

This translates into engine specifications such as a larger displacement and a higher stroke-to-bore ratio. . . . Tacoma's higher road load and more severe utility requirements push engine operation more frequently to the less efficient regions of the engine map and limit the level of Atkinson operation . . . This endeavor is not a simple substitution where the performance of a shared technology is universal. Consideration of specific vehicle requirements during the vehicle design and engineering process determine the best applicable powertrain.''

[222] 2015 NAS Report, Chapter 6, p. 207–242.

[223] There are three manufacturers that met the criteria (near 100 percent turbo downsized fleet, and future hybrid systems are based on turbo-downsized engines) described and were excluded: BMW of North America, LLC, Daimler, and Jaguar Land Rover.

using contours overlaid across the speed and load map. The contours provide the values for the third characteristic in the regions of operation covered on the map. Other characteristics typically overlaid on an engine map include engine emissions, engine efficiency, and engine power. We refer to the engine maps developed to model the behavior of the engines in this analysis as engine map models.

The engine map models we use in this analysis are representative of technologies that are currently in production or are expected to be available in the rulemaking timeframe. We develop the engine map models to be representative of the performance achievable across industry for a given technology, and they are not intended to represent the performance of a single manufacturer's specific engine. We target a broadly representative performance level because the same combination of technologies produced by different manufacturers will have differences in performance, due to manufacturer-specific designs for engine hardware, control software, and emissions calibration. Accordingly, we expect that the engine maps developed for this analysis will differ from engine maps for manufacturers' specific engines. However, we intend and expect that the incremental changes in performance modeled for this analysis, due to changes in technologies or technology combinations, will be similar to the incremental changes in performance observed in manufacturers' engines for the same changes in technologies or technology combinations.

IAV developed most of the LD engine map models we use in this analysis. IAV is one of the world's leading automotive industry engineering service partners with an over 35-year history of performing research and development for powertrain components, electronics, and vehicle design.[224] Southwest Research Institute (SwRI) developed the LD diesel and HDPUV engine maps for this analysis. SwRI has been providing automotive science, technology, and engineering services for over 70 years.[225] Both IAV and SwRI developed our engine maps using the GT–POWER© Modeling tool (GT–POWER). GT–POWER is a commercially available, industry standard, engine performance simulation tool. GT–POWER can be used to predict detailed engine performance characteristics such as power, torque, airflow, volumetric efficiency, fuel consumption, turbocharger performance and matching, and pumping losses.[226]

Just like ANL optimizes a single vehicle model in Autonomie following the addition of a singular technology to the vehicle model, our engine map models were built in GT–POWER by incrementally adding engine technology to a baseline engine—built using engine test data, component test data, and manufacturers' and suppliers' technical publications—and then optimizing the engine to consider real-world constraints like heat, friction, and knock. We use a small number of baseline engine configurations with well-defined BSFC maps, and then, in a very systematic and controlled process, add specific well-defined technologies to create a BSFC map for each unique technology combination. This could theoretically be done through engine or vehicle testing, but we would need to conduct tests on a single engine, and each configuration would require physical parts and associated engine calibrations to assess the impact of each technology configuration, which is impractical for the rulemaking analysis because of the extensive design, prototype part fabrication, development, and laboratory resources that are required to evaluate each unique configuration. We and the automotive industry use modeling as an approach to assess an array of technologies with more limited testing. Modeling offers the opportunity to isolate the effects of individual technologies by using a single or small number of baseline engine configurations and incrementally adding technologies to those baseline configurations. This provides a consistent reference point for the BSFC maps for each technology and for combinations of technologies that enables us to carefully identify and quantify the differences in effectiveness among technologies.

Before use in the Autonomie analysis, both IAV and SwRI validated the generated engine maps against a global database of benchmarked data, engine test data, single cylinder test data, prior modeling studies, technical studies, and information presented at conferences.[227] IAV and SwRI also validated the effectiveness values from the simulation results against detailed engine maps produced from the ANL engine benchmarking programs, as well as published information from industry and academia.[228] [229] This ensures reasonable representation of simulated engine technologies. Additional details and assumptions that we use in the engine map modeling are described in detail in Chapter 3.1 of the Draft TSD and the CAFE Analysis Autonomie Model Documentation chapter titled ''Autonomie—Engine Model.''

Note that we never apply absolute BSFC levels from the engine maps to any vehicle model or configuration for the rulemaking analysis. We only use the absolute fuel economy values from the full vehicle Autonomie simulations to determine incremental effectiveness for switching from one technology to another technology. The incremental effectiveness is then applied to the absolute fuel economy or fuel consumption value of vehicles in the analysis fleet, which are based on CAFE or FE compliance data. For subsequent technology changes, we apply incremental effectiveness changes to the absolute fuel economy level of the previous technology configuration. Therefore, for a technically sound analysis, it is most important that the differences in BSFC among the engine maps be accurate, and not the absolute values of the individual engine maps.

While the fuel economy improvements for most engine technologies in the analysis are derived from the database of Autonomie full-vehicle simulation results, the analysis incorporates a handful of what we refer to as analogous effectiveness values. We use these when we do not have an engine map model for a particular technology combination. To generate an analogous effectiveness value, we use data from analogous technology combinations for which we do have engine map models and conduct a pairwise comparison to generate a data set of emulated performance values for adding technology to a baseline application. We only use analogous

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[224] IAV Automotive Engineering. Available at: *https://www.iav.com/en.* (Accessed: May 31, 2023).

[225] Southwest Research Institite. Available at: *https://www.swri.org.* (Accessed: May 31, 2023).

[226] For additional information on the GT–POWER tool please see *https://www.gtisoft.com/gt-suite-applications/propulsion-systems/gt-power-engine-simulation-software.*

[227] Friedrich, I. et al. 2006. Automatic Model Calibration for Engine-Process Simulation with Heat-Release Prediction. SAE Technical Paper. Available at: *https://doi.org/10.4271/2006-01-0655.* (Accessed: May 31, 2023); Rezaei, R. et al. 2012. Zero-Dimensional Modeling of Combustion and Heat Release Rate in DI Diesel Engines. SAE International Journal Of Engines 5(3): pp. 874–885. Available at: *https://doi.org/10.4271/2012-01-1065.* (Accessed: May 31, 2023); Multistage Supercharging for Downsizing with Reduced Compression Ratio. 2015. MTZ Rene Berndt, Rene Pohlke, Christopher Severin, and Matthias Diezemann IAV GmbH.; Symbiosis of Energy Recovery and Downsizing. 2014. September 2014 MTZ Publication Heiko Neukirchner, Torsten Semper, Daniel Luederitz and Oliver Dingel IAV GmbH.

[228] Bottcher, L., & Grigoriadis, P. 2019. ANL—BSFC Map Prediction Engines 22–26. IAV.

[229] Reinhart, T. 2022. Engine Efficiency Technology Study. Final Report. SwRI Project No. 03.26457.

effectiveness values for four technologies that are all SOHC technologies. We determined that the effectiveness results using these analogous effectiveness values provided reasonable results. This process is discussed further in Chapter 3.1.4.2 of the Draft TSD.

Figure II–13, Figure II–14, and Figure II–15 show the engine technology effectiveness values for all vehicle technology classes. These values show the calculated improvement for upgrading only the listed engine technology for a given combination of other technologies. In other words, the range of effectiveness values seen for each specific technology (*e.g.,* TURBO1) represents the addition of the TURBO1 technology to every technology combination that could select the addition of TURBO1.

These values are derived from the ANL Autonomie simulation dataset and the righthand side Y-axis shows the number of Autonomie simulations that achieve each percentage effectiveness improvement point. The dashed line and grey shading indicate the median and 1.5X interquartile range (IQR), which is a helpful metric to use to identify outliers. Comparing these histograms to the box and whisker plots presented in prior CAFE program rule documents, it is much easier to see that the number of effectiveness outliers is extremely small.

Some advanced engine technologies have values that indicate low effectiveness. We determined the low effectiveness resulted from the application of advanced engines to existing P2 architectures. This effect is expected and illustrates the importance of using the full vehicle modeling to capture interactions between technologies, and capture instances of both complimentary technologies and non-complimentary technologies. In this instance, the P2 powertrain improves fuel economy, in part, by allowing the engine to spend more time operating at efficient engine speed and load conditions. This reduces the advantage of adding advanced engine technologies, which also improve fuel economy, by broadening the range of speed and load conditions for the engine to operate at high efficiency. This redundancy in fuel savings mechanism results in a lower effectiveness when the technologies are added to each other.

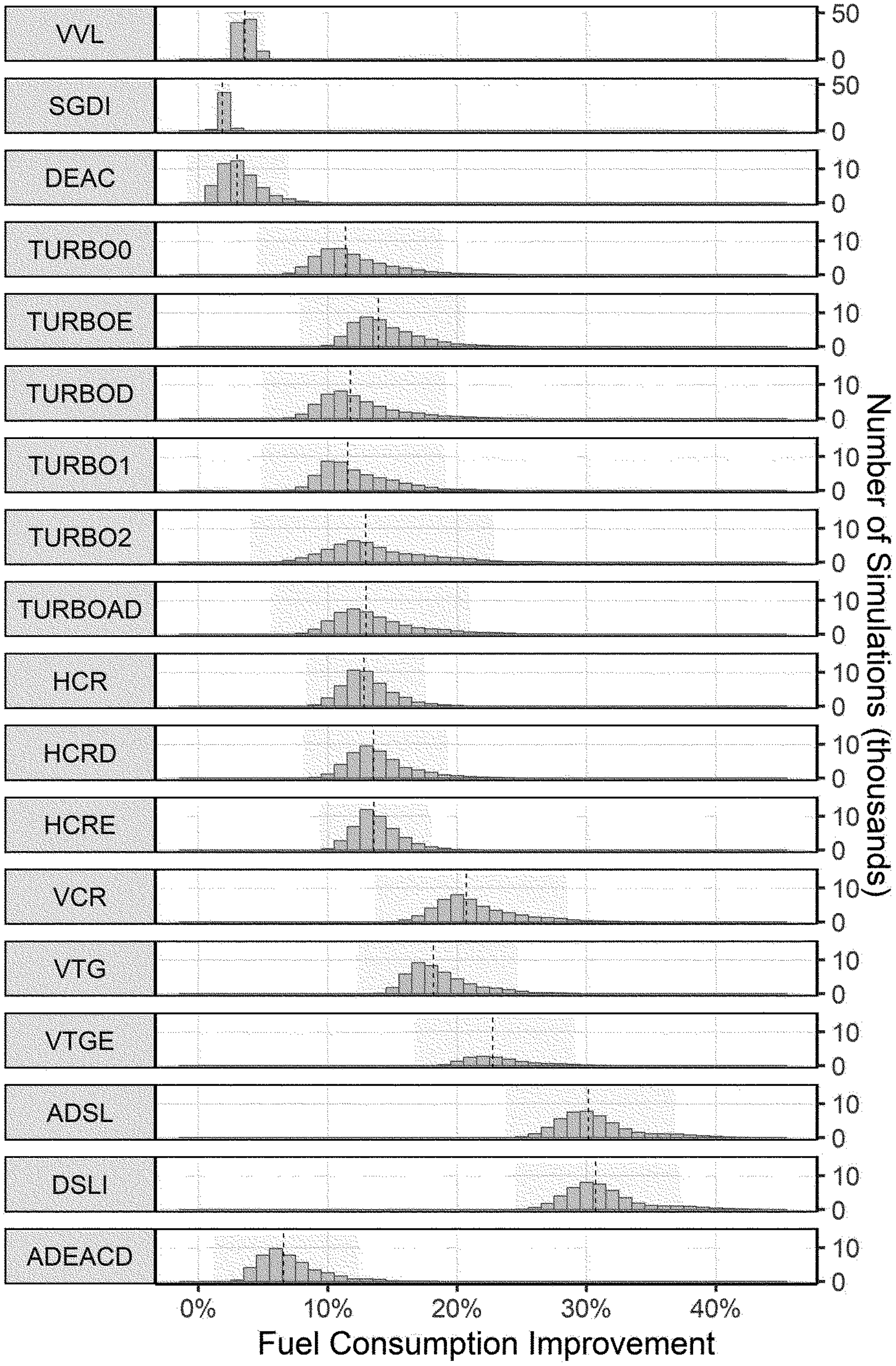

Figure II-13: Engine Technology Effectiveness Values for All LDV Technology Classes

(Unconstrained)

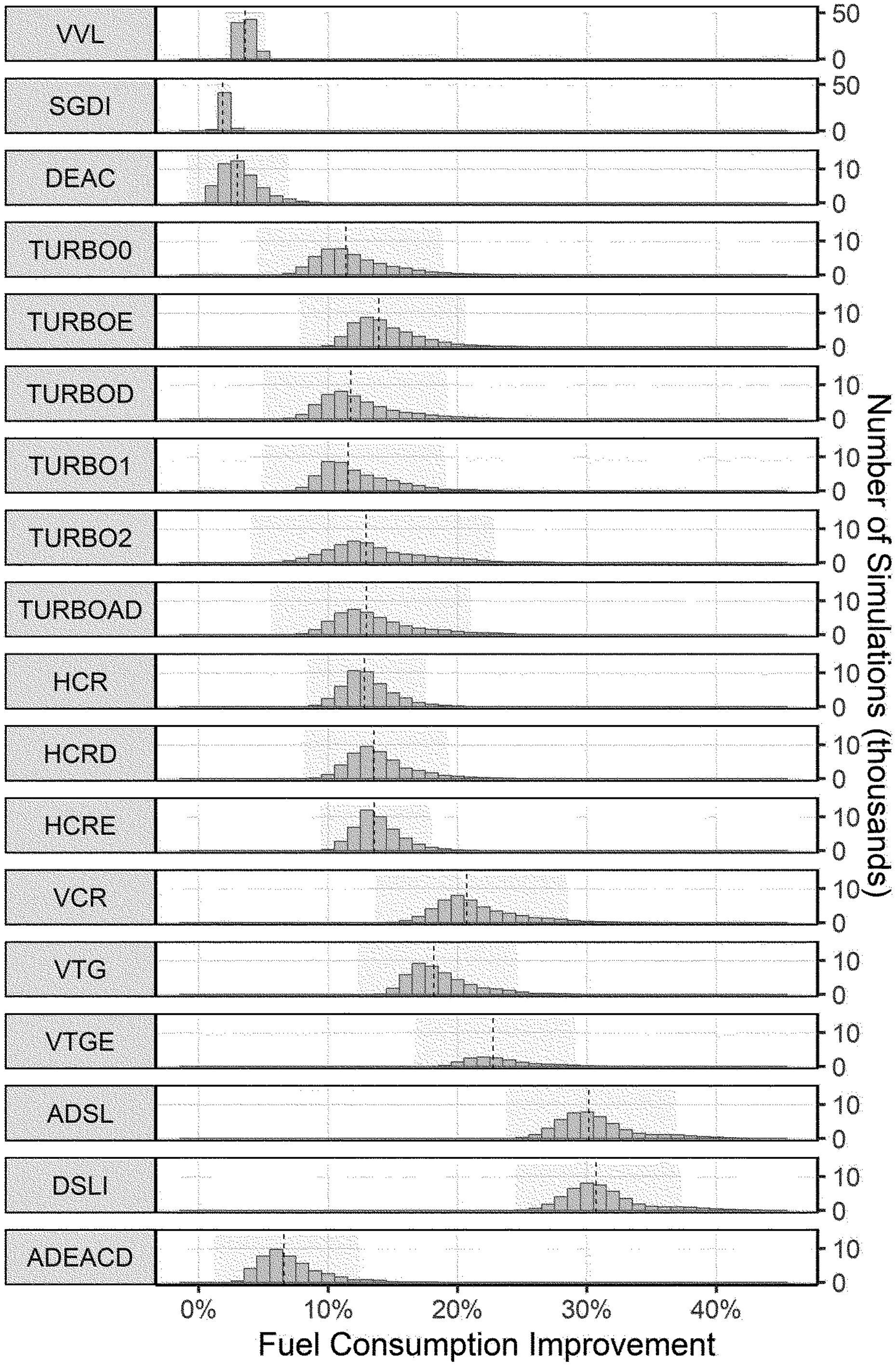

Figure II-14: Engine Technology Effectiveness Values for All LDV Technology Classes

(Standard Setting)

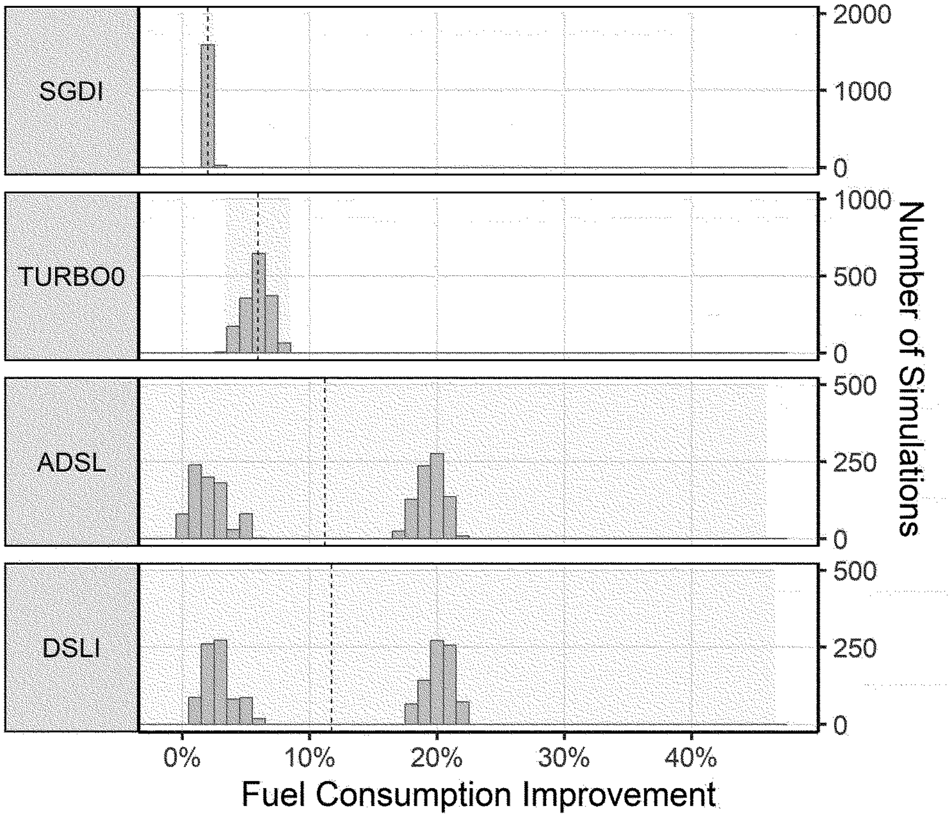

Figure II-15: Engine Technology Effectiveness Values for All HDPUV Vehicle Technology Classes

The engine costs in our analysis are the product of engine DMCs, RPE, the LE, and updating to a consistent dollar year. We sourced engine DMCs from multiple sources, but primarily from the 2015 NAS report.[230] For VTG and VTGE technologies (*i.e.,* Miller Cycle), we used cost data from a FEV technology cost assessment performed for ICCT,[231] aggregated using individual component and system costs from the 2015 NAS report. We considered costs from the 2015 NAS report that referenced a Northeast States Center for a Clean Air Future (NESCCAF) 2004 report,[232] but believe the reference material from the FEV report provides more updated cost estimates for the VTG technology.

All engine technology costs start with a base engine cost, and then additional technology costs are based on cylinder and bank count and configuration; the DMC for each engine technology is a function of unit cost times either the number of cylinders or number of banks, based on how the technology is applied to the system. The total costs for all engine technologies in all MYs across all vehicle classes can be found in the Technologies Input file.

2. Transmission Paths

Transmissions transmit torque generated by the engine from the engine to the wheels. Transmissions primarily use two mechanisms to improve fuel efficiency: (1) a wider gear range, which allows the engine to operate longer at higher efficiency speed-load points; and (2) improvements in friction or shifting efficiency (*e.g.,* improved gears, bearings, seals, and other components), which reduce parasitic losses.

We only model automatic transmissions in both the LD and HDPUV analyses. The four subcategories of automatic transmissions that we model in the LD analysis include traditional automatic transmissions (AT), dual clutch transmissions (DCT), continuously variable transmissions (CVT and eCVT), and direct drive (DD) transmissions.[233] We also include high efficiency gearbox (HEG) technology improvements as options to the transmission technologies (designated as L2 or L3 in our analysis to indicate level of technology improvement).[234] There has been a significant reduction in manual transmissions over the years and they made up less than 1% of the vehicles produced in MY 2021.[235] Due to the trending decline of manual transmissions and their current low production volumes, we have removed

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[230] 2015 NAS Report, Table S.2, p. 7–8.

[231] Isenstadt, A. et al. 2016. Downsized, Boosted Gasoline Engines. Working Paper. ICCT 2016–22: p. 28.

[232] NESCCAF. 2004. Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles. Available at: *http://www.nesccaf.org/documents/rpt040923ghglightduty.pdf.* (Accessed: May 31, 2023).

[233] Note that eCVT and DD transmissions are only coupled with electrified drivetrains and are therefore not included as a standalone transmission option on the CAFE Model's technology pathways.

[234] See 2015 NAS Report, at 191. HEG improvements for transmissions represent incremental advancements in technology that improve efficiency, such as reduced friction seals, bearings and clutches, super finishing of gearbox parts, and improved lubrication. These advancements are all aimed at reducing frictional and other parasitic loads in transmissions to improve efficiency. We consider three levels of HEG improvements in this analysis based on the National Academy of Sciences (NAS) 2015 recommendations, and CBI data.

[235] 2022 EPA Automotive Trends Report.

manual transmissions from this analysis.

We only model ATs in the HDPUV analysis because, except for DD transmissions that are only included as part of an electrified drivetrain, all HDPUV fleet baseline vehicles use ATs. In addition, from an engineering standpoint, DCTs and CVTs are not suited for HDPUV work requirements, as discussed further below. The HDPUV automatic transmissions work in the same way as the LD ATs and are labeled the same, but they are sized and mapped, in the Autonomie effectiveness modeling,[236] to account for the additional work, durability, and payload these vehicles are designed to conduct. The HDPUV transmissions are sized with larger clutch packs, higher hydraulic line pressures, different shift schedules, larger torque converter and different lock up logic, and stronger components when compared to their LD counterparts. Chapter 3.2.1 of the Draft TSD discusses the technical specifications of the four different AT subtypes in more detail. Figure II–16 and Figure II–17 show the LD and HDPUV transmission technology paths.

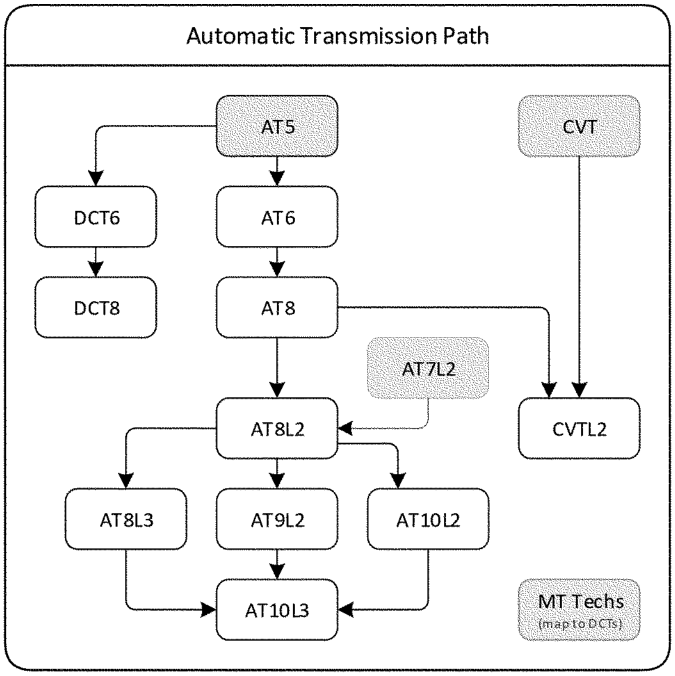

Figure II-16: LD Transmission Technology Paths

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[236] ANL—All Assumptions_Summary_NPRM_ 2206.xlsx, ANL—Data Dictionary_NPRM_2206.xlsx, ANL—Summary of Main Component Performance, Assumptions_NPRM_2206.xlsx. ANL—All Assumptions Summary—(2b–3) FY22 NHTSA—220811.xlsx, ANL—Data Dictionary—(2b–3) FY22 NHTSA—2200811.xlsx, ANL—Summary of Main Component Performance Assumptions—(2b–3) FY22 NHTSA—220811.xlsx.

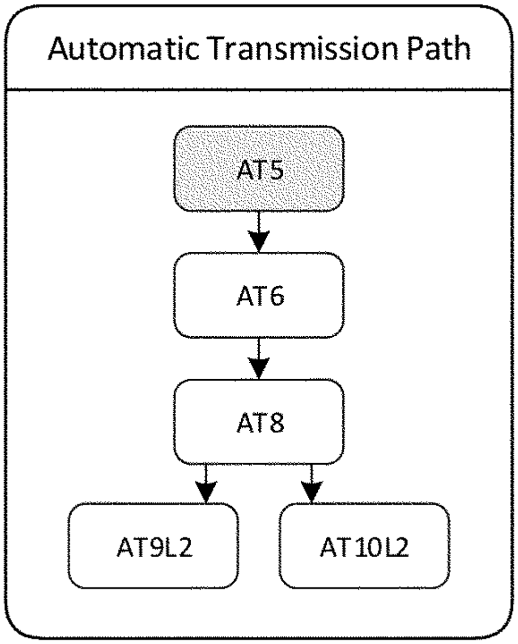

Figure II-17: HDPUV Transmission Technology Paths

To assign transmission technologies to vehicles in the baseline fleets, we identify which Autonomie transmission model is most like a vehicle's real-world transmission, considering the transmission's configuration, costs, and effectiveness. Like with engines, we use manufacturer CAFE compliance submissions and publicly available information to assign transmissions to vehicles and determine which platforms share transmissions. To link shared transmissions in a manufacturer's fleet, we use transmission codes that include information about the manufacturer, drive configuration, transmission type, and number of gears. Just like manufacturers share transmissions in multiple vehicles, the CAFE Model will treat transmissions as "shared" if they share a transmission code and transmission technologies will be adopted together.

While identifying an ATs gear count is fairly easy, identifying HEG levels for ATs and CVTs is more difficult. We reviewed the age of the transmission design, relative performance versus previous designs, and technologies incorporated to assign an HEG level. There are no HEG Level 3 automatic transmissions in either the LD or the HDPUV baseline fleets. For the LD analysis we found all 7-speed, all 9-speed, all 10-speed, and some 8-speed automatic transmissions to be advanced transmissions operating at HEG Level 2 equivalence. We assigned eight-speed automatic transmissions and CVTs newly introduced for the LD market in MY 2016 and later as HEG Level 2. All other automatic transmissions are assigned to their respective transmissions baseline level (*i.e.,* AT6, AT8, and CVT). For DCTs, the number of gears in the assignments for DCTs usually match the number of gears listed by the data sources, with some exceptions (we assign dual-clutch transmissions with seven and nine gears to DCT6 and DCT8 respectively). We assigned vehicles in either the LD or HDPUV analyses fleets with a fully electric powertrain a DD transmission. We assigned any vehicle in the LD analysis fleet with a power-split hybrid (SHEVPS) powertrain an electronic continuously variable transmission (eCVT). Finally, we assigned the limited number of manual transmissions in the LD fleet as DCTs, as we did not model manual transmissions in Autonomie for this analysis.

Most transmission adoption features are instituted through technology path logic (*i.e.,* decisions about how less advanced transmissions of the same type can advance to more advanced transmissions of the same type). Technology pathways are designed to prevent "branch hopping"—changes in transmission type that would correspond to significant changes in transmission architecture—for vehicles that are relatively advanced on a given pathway. For example, any automatic transmission with more than five gears cannot move to a dual-clutch transmission. We also prevent "branch hopping" as a proxy for stranded capital, which is discussed in more detail in Section II.C and Chapter 2.5 of the Draft TSD. The LD and HDPUV transmission paths are shown above in Figure II–16 and Figure II–17.

For the LD analysis, the automatic transmission path precludes adoption of other transmission types once a platform progresses past an AT8. We use this restriction to avoid the significant level of stranded capital loss that could result from adopting a completely different transmission type shortly after adopting an advanced transmission, which would occur if a different transmission type were adopted after AT8 in the rulemaking timeframe. Vehicles that did not start out with AT7L2 transmissions cannot adopt that technology in the model. It is likely that other vehicles will not adopt the AT7L2 technology, as vehicles that have moved to more advanced automatic transmissions have overwhelmingly moved to 8-speed and 10-speed transmissions.[237]

CVT adoption is limited by technology path logic and is only available in the LD fleet analysis and therefore, not in the technology path for the HDPUV analysis. Vehicles that do not originate with a CVT or vehicles

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[237] 2022 EPA Automotive Trends Report, at p. 66, Figure 4.21.

with multispeed transmissions beyond AT8 in the baseline fleet cannot adopt CVTs. Vehicles with multispeed transmissions greater than AT8 demonstrate increased ability to operate the engine at a highly efficient speed and load. Once on the CVT path, the platform is only allowed to apply improved CVT technologies. Due to the limitations of current CVTs, discussed in Draft TSD Chapter 3.2, this analysis restricts the application of CVT technology on LDVs with greater than 300 lb.-ft of engine torque. This is because of the higher torque (load) demands of those vehicles and CVT torque limitations based on durability constraints. We believe the 300 lb.-ft restriction represents an increase over current levels of torque capacity that is likely to be achieved during the rule making timeframe. This restriction aligns with CVT application in the baseline fleet, in that CVTs are only witnessed on vehicles with under 280 lb.-ft of torque.[238] Additionally, this restriction is used to avoid stranded capital. Finally, the analysis allows vehicles in the baseline fleet that have DCTs to apply an improved DCT and allows vehicles with an AT5 to consider DCTs. Drivability and durability issues with some DCTs have resulted in a low relative adoption rate over the last decade. This is also broadly consistent with manufacturers' technology choices.[239] DCTs are not a selectable technology for the HDPUV analysis.

Autonomie models transmissions as a sequence of mechanical torque gains. The torque and speed are multiplied and divided, respectively, by the current ratio for the selected operating condition. Furthermore, torque losses corresponding to the torque/speed operating point are subtracted from the torque input. Torque losses are defined based on a three-dimensional efficiency lookup table that has the following inputs: input shaft rotational speed, input shaft torque, and operating condition. We populate transmission template models in Autonomie with characteristics data to model specific transmissions.[240] Characteristics data are typically tabulated data for transmission gear ratios, maps for transmission efficiency, and maps for torque converter performance, as applicable. Different transmission types require different quantities of data. The characteristics data for these models come from peer-reviewed sources, transmission and vehicle testing programs, results from simulating current and future transmission configurations, and confidential data obtained from OEMs and suppliers.[241] We model HEG improvements by modeling improvements to the efficiency map of the transmission. As an example, the baseline AT8 model data comes from a transmission characterization study.[242] The AT8L2 has the same gear ratios as the AT8, however, we improve the gear efficiency map to represent application of the HEG level 2 technologies. The AT8L3 models the application of HEG level 3 technologies using the same principle, further improving the gear efficiency map over the AT8L2 improvements. Each transmission (15 for the LD analysis and 6 for the HDPUV analysis) is modeled in Autonomie with defined gear ratios, gear efficiencies, gear spans, and unique shift logic for the technology configuration the transmission is applied to. These transmission maps are developed to represent the gear counts and span, shift and torque converter lockup logic, and efficiencies that can be seen in the fleet, along with upcoming technology improvements, all while balancing key attributes such as drivability, fuel economy, and performance neutrality. This modeling is discussed in detail in Chapter 3.2 of the Draft TSD and the CAFE Analysis Autonomie Documentation chapter titled ''Autonomie—Transmission Model.''

The effectiveness values for the transmission technologies, for all LD and HDPUV technology classes, are shown in Figure II–18, Figure II–19, and Figure II–20. Note that the effectiveness for the AT5, eCVT and DD technologies is not shown. The DD and eCVT transmissions do not have standalone effectiveness values because those technologies are only implemented as part of electrified powertrains. The AT5 has no effectiveness values because it is a baseline technology against which all other transmission technologies are compared.

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[238] Market Data Input File.

[239] 2022 EPA Automotive Trends Report, at p. 66, Figure 4.21.

[240] ANL—All Assumptions_Summary_NPRM_2206.xlsx, ANL—Data Dictionary_NPRM_2206.xlsx, ANL—Summary of Main Component Performance, Assumptions_NPRM_2206.xlsx. ANL—All Assumptions Summary—(2b–3) FY22 NHTSA—220811.xlsx, ANL—Data Dictionary—(2b–3) FY22 NHTSA—2200811.xlsx, ANL—Summary of Main Component Performance Assumptions—(2b–3) FY22 NHTSA—220811.xlsx.

[241] Downloadable Dynamometer Database.: *https://www.anl.gov/energy-systems/group/downloadable-dynamometer-database.* (Accessed: May 31, 2023); Kim, N. et al. 2014. Advanced Automatic Transmission Model Validation Using Dynamometer Test Data. SAE 2014–01–1778. SAE World Congress: Detroit, MI.; Kim, N. et al. 2014. Development of a Model of the Dual Clutch Transmission in Autonomie and Validation With Dynamometer Test Data. International Journal of Automotive Technologies Volume 15, Issue 2: pp 263–71.

[242] CAFE Analysis Autonomie Documentation chapter titled ''Autonomie—Transmission Model.''

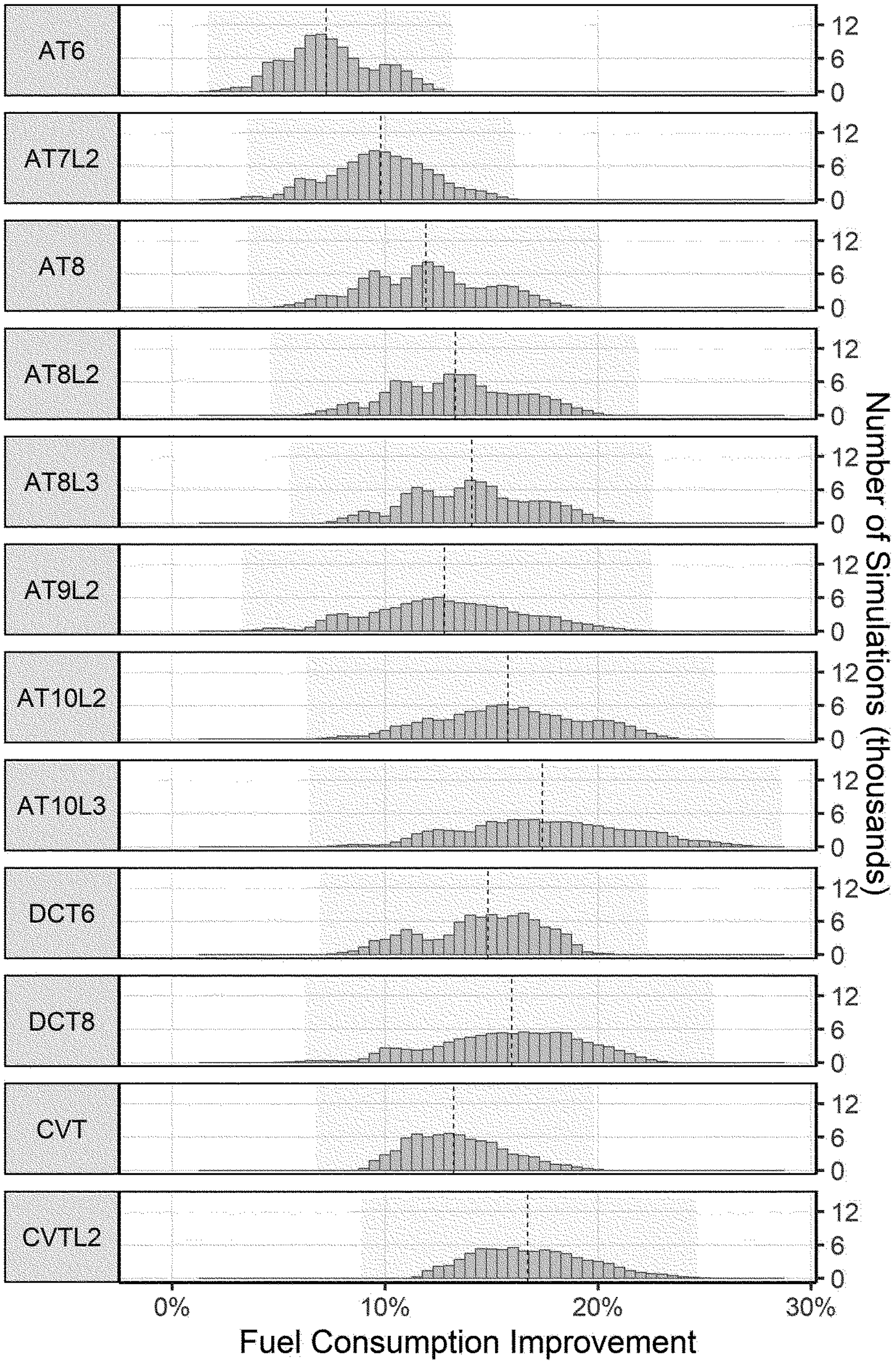

Figure II-18: Light Duty Transmission Technology Effectiveness Values for All Vehicle Technology Classes (Unconstrained)

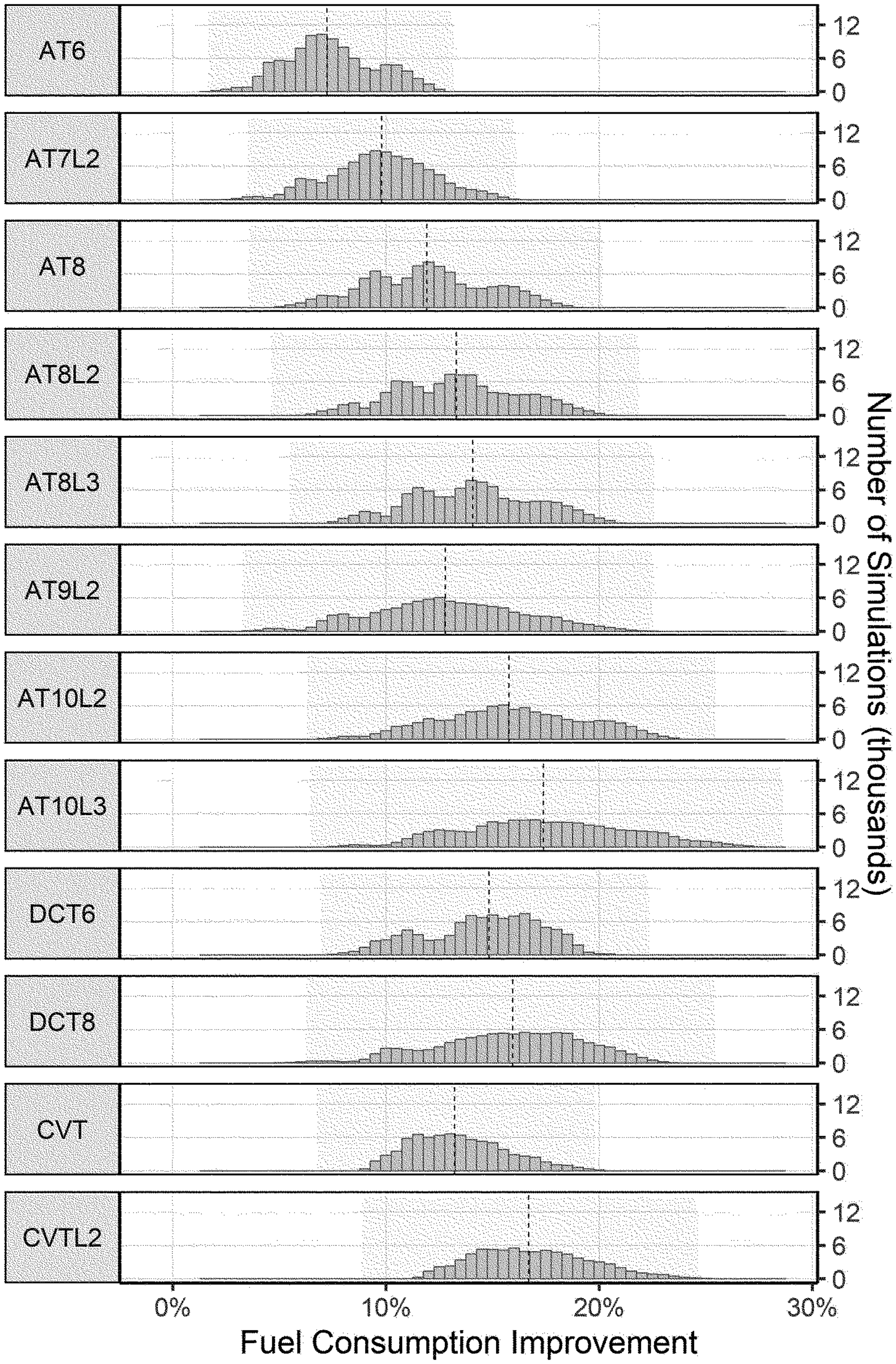

Figure II-19: Light Duty Transmission Technology Effectiveness Values for All Vehicle Technology Classes (Standard Setting)

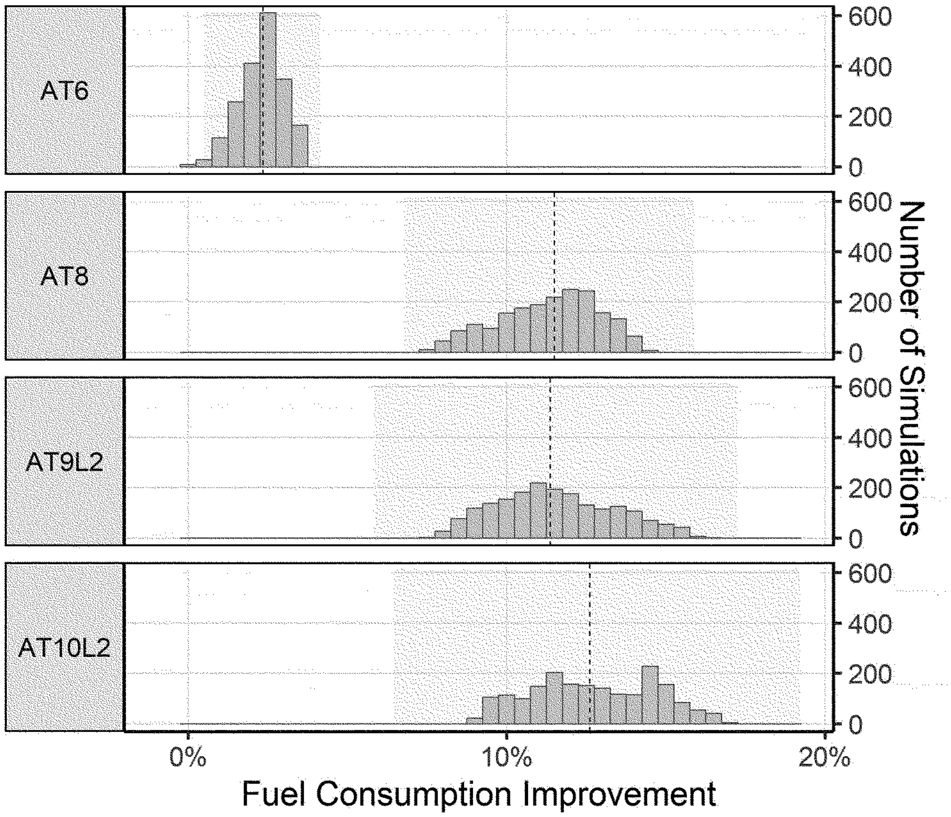

Figure II-20: HDPUV Transmission Technology Effectiveness Values for All Vehicle Technology Classes

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Our transmission DMCs come from the 2015 NAS report and studies cited therein. The LD costs are taken almost directly from the 2015 NAS report adjusted to the current dollar year or for the appropriate number of gears. We applied a 20% cost increase for HDPUV transmissions based on comparing the additional weight, torque capacity, and durability required in the HDPUV segment. Chapter 3.2 of the Draft TSD discusses the specific 2015 NAS report costs used to generate our transmission cost estimates, and all transmission costs across all MYs can be found in CAFE Model's Technologies Input file. We have used the 2015 NAS report transmission costs for the last several LD CAFE Model analyses (since reevaluating all transmission costs for the 2020 final rule) and have received no comments or feedback on these costs. We seek comment on our approach to estimating all transmission costs, but in particular on HDPUV transmission costs for this analysis, in addition to any publicly available data from manufacturers or reports on the cost of HDPUV transmissions.

3. Electrification Paths

The electrification paths include a set of technologies that share common electric powertrain components, like batteries and electric motors, for certain vehicle functions that were traditionally powered by combustion engines. While all vehicles (including conventional ICE vehicles) use batteries and electric motors in some form, some component designs and powertrain architectures contribute to greater levels of electrification than others—allowing the vehicle to be less reliant on gasoline or other fuel.

Unlike other technologies in the analysis, including other electrification technologies, Congress placed specific limitations on how we consider the fuel economy of PHEVs and BEVs when setting CAFE standards.[243] We implement these restrictions in the CAFE Model by using fuel economy values that assume ''charge sustaining'' (gasoline-only) PHEV operation,[244] and by restricting technologies that convert a vehicle to a BEV or a FCEV from being applied during ''standard-setting'' years.[245] However, there are several reasons why we must still accurately model PHEVs and BEVs in the analysis; these reasons are discussed in detail throughout this preamble and, in particular, in Sections III and V. In brief: we must consider the existing fleet fuel economy level in calculating the maximum feasible fuel economy level that manufacturers can achieve in future years. Accurately calculating the pre-existing fleet fuel economy level is crucial because it marks the starting point for determining what further efficiency gains will be feasible during the rulemaking timeframe. As discussed in detail above and in Chapter 2.2 of the Draft TSD, PHEVs, BEVs, and FCEVs currently exist in manufacturer's fleets

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[243] 49 U.S.C. 32902(h)(1), (2). In determining maximum feasible fuel economy levels, ''the Secretary of Transportation—(1) may not consider the fuel economy of dedicated automobiles; [and] (2) shall consider dual fueled automobiles to be operated only on gasoline or diesel fuel.''

[244] We have two sets of fuel consumption improvement data from ANL: one that does not include charge depleting and charge sustaining for PHEVS, and one with both.

[245] CAFE Model Documentation at S4.6 Technology Fuel Economy Improvements.

and count towards manufacturer's compliance fuel economy values.

In addition to accurately capturing the ''baseline fleet'' of vehicles in a given MY, we must capture a regulatory ''no action'' baseline in each MY; that is, the regulatory baseline captures what the world will be like if our rule is not adopted, to accurately capture the costs and benefits of CAFE standards. The ''no-action'' baseline includes our representation of the existing fleet of vehicles (*i.e.,* the LD and HDPUV baseline fleets) and (with some restrictions) our representation of manufacturer's fleets in the absence of our standards. Specifically, we assume that in the absence of CAFE and HDPUV FE standards, manufacturers will produce certain BEVs to comply with California's ACCs and ACT program. Accounting for electrified vehicles that manufacturers produced in response to state regulatory requirements improves the accuracy of the analysis of the costs and benefits of additional technology added to vehicles in response to CAFE standards, while adhering to the statutory prohibition against considering the fuel economy gains that could be achieved if manufacturers create new dedicated automobiles to comply with the CAFE standards.

Next, the costs and benefits of CAFE standards do not end in the MYs for which we are setting standards. Vehicles produced in standard-setting years, *e.g.,* MYs 2027 and beyond in this analysis, will continue to have effects for years after they are produced as the vehicles are sold and driven. To accurately capture the costs and benefits of vehicles subject to the standards in future years, the CAFE Model projects compliance through MY 2050. Outside of the standard-setting years, we model the extent to which manufacturers could produce electrified vehicles, in order to improve the accuracy and realism of our analysis in situations where statute does not prevent us from doing so. Finally, we do consider the effects of electrified vehicle adoption in the CAFE Model under a ''real-world'' scenario where we lift EPCA/EISA's restrictions on our decision-making. This ''real-world'' analysis forms the basis of our NEPA analysis, so that we can consider the actual environmental impacts of our actions in the decision-making process.[246]

For those reasons, we must still accurately model electrified vehicles. That said, PHEVs, BEVs, and FCEVs only represent a portion of the electrified technologies that we include in the analysis. We discuss the range of modeled electrified technologies below and in detail in Chapter 3.3.1 of the Draft TSD.

Among the simpler configurations with the fewest electrification components, micro HEV technology (SS12V) uses a 12-volt system that simply restarts the engine from a stop. Mild HEVs use a 48-volt belt integrated starter generator (BISG) system that restarts the vehicle from a stop and provides some regenerative braking functionality.[247] Mild HEVs are often also capable of minimal electric assist to the engine on take-off.

Strong hybrid-electric vehicles (SHEVs) have higher system voltages, compared to mild hybrids with BISG systems, and are capable of engine start/stop and regenerative braking, electric motor assist of the engine at higher speeds and power demands, and can provide limited all-electric propulsion. Common SHEV powertrain architectures, classified by the interconnectivity of common electrified vehicle components, include both a series-parallel architecture by power-split device (SHEVPS) as well as a parallel architecture (P2 [248]). P2s—although enhanced by the electrification components, including just one electric motor—remains fundamentally similar to a conventional powertrain.[249] In contrast, SHEVPS is considerably different than a conventional powertrain; SHEVPSs use two electric motors, which allows the use of a lower-power-density engine. This results in a higher potential for fuel economy improvement compared to a P2, although the SHEVPS' engine power density is lower.[250] Or, put another way, ''[a] disadvantage of the power split architecture is that when towing or driving under other real-world conditions, performance is not optimum.'' [251] In contrast, ''[o]ne of the main reasons for using parallel hybrid architecture is to enable towing and meet maximum vehicle speed targets.'' [252] This is an important distinction to comprehend to understand why we allow certain types of vehicles to adopt P2 powertrains and not SHEVPS powertrains, and to understand why we include only P2 architectures in the HDPUV analysis. Both concepts are discussed further below.

PHEVs utilize a combination gasoline-electric powertrain, like that of a SHEV, but have the ability to plug into the electric grid to recharge the battery, like that of a BEV; this contributes to all-electric mode capability in both blended and non-blended PHEVs.[253] The analysis includes PHEVs with an AER of 20 and 50 miles to encompass the range of PHEV AER in the market today. BEVs have an all-electric powertrain and use only batteries for the source of propulsion energy. BEVs with ranges of 200 to more than 350 miles are used in the analysis. Finally, FCEVs are another form of electrified vehicle that have a fully electric powertrain that uses a fuel cell system to convert hydrogen fuel into electrical energy. Table II–9 and Table II–10 list every electrification technology considered in the analysis, including its acronym and a brief description. For brevity, we refer to technologies by their acronyms in this section.

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[246] 40 CFR 1500.1(a).

[247] See 2015 NAS Report, at 130. (''During braking, the kinetic energy of a conventional vehicle is converted into heat in the brakes and is thus lost. An electric motor/generator connected to the drivetrain can act as a generator and return a portion of the braking energy to the battery for reuse. This is called regenerative braking. Regenerative braking is most effective in urban driving and in the urban dynamometer driving schedule (UDDS) cycle, in which about 50 percent of the propulsion energy ends up in the brakes (NRC 2011, 18).'').

[248] Readers familiar with the last CAFE Model analysis may remember this category of powertrains referred to as ''SHEVP2s.'' Now that the SHEVP2 pathway has been split into three pathways based on the paired ICE technology, we refer to this broad category of technologies as ''P2s.''

[249] Kapadia, J. et al. 2017. Powersplit or Parallel—Selecting the Right Hybrid Architecture. SAE International Journal of Alternative Power 6(1). Available at: *https://doi.org/10.4271/2017-01-1154.* (Accessed: May 31, 2023) (Parallel hybrids architecture typically adds the electrical system components to an existing conventional powertrain).

[250] Kapadia, J. et al. 2017. Powersplit or Parallel—Selecting the Right Hybrid Architecture. SAE International Journal of Alternative Power 6(1). Available at: *https://doi.org/10.4271/2017-01-1154.* (Accessed: May 31, 2023).

[251] 2015 NAS report, at 134.

[252] Kapadia, J. et al. 2017. Powersplit or Parallel—Selecting the Right Hybrid Architecture. SAE International Journal of Alternative Power 6(1). Available at: *https://doi.org/10.4271/2017-01-1154.* (Accessed: May 31, 2023).

[253] Some PHEVs operate in charge-depleting mode (*i.e.,* ''electric-only'' operation—depleting the high-voltage battery's charge) before operating in charge-sustaining mode (similar to strong hybrid operation, the gasoline and electric powertrains work together), while other (blended) PHEVs switch between charge-depleting mode and charge-sustaining mode during operation.

Table II–9—Light-Duty Electrification Path Technologies

Technology	Description
SS12V	12-Volt Stop-Start (Micro Hybrid-Electric Vehicle).
BISG	48V Belt Mounted Integrated Starter/Generator (Mild Hybrid-Electric Vehicle).
SHEV–P2SGDID	P2 Strong Hybrid-Electric Vehicle with a Dual Over-Head Cam Engine and Gasoline Direct Injection.
SHEV–P2SGDIS	P2 Strong Hybrid-Electric Vehicle with a Single Over-Head Cam Engine and Gasoline Direct Injection.
SHEV–P2TRB1	P2 Strong Hybrid-Electric Vehicle with a TURBO1 Powertrain.
SHEV–P2TRB2	P2 Strong Hybrid-Electric Vehicle with a TURBO2 Powertrain.
SHEV–P2TRBE	P2 Strong Hybrid-Electric Vehicle with a TURBOE Powertrain.
SHEV–P2HCR	P2 Strong Hybrid-Electric Vehicle with a High Compression Ratio Powertrain.
SHEV–P2HCRE	P2 Strong Hybrid-Electric Vehicle with an E-High Compression Ratio Powertrain.
SHEV–PS	Power Split (PS) Strong Hybrid/Electric Vehicle.
PHEV20PS	Plug-In Hybrid with Power-Split device and 20-mile All Electric Range.
PHEV50PS	Plug-In Hybrid with Power-Split device and 50-mile All Electric Range.
PHEV20T	PHEV20 with Turbo Engine and 20-mile All Electric Range.
PHEV50T	PHEV50 with Turbo Engine and 50-mile All Electric Range.
PHEV20H	PHEV20 with High Compression Ratio Engine and 20-mile All Electric Range.
PHEV50H	PHEV50 with High Compression Ratio Engine and 50-mile All Electric Range.
BEV1	~200-mile Battery Electric Vehicle $\mathrm{BEV1}_{\mathrm{LD}} \leq 250$ miles.
BEV2	~250-mile Battery Electric Vehicle 225 miles $< \mathrm{BEV2}_{\mathrm{LD}} \leq 275$ miles.
BEV3	~300-mile Battery Electric Vehicle 275 miles $< \mathrm{BEV3}_{\mathrm{LD}} \leq 350$ miles.
BEV4	~400-mile Battery Electric Vehicle 350 miles $< \mathrm{BEV3}_{\mathrm{LD}}$.
FCEV	Fuel Cell Electric Vehicle.

Table II–10—HDPUV Electrification Path Technologies

Technology	Description
SS12V	12-Volt Stop-Start (Micro Hybrid-Electric Vehicle).
BISG	48V Belt Mounted Integrated Starter/Generator (Mild Hybrid-Electric Vehicle).
SHEV–P2SGDIS	P2 Strong Hybrid-Electric Vehicle with a Single Over-Head Cam Engine and Gasoline Direct Injection.
PHEV50H[254]	PHEV50 with a Single Over-Head Cam Engine and Gasoline Direct Injection and 50-mile All Electric Range.
BEV1	Battery Electric Vehicle: 150-mile Range for Vans and 200-mile Range for Pickups.
BEV2	Battery Electric Vehicle: 250-mile Range for Vans and 300-mile Range for Pickups.
FCEV	Fuel Cell Electric Vehicle.

Readers familiar with previous LD CAFE analyses will notice that we have increased the number of engine options available for strong hybrid-electric vehicles and plug-in hybrid-electric vehicles. As discussed above, this better represents the diversity of different hybrid architectures and engine options available in the real world for strong and PHEVs, while still maintaining a reasonable level of analytical complexity. In addition, we now refer to the BEV options as BEV1, 2, 3, and 4, rather than by their range assignments as in the previous analysis, to accommodate using the same model code for the LD and HDPUV analyses. Note that BEV1 and BEV2 have different range assignments in the LD and HDPUV analyses; further, within the HDPUV fleet, different range assignments exist for HD pickups and HD vans.

In the CAFE Model, HDPUVs only have one strong hybrid engine/powertrain option, and one PHEV option.[255] The P2 architecture supports high payload and high towing requirements versus other types of hybrid architecture,[256] which are important considerations for HDPUV commercial operations. The mechanical connection between the engine, transmission, and P2 hybrid systems enables continuous power flow to be able to meet high towing weights and loads at the cost of system efficiency. We do not allow engine downsizing in this setup in so that when the battery storage system is depleted, the vehicle is still able to operate. We picked the P2 strong hybrid architecture for HDPUV PHEVs because although there are currently no PHEV HDPUVs in the market to base a technology choice, we believe that the P2 strong hybrid architecture would more likely be picked than other architecture options. This is because, as discussed above, the P2 architecture ''can be integrated with existing conventional powertrain systems that already meet the additional attribute requirements of these large vehicle segments.'' [257]

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[254] Note that the HDPUV PHEV is labeled ''PHEV50H'' but that is only so it can use the designated PHEV50H ''box'' on the technology tree. The HDPUV PHEV engine is a basic single overhead cam engine with GDI, as described in the table.

[255] Note that while the HDPUV PHEV option is labeled ''PHEV50H'' in the technology pathway, it actually uses a basic engine. This is so the same technology pathway can be used in the LD and HDPUV CAFE Model analyses.

[256] Kapadia, J. et al. 2017. Powersplit or Parallel—Selecting the Right Hybrid Architecture. SAE International Journal of Alternative Power 6(1): pp. 68–76. Available at: *https://doi.org/10.4271/2017-01-1154.* (Accessed: May 31, 2023) (Using current powersplit design approaches, critical attribute requirements of larger vehicle segments, including towing capability, performance and higher maximum vehicle speeds, can be difficult and in some cases impossible to meet. Further work is needed to resolve the unique challenges of adapting powersplit systems to these larger vehicle applications. Parallel architectures provide a viable alternative to powersplit for larger vehicle applications because they can be integrated with existing conventional powertrain systems that already meet the additional attribute requirements of these large vehicle segments).

[257] Kapadia, J. et al. 2017. Powersplit or Parallel—Selecting the Right Hybrid Architecture. SAE

Continued

We only include one HDPUV PHEV option as there are no PHEVs in the baseline HDPUV fleet, and there are no announcements from major manufacturers that indicate this a pathway that they will pursue in the short term.[258] We believe this is in part because PHEVs, which are essentially two separate powertrains combined, can decrease HDPUV capability by increasing the curb weight of the vehicle and reducing cargo capacity. A manufacturer's ability to use PHEVs in the HDPUV segment is highly dependent on the load requirements and the duty cycle of the vehicle. However, in the right operation, HDPUV PHEVs can have a cost-effective advantage over their conventional counterparts.[259] [260] [261] More specifically, there would be a larger fuel economy benefit the more the vehicle could rely on its electric operation, with partial help from the ICE; examples of duty cycles where this would be the case include short delivery applications or construction trucks that drive between work sites in the same city. Accordingly, we do think that PHEVs can be a technology option for adoption in the rulemaking timeframe. We picked a 50-mile AER for this segment based on discussions with experts at ANL, who were also involved in DOE projects and provided guidance for this segment.[262] [263]

Additional information about each technology we considered is located in Chapter 3.3.1 of the Draft TSD. We seek comment on the range of HDPUV electrification path technologies.

The full set of LD and HDPUV Electrification Path and Hybrid/Electric Paths Collection technologies are shown in Figure II–21 and Figure II–22 below, respectively.

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International Journal of Alternative Power 6(1): pp. 68–76. Available at: *https://doi.org/10.4271/2017-01-1154.* (Accessed: May 31, 2023).

[258] We recognize that there are some third-party companies that have converted HDPUVs into PHEVs, however, HDPUV incomplete vehicles that are retrofitted with electrification technology in the aftermarket are not regulated under this rulemaking unless the manufacturer optionally chooses to certify them as a complete vehicle. *See* 49 CFR 523.7.

[259] National Renewable Energy Laboratory. 2023. Electric and Plug-in Hybrid Electric Vehicle Publications. Available at: *https://www.nrel.gov/transportation/fleettest-publications-electric.html.* (Accessed: May 31, 2023).

[260] For the purpose of the Fuel Efficiency regulation, HDPUVs are assessed on the 2-cycle test procedure similar to the LDVs. The GVWR does not exceed 14,000 lbs in this segment.

[261] Birky, A. et al. 2017. Electrification Beyond Light Duty: Class 2b–3 Commercial Vehicles. Final Report. ORNL/TM–2017/744. Available at: *https://doi.org/10.2172/1427632.* (Accessed: May 31, 2023).

[262] DOE, Vehicle Technologies Office. 2023. 21st Century Truck Partnership. Available at: *https://www.energy.gov/eere/vehicles/21st-century-truck-partnership.* (Accessed: May 31, 2023).

[263] Islam, E. et al. 2022. A Comprehensive Simulation Study to Evaluate Future Vehicle Energy and Cost Reduction Potential. Final Report. ANL/ESD–22/6.

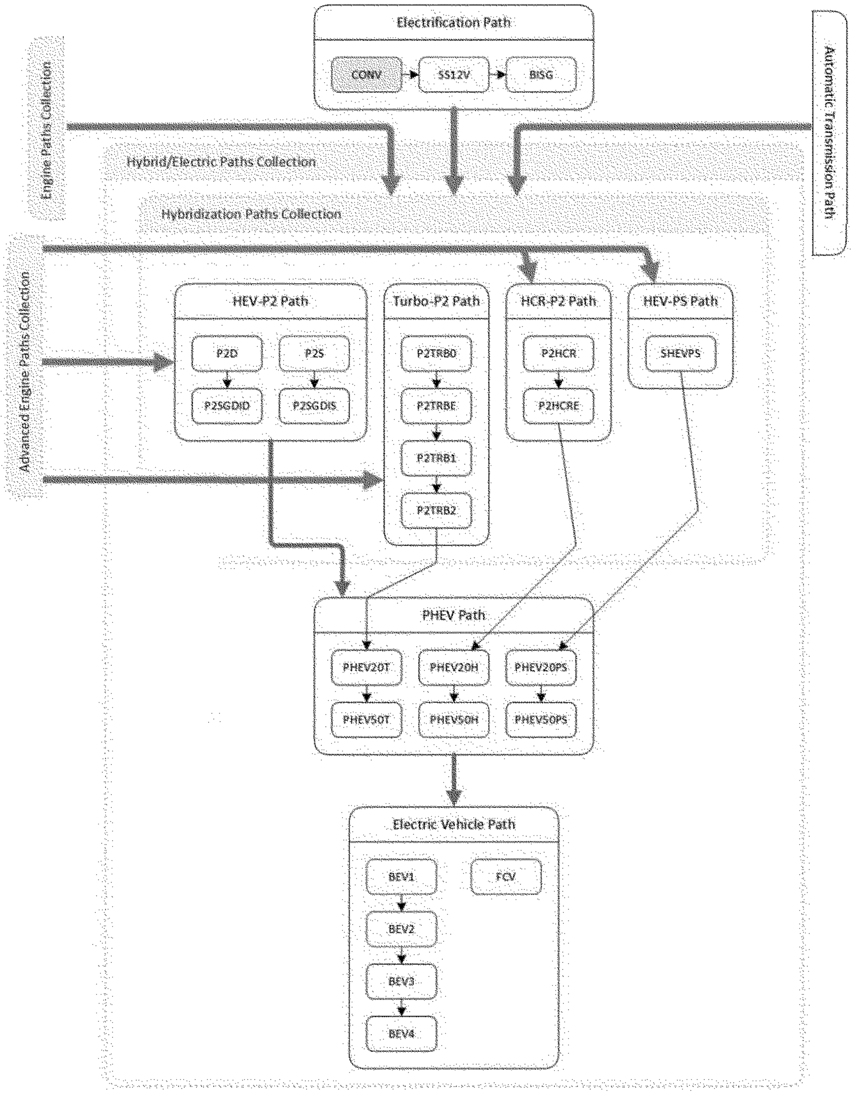

Figure II-21: Light-Duty Electrification and Hybrid/Electric Paths Collection Technologies

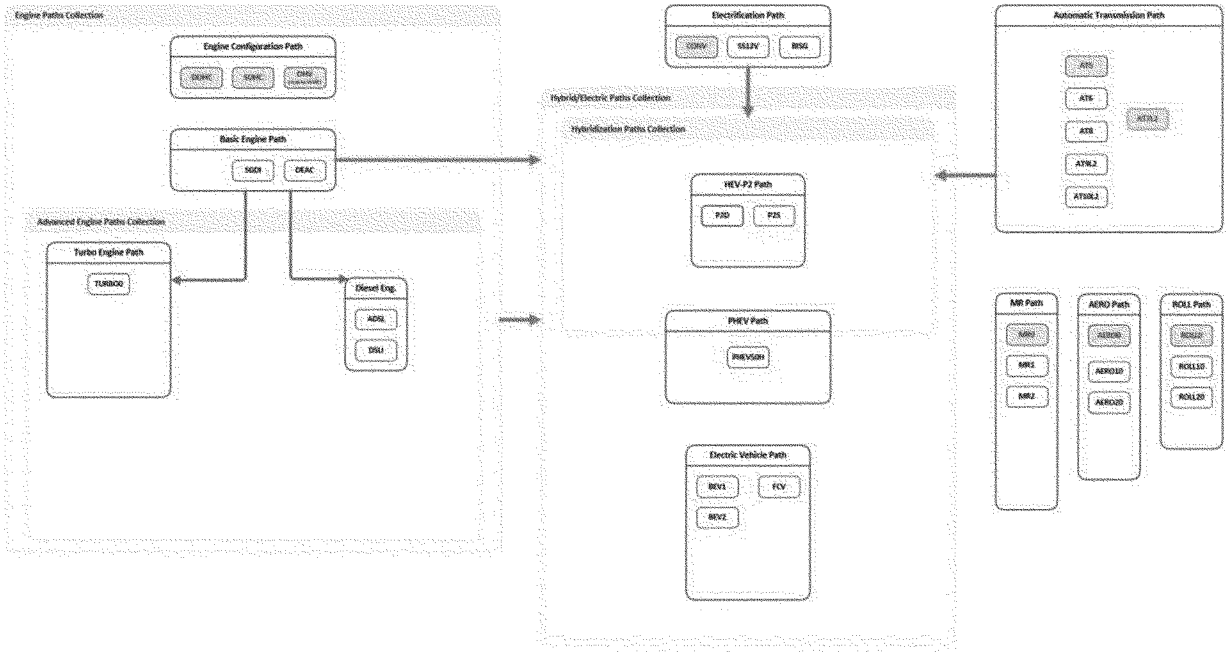

Figure II-22: HDPUV Electrification and Hybrid/Electric Paths Collection Technologies

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We assigned electrification technologies to vehicles in the baseline LD and HDPUV fleets using manufacturer-submitted CAFE compliance information, publicly available technical specifications, marketing brochures, articles from reputable media outlets, and data from Wards Intelligence.[264] Table II–11 and Table II–12 below show the baseline penetration rates of electrification technologies in the LD and HDPUV fleets, respectively. Over half the LD fleet has some level of electrification, with the vast majority—over 50 percent of the fleet—being micro hybrids; BEV3 (>275 miles; ≤350 miles) is the most common LD BEV technology. The HDPUV fleet has 6.22 percent level of electrification with BEV2s (>150 miles; ≤250 miles) representing all of the electrified vehicles in that fleet, with the remaining having a conventional non-electrified powertrain.

TABLE II–11—ELECTRIFICATION TECHNOLOGY PENETRATION RATES IN THE MY 2022 LD FLEET

Electrification technology	Sales volume with this technology	Penetration rate in 2022 baseline fleet (%)
None	4,244,826	29.52
SS12V	7,569,293	52.63
BISG	521,786	3.63
P2	245,778	1.71
SHEVPS	745,535	5.18
PHEV20PS	31,966	0.22
PHEV20H	50,643	0.35
PHEV20T	132,181	0.92
PHEV50PS	0	0.000
PHEV50H	27,776	0.19
PHEV50T	200	0.001
BEV1	45,754	0.32
BEV2	233,631	1.62
BEV3	335,244	2.33
BEV4	129,860	0.90
FCEV	4,419	0.03
Total	14,380,891	100

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[264] Wards Intelligence. 2022. U.S. Car and Light Truck Specifications and Prices, '22 Model Year. Available at: *https://wardsintelligence.informa.com/WI966023/US-Car-and-Light-Truck-Specifications-and-Prices-22-Model-Year.* (Accessed: May 31, 2023).

TABLE II–12—ELECTRIFICATION TECHNOLOGY PENETRATION RATES IN THE BASELINE HDPUV FLEET

Electrification technology	Sales volume with this technology	Penetration rate in baseline fleet (%)
None	822,409	93.78
SS12V	0	0.00
BISG	0	0.00
P2	0	0.00
PHEV50H	0	0.00
BEV1	0	0.00
BEV2	54,508	6.22
FCEV	0	0.00
Total	876,917	100

Like the other technology pathways, as the CAFE Model adopts electrification technologies for vehicles, more advanced levels of hybridization or electrification technologies will supersede all prior levels, while certain technologies within each level are mutually exclusive. The only adoption feature applicable to micro (SS12V) and mild (BISG) hybrid technology is path logic; vehicles can only adopt micro and mild hybrid technology if the vehicle did not already have a more advanced level of electrification.

The adoption features that we apply to strong hybrid technologies include path logic, powertrain substitution, and vehicle class restrictions. Per the defined (applicable) technology pathways, SHEVPS, P2x, P2TRBx, and the P2HCRx technologies are considered mutually exclusive. In other words, when the model applies one of these technologies, the others are immediately disabled from future application. However, all vehicles on the strong hybrid pathways can still advance to one or more of the plug-in technologies, when applicable in the modeling scenario (*i.e.,* allowed in the model).

When the model applies any strong hybrid technology to a vehicle, the transmission technology on the vehicle is superseded; regardless of the transmission originally present, P2 hybrids adopt an advanced 8-speed automatic transmission (AT8L2), and PS hybrids adopt a continuously variable transmission via power-split device (eCVT). When the model applies the P2 technology, the model can consider various engine options to pair with the P2 architecture according to existing engine path constraints—taking into account relative cost effectiveness. For SHEVPS technology, the existing engine is replaced with a full time Atkinson cycle engine.[265] For P2s, we picked the 8-speed automatic transmission to supersede the vehicle's incoming transmission technology. This is because most P2s in the market use an 8-speed automatic transmission,[266] therefore it is representative of the fleet now. We also think that 8-speed transmissions are representative of the transmissions that will continue to be used in these hybrid vehicles, as we anticipate manufacturers will continue to use these ''off the shelf'' transmissions based on availability and ease of incorporation in the powertrain. The eCVT (power-split device) *is* the transmission for SHEVPSs and is therefore the technology we picked to supersede the vehicle's prior transmission when adopting the SHEVPS powertrain.

SKIP logic is also used to constrain adoption for SHEVPS and PHEV20/50PS technologies. These technologies are ''skipped'' for vehicles with engines [267] that meet one of the following conditions: the engine belongs to an excluded manufacturer; [268] the engine belongs to a pickup truck (*i.e.,* the engine is on a vehicle assigned the ''pickup'' body style); the engine's peak horsepower is more than 405 hp; or if the engine is on a non-pickup vehicle but is shared with a pickup. The reasons for these conditions are similar to those for the SKIP logic that we apply to HCR engine technologies, discussed in more detail in Section II.D.1. In the real world, performance vehicles with certain powertrain configurations cannot adopt the technologies listed above and maintain vehicle performance without redesigning the entire powertrain. It may be helpful to understand why we do not apply SKIP logic to P2s and to understand why we do apply SKIP logic to SHEVPSs. Remember the difference between P2 and SHEVPS architectures: P2 architectures are better for ''larger vehicle applications because they can be integrated with existing conventional powertrain systems that already meet the additional attribute requirements'' of large vehicle segments.[269] No SKIP logic applies to P2s because we believe that this type of electrified powertrain is sufficient to meet all of the performance requirements for all types of vehicles. Manufacturers have proven this now with vehicles like the Ford F–150 Hybrid and Toyota Tundra Hybrid.[270] [271] In contrast, ''[a] disadvantage of the power split architecture is that when towing or driving under other real-world conditions, performance is not optimum.'' [272] If we were to size (in the Autonomie simulations) the PS motors and engines to achieve not ''not optimum'' performance, the electric motors would be unrealistically large (on both a size and cost basis), and the accompanying engine would also have to be a very large displacement engine, which is not characteristic of how vehicle manufacturers apply PS IC engines in the real-world. Instead, for vehicle applications that have particular performance requirements—defined in our analysis as vehicles with engines that belong to an excluded

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[265] Designated Eng26 in the list of engine map models used in the analysis. See Draft TSD Chapter 3.1.1.2.3 for more information.

[266] We are aware that some Hyundai vehicles use a 6-speed transmission and some Ford vehicles use a 10-speed transmission, but on balance we have observed that the majority of P2s use an 8-speed transmission.

[267] This refers to the engine assigned to the vehicle in the 2022 baseline fleet.

[268] Excluded manufacturers included BMW, Daimler, and Jaguar Land Rover.

[269] Kapadia, J. et al. 2017. Powersplit or Parallel—Selecting the Right Hybrid Architecture. SAE International Journal of Alternative Power 6(1). Available at: *https://doi.org/10.4271/2017-01-1154.* (Accessed: May 31, 2023).

[270] SAE International. 2021. 2022 Toyota Tundra: V8 Out, Twin-Turbo Hybrid Takes Over. Last revised: September 22, 2021. Available at: *https://www.sae.org/news/2021/09/2022-toyota-tundra-gains-twin-turbo-hybrid-power.* (Accessed: May 30, 2023).

[271] SAE International. 2020. Hybridization the Highlight of Ford's All-New 2021 F–150. Last revised: June 30, 2020. Available at: *https://www.sae.org/news/2020/06/2021-ford-f-150-reveal.* (Accessed: May 30, 2023).

[272] 2015 NAS report, at 134.

manufacturer, engines belonging to a pickup truck or shared with a pickup truck, or the engine's peak horsepower is more than 405hp—those vehicles can adopt P2 architectures that should be able to handle the vehicle's performance requirements.

LD PHEV adoption is limited only by technology path logic; however, in the HDPUV analysis, PHEV technology is not available in the model until MY 2025 for HD vans and MY 2027 for HD pickups. As discussed above, there are no PHEVs in the baseline HDPUV fleet and there are no announcements from major manufacturers that indicate this a pathway that they will pursue in the short term; that said, we do believe this is a technology that could be beneficial for very specific HDPUV applications. However, the technology is fully available for adoption by HDPUVs in the rulemaking timeframe (*i.e.,* MYs 2030 and beyond). Note that we also conducted two sensitivity cases varying the year that HDPUV PHEVs are available in the model, allowing them to be introduced in MYs 2025 and 2030. PRIA Chapter 9 shows that under the ''PHEV available in MY 2025'' sensitivity case, there are approximately double (19.6 percent versus 9.1%) the number of PHEVs in the no-action sensitivity case compared to the no-action central case and no-action ''PHEV available in MY 2030'' case by MY 2038. However, in response to CAFE standards, PHEVs increase in all three cases by 1.5 percent. This results in functionally no difference in total SCs, total social benefits, and accordingly net social benefits from varying the HDPUV PHEV availability year, in addition to functionally no difference in gasoline consumption, CO_2 emissions, and other economic and environmental parameters. We seek comment on this assumption, and any other information available from manufacturers or other stakeholders on the potential that original equipment manufacturers will implement PHEV technology prior to MY 2025 for HD vans, and prior to MY 2027 for HD pickups.

The engine and transmission technologies on a vehicle are superseded when PHEV technologies are applied. For example, the model applies an AT8L2 transmission with all PHEV20T/50T plug-in technologies, and the model applies an eCVT transmission for all PHEV20PS/50PS and PHEV20H/50H plug-in technologies. A vehicle adopting PHEV20PS/50PS receives a hybrid full Atkinson cycle engine, and a vehicle adopting PHEV20H/PHEV50H receives an HCR engine. For PHEV20T/50T, the vehicle receives a TURBO1 engine.

Adoption of BEVs and FCEVs is limited by both path logic and phase-in caps. They are applied as end-of-path technologies that supersede previous levels of electrification. Phase-in caps, which are defined in the CAFE Model Input Files, are percentages that represent the maximum rate of increase in penetration rate for a given technology. They are accompanied by a phase-in start year, which determines the first year the phase-in cap applies. Together, the phase-in cap and start year determine the maximum penetration rate for a given technology in a given year; the maximum penetration rate equals the phase-in cap times the number of years elapsed since the phase-in start year. Note that phase-in caps do not inherently dictate how much a technology is applied by the model. Rather, they represent how much of the fleet could have a given technology by a given year.

Because BEV1 costs less and has slightly higher effectiveness values than other advanced electrification technologies,[273] the model will have vehicles adopt it first, until it is restricted by the phase-in cap. Table II–13 shows the phase-in caps, phase-in year, and maximum penetration rate through 2050 for BEV and FCEV technologies. For comparison, we also list the actual penetration rate of each technology in the 2022 baseline fleet in the fourth column from the left.

Table II-13: Phase-In Caps for FCEV and BEV Technologies

Fleet	Technology Name	Phase-In Cap	Phase-In Start Year	Actual Penetration Rate in 2022 (Baseline Fleet)	Maximum Penetration Rate in 2022	Maximum Penetration Rate in 2025	Maximum Penetration Rate in 2030	Maximum Penetration Rate in 2035	Maximum Penetration Rate in 2040	Maximum Penetration Rate in 2045	Maximum Penetration Rate in 2050
LD	BEV1	0.09%	1998	0.36%	2.16%	2.43%	2.88%	3.33%	3.78%	4.23%	4.68%
	BEV2	1.40%	2009	1.51%	18.20%	22.40%	29.40%	36.40%	43.40%	50.40%	57.40%
	BEV3	6.67%	2016	2.17%	40.02%	60.03%	93.38%	100%	100%	100%	100%
	BEV4	10.00%	2021	0.85%	10.00%	40.00%	90.00%	100%	100%	100%	100%
	FCEV	0.02%	2016	0.03%	0.12%	0.18%	0.28%	0.28%	0.48%	0.58%	0.68%
HDPUV	BEV1	6.00%	2021	-	6.00%	24.00%	54.00%	84.00%	100%	100%	100%
	BEV2	10.00%	2021	-	10.00%	40.00%	90.00%	100%	100%	100%	100%
	FCEV	0.02%	2016	-	0.12%	0.18%	0.28%	0.28%	0.48%	0.58%	0.68%

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[273] This is because BEV1 uses fewer batteries and weighs less than BEVs with greater ranges.

The LD BEV1 phase-in cap is informed by manufacturers' tendency to move away from low-range passenger vehicle offerings in part because of potential consumer concern with range anxiety.[274] [275] [276] In some cases, the advertised range on EVs may not reflect the actual real-world range in cold and hot ambient temperatures and real-world driving conditions, affecting the utility of these lower range vehicles.[277] Many manufacturers have told us that the portion of consumers willing to accept a vehicle with the lowest modeled range is small, with manufacturers targeting range values above BEV1 range.

Furthermore, the average BEV range has steadily increased over the past decade,[278] due to battery technological progress increasing energy density as well as batteries becoming more cost effective. EPA observed in its 2022 Automotive Trends Report that ''the average range of new EVs has climbed substantially. In MY 2021, the average new EV is projected to have a 298-mile range, or about four times the range of an average EV in 2011.'' [279] Based on the cited examples and basis described in this section, the maximum growth rate for LD BEV1s in the model is set accordingly low to less than 0.1 percent per year. While this rate is significantly lower than that of the other BEV technologies, the BEV1 phase-in cap allows the penetration rate of low-range BEVs to grow by a multiple of what is currently observed in the market.

For higher BEV ranges (such as that for BEV2 for both LD and HDPUVs), phase-in caps are intended to conservatively reflect potential challenges in the scalability of BEV manufacturing and implementing BEV technology on many vehicle configurations, including larger vehicles. In the short term, the penetration of BEVs is largely limited by battery material acquisition and manufacturing.[280] Incorporating battery packs with the capacity to provide greater electric range also poses its own engineering challenges. Heavy batteries and large packs may be difficult to integrate for many vehicle configurations and require vehicle structure modifications. Pickup trucks and large SUVs, in particular, require higher levels of energy as the number of passengers and/or payload increases, for towing and other high-torque applications. In the LD analysis, we use the LD BEV3 and BEV4 phase-in caps to reflect these transitional challenges and use similar phase-in caps for the HDPUV analysis.

We seek comment on the BEV phase-in caps for the LD and HDPUV analyses. Remember when submitting comments that BEV phase-in caps are a tool that we use in the model to allow the model to build higher-range BEVs (when the modeling scenario allows, as in outside of standard-setting years), because if we did not, the model would only build BEV1s, as they are the most cost-effective BEV technology. Based on the analysis provided above, we believe there is a reasonable justification for different BEV phase-in caps based on expected BEV ranges in the future.

The phase-in cap for FCEVs is assigned based on existing market share as well as historical trends in FCEV production for LD and HDPUV. FCEV production share in the past five years has been extremely low and the lack of fueling infrastructure remains a limiting factor [281]—we set the phase-in cap accordingly.[282] As with BEV1, however, the phase-in cap still allows for the market share of FCEVs to grow several times over.

Autonomie determines the effectiveness of each electrified powertrain type by modeling the basic components, or building blocks, for each powertrain, and then combining the components modularly to determine the overall efficiency of the entire powertrain. The components, or building blocks, that contribute to the effectiveness of an electrified powertrain in the analysis include the vehicle's battery, electric motors, power electronics, and accessory loads. Autonomie identifies components for each electrified powertrain type and then interlinks those components to create a powertrain architecture. Autonomie then models each electrified powertrain architecture and provides an effectiveness value for each architecture. For example, Autonomie determines a BEV's overall efficiency by considering the efficiencies of the battery (including charging efficiency), the electric traction drive system (the electric machine and power electronics), and mechanical power transmission devices.[283] Or, for a PHEV, Autonomie combines a very similar set of components to model the electric portion of the hybrid powertrain and then also includes the ICE and related power for transmission components.[284] ANL uses data from their Advanced Mobility Technology Laboratory (AMTL) to develop Autonomie's electrified powertrain models. The modeled powertrains are not intended to represent any specific manufacturer's architecture but act as surrogates predicting representative levels of effectiveness for each electrification technology. We discuss the procedures for modeling each of these sub-systems in detail in the Draft TSD and in the CAFE Analysis Autonomie Documentation and include a brief summary below.

The fundamental components of an electrified powertrain's propulsion system—the electric motor and inverter—ultimately determine the vehicle's performance and efficiency. For this analysis, Autonomie employed a set of electric motor efficiency maps created by Oak Ridge National Laboratory (ORNL), one for a traction motor and an inverter, the other for a motor/generator and inverter.[285] Autonomie also uses test data validations from technical publications to determine the peak efficiency of BEVs

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[274] Pratt, D. 2021. How Much Do Cold Temperatures Affect an Electric Vehicle's Driving Range? Last Revised: Dec. 19, 2021. Available at: *https://www.consumerreports.org/hybrids-evs/how-much-do-cold-temperatures-affect-an-evs-driving-range-a5751769461.* (Accessed: May 31, 2023).

[275] 2022 EPA Trends Report at page 60.

[276] IEA. 2022. Trends in Electric Light-Duty Vehicles. Available at: *https://www.iea.org/reports/global-ev-outlook-2022/trends-in-electric-light-duty-vehicles.* (Accessed: May 31, 2023).

[277] AAA. 2019. AAA Electric Vehicle Range Testing. Last Revised: Feb. 2019. Available at: *https://www.aaa.com/AAA/common/AAR/files/AAA-Electric-Vehicle-Range-Testing-Report.pdf.* (Accessed: May 31, 2023).

[278] 2022 EPA Automotive Trends Report, at p. 62, Figure 4.17. See also United States DOE Vehicle Technologies Office Fact of the Week (FOTW) #1290, In Model Year 2022, the Longest-Range EV Reached 520 Miles on a Single Charge (May 15, 2023). Available at *https://www.energy.gov/eere/vehicles/articles/fotw-1290-may-15-2023-model-year-2022-longest-range-ev-reached-520-miles.* (Accessed: May 31, 2023).

[279] 2021 EPA Automotive Trends Report, at p. 58 (citing DOE, Vehicle Technologies Office. FOTW #1234, April 18, 2022: Volumetric Energy Density of Lithium-ion Batteries Increased by More than Eight Times Between 2008 and 2020. Available at: *https://www.energy.gov/eere/vehicles/articles/fotw-1234-april-18-2022-volumetric-energy-density-lithium-ion-batteries.* (Accessed: May 31, 2023).

[280] See, *e.g.,* Henze, V. 2022. China's Battery Supply Chain Tops BNEF Ranking for Third Consecutive Time, with Canada a Close Second. Bloomberg New Energy Finance. Last Revised: Nov. 12, 2022. Available at: *https://about.bnef.com/blog/chinas-battery-supply-chain-tops-bnef-ranking-for-third-consecutive-time-with-canada-a-close-second/*. (Accessed: May 31, 2023).

[281] DOE, Alternative Fuels Data Center. Hydrogen Refueling Infrastructure Development. Available at: *https://afdc.energy.gov/fuels/hydrogen_infrastructure.html.* (Accessed: May 31, 2023).

[282] 2022 EPA Automotive Trends Report, at p. 60, Figure 4.14.

[283] Iliev, S. et al. 2023. Vehicle Technology Assessment, Model Development, and Validation of a 2021 Toyota RAV4 Prime. Report No. DOT HS 813 356. National Highway Traffic Safety Administration.

[284] See the CAFE Analysis Autonomie Documentation.

[285] Oak Ridge National Laboratory. 2008. Evaluation of the 2007 Toyota Camry Hybrid Synergy Drive System; Oak Ridge National Laboratory. 2011. Annual Progress Report for the Power Electronics and Electric Machinery Program.

and FCEVs. The electric motor efficiency maps, created from production vehicles like the 2007 Toyota Camry hybrid, 2011 Hyundai Sonata hybrid, and 2016 Chevrolet Bolt, represent electric motor efficiency as a function of torque and motor Rotations Per Minute (RPM). These efficiency maps provide nominal and maximum speeds, as well as a maximum torque curve. ANL uses the maps to determine the efficiency characteristics of the motors, which includes some of the losses due to power transfer through the electric machine.[286] Specifically, ANL scales the efficiency maps, specific to powertrain type, to have total system peak efficiencies ranging from 96–98 percent [287]—such that their peak efficiency value corresponds to the latest state-of-the-art technologies, opposed to retaining dated system efficiencies (90–93 percent).[288]

Beyond the powertrain components, Autonomie also considers electric accessory devices that consume energy and affect overall vehicle effectiveness, such as headlights, radiator fans, wiper motors, engine control units, transmission control units, cooling systems, and safety systems. In real-world driving and operation, the electrical accessory load on the powertrain varies depending on how the driver uses certain features and the condition in which the vehicle is operating, such as for night driving or hot weather driving. However, for regulatory test cycles related to fuel economy, the electrical load is repeatable because the fuel economy regulations control for these factors. Accessory loads during test cycles do vary by powertrain type and vehicle technology class, since distinctly different powertrain components and vehicle masses will consume different amounts of energy.

The baseline fleet consists of different vehicle types with varying accessory electrical power demand. For instance, vehicles with different motor and battery sizes will require different sizes of electric cooling pumps and fans to optimally manage component temperatures. Autonomie has built-in models that can simulate these varying sub-system electrical loads. However, for this analysis, we use a fixed (by vehicle technology class and powertrain type), constant power draw to represent the effect of these accessory loads on the powertrain on the 2-cycle test. We intend and expect that fixed accessory load values will, on average, have similar impacts on effectiveness as found on actual manufacturers' systems. This process is in line with the past analyses.[289] [290] For this analysis, we aggregate electrical accessory load modeling assumptions for the different powertrain types (electrified and conventional) and technology classes (both LD and HDPUV) from data from the Draft TAR, EPA Proposed Determination,[291] data from manufacturers,[292] research and development data from DOE's Vehicle Technologies Office,[293] [294] [295] and DOT-sponsored vehicle benchmarking studies completed by ANL's AMTL.

Certain technologies' effectiveness for reducing fuel consumption requires optimization through the appropriate sizing of the powertrain. Autonomie uses sizing control algorithms based on data collected from vehicle benchmarking,[296] [297] and the modeled electrification components are sized based on performance neutrality considerations. This analysis iteratively minimizes the size of the powertrain components to maximize efficiency while enabling the vehicle to meet multiple performance criteria. The Autonomie simulations use a series of resizing algorithms that contain ''loops,'' such as the acceleration performance loop (0–60 mph), which automatically adjusts the size of certain powertrain components until a criterion, like the 0–60 mph acceleration time, is met. As the algorithms examine different performance or operational criteria that must be met, no single criterion can degrade; once a resizing algorithm completes, all criteria will be met, and some may be exceeded as a necessary consequence of meeting others.

Autonomie applies different powertrain sizing algorithms depending on the type of vehicle considered because different types of vehicles not only contain different powertrain components to be optimized, but they must also operate in different driving modes. While the conventional powertrain sizing algorithm must consider only the power of the engine, the more complex algorithm for electrified powertrains must simultaneously consider multiple factors, which could include the engine power, electric machine power, battery power, and battery capacity. Also, while the resizing algorithm for all vehicles must satisfy the same performance criteria, the algorithm for some electric powertrains must also allow those electrified vehicles to operate in certain driving cycles, like the US06 cycle, without assistance of the combustion engine and ensure the electric motor/generator and battery can handle the vehicle's regenerative braking power, all-electric mode operation, and intended range of travel.

To establish the effectiveness of the technology packages, Autonomie simulates the vehicles' performance on compliance test cycles.[298] [299] [300] For vehicles with conventional powertrains and micro hybrid powertrains, Autonomie simulates the vehicles using the 2-cycle test procedures and guidelines.[301] For mild HEVs, strong HEVs, and FCEVs, Autonomie simulates the same 2-cycle test, with the addition of repeating the drive cycles until the final State of charge (SOC) is approximately the same as the initial SOC, a process described in SAE J1711. For PHEVs, Autonomie simulates vehicles performing the test cycles per

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[286] CAFE Analysis Autonomie Documentation chapter titled ''Vehicle and Component Assumptions—Electric Machines—Electric Machine Efficiency Maps.''

[287] CAFE Analysis Autonomie Documentation chapter titled ''Vehicle and Component Assumptions—Electric Machines—Electric Machine Peak Efficiency Scaling.''

[288] Oak Ridge National Laboratory. 2008. Evaluation of the 2007 Toyota Camry Hybrid Synergy Drive System; Oak Ridge National Laboratory. 2011. Annual Progress Report for the Power Electronics and Electric Machinery Program.

[289] Technical Assessment Report (July 2016), Chapter 5.

[290] EPA Proposed Determination TSD (November 2016), at pp. 2–270.

[291] EPA Proposed Determination TSD (November 2016), at pp. 2–270.

[292] Alliance of Automobile Manufacturers (now Alliance for Automotive Innovation) Comments on Draft TAR, at p. 30.

[293] DOE, Vehicle Technologies Office. Electric Drive Systems Research and Development. Available at: *https://www.energy.gov/eere/vehicles/vehicle-technologies-office-electric-drive-systems.* (Accessed: May 31, 2023).

[294] ANL. 2023. Advanced Mobility Technology Laboratory (AMTL). Available at: *https://www.anl.gov/es/advanced-mobility-technology-laboratory.* (Accessed: May 31, 2023).

[295] DOE's lab years are ten years ahead of manufacturers' potential production intent (*e.g.,* 2020 Lab Year is MY 2030).

[296] CAFE Analysis Autonomie Documentation chapter titled ''Vehicle Sizing Process—Vehicle Powertrain Sizing Algorithms—Light-Duty Vehicles—Conventional Vehicle Sizings Algorithm.''

[297] CAFE Analysis Autonomie Documentation chapter titled ''Vehicle Sizing Process—Vehicle Powertrain Sizing Algorithms—Heavy-Duty Pickups and Vans—Conventional Vehicle Sizings Algorithm.''

[298] Enviromental Protection Agency. 2023. How Vehicles are Tested. Available at: *https://www.fueleconomy.gov/feg/how_tested.shtml.* (Accessed: May 31, 2023).

[299] CAFE Analysis Autonomie Documentation, Chapter titled 'Test Procedure and Energy Consumption Calculations'.

[300] EPA. 2017. EPA Test Procedures for Electric Vehicles and Plug-in Hybrids. Draft Summary. Available at: *https://www.fueleconomy.gov/feg/pdfs/EPA%20test%20procedure%20for%20EVs-PHEVs-11-14-2017.pdf.* (Accessed: May 31, 2023).

[301] 40 CFR part 600.

guidance provided in SAE J1711.[302] PHEVs have a different range of modeled effectiveness during ''standard setting'' CAFE Model runs, in which the PHEV operates under a ''charge sustaining'' mode (similar to how SHEVs function) compared to ''EIS'' runs, in which the same PHEV operates under a ''charge depleting'' mode (similar to how BEVs function). For BEVs and FCEVs, Autonomie simulates vehicles performing the test cycles per guidance provided in SAE J1634.[303]

Chapters 2.4 and 3.3 of the Draft TSD and the CAFE Analysis Autonomie Documentation chapter titled ''Test Procedure and Energy Consumption Calculations'' discuss the components and test cycles used to model each electrified powertrain type; please refer to those chapters for more technical details on each of the modeled technologies discussed in this section.

The range of effectiveness for the electrification technologies in this analysis is a result of the interactions between the components listed above and how the modeled vehicle operates on its respective test cycle. This range of values will result in some modeled effectiveness values being close to real-world measured values, and some modeled values that will depart from measured values, depending on the level of similarity between the modeled hardware configuration and the real-world hardware and software configurations. The range of effectiveness values for the electrification technologies applied in the LD fleets are shown in Figure II–23 and Figure II–24. Effectiveness values for electrification technologies in the HDPUV fleet are shown in Figure II–25.

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[302] PHEV testing is broken into several phases based on SAE J1711: charge-sustaining on the city and HWFET cycle, and charge-depleting on the city and HWFET cycles.

[303] SAE J1634. Battery Electric Vehicle Energy Consumption and Range Test Procedure. July 12, 2017.

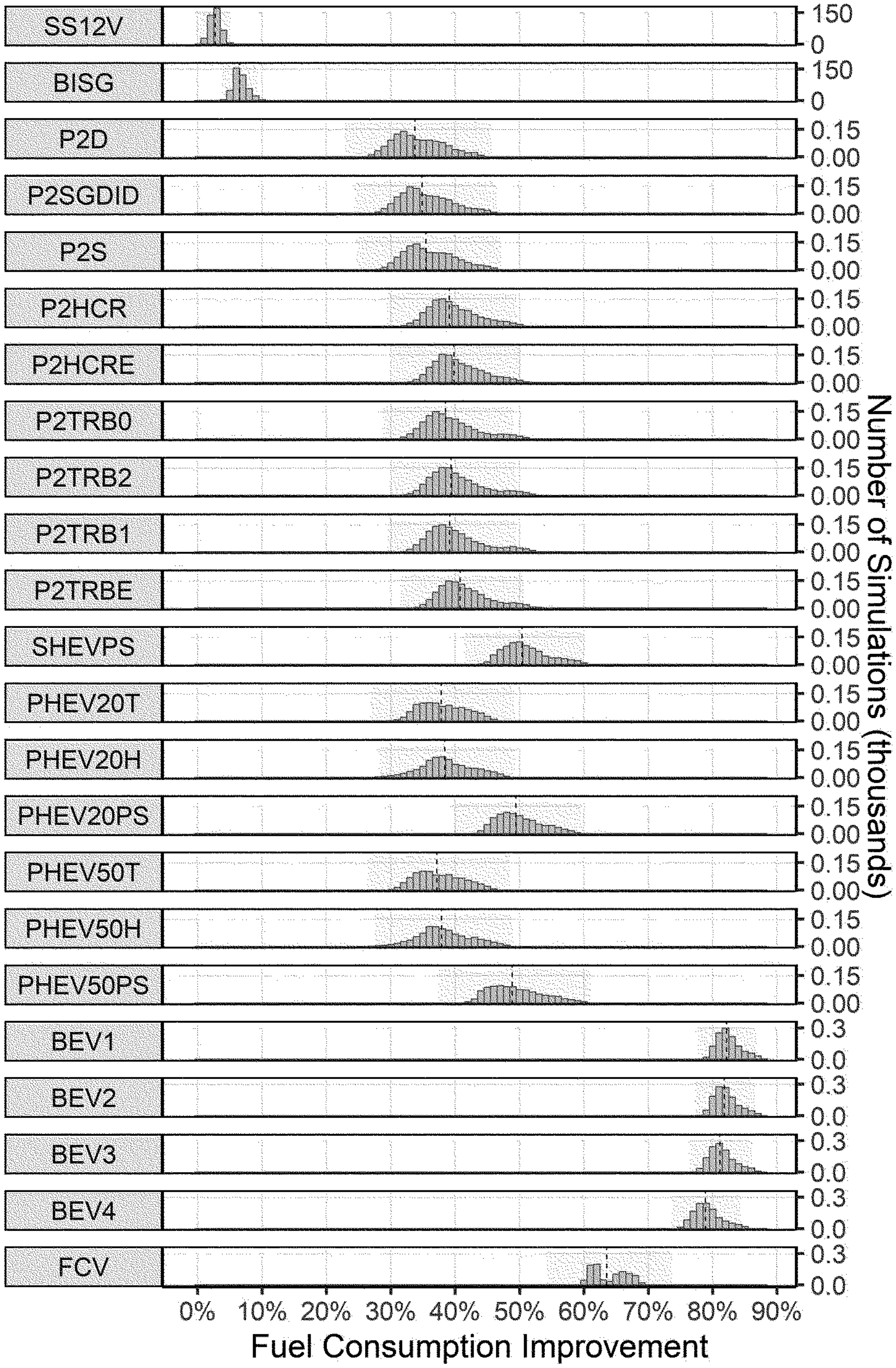

Figure II-23: Light-Duty Electrification Technology Effectiveness Values for All Vehicle Technology Classes (Standard Setting)

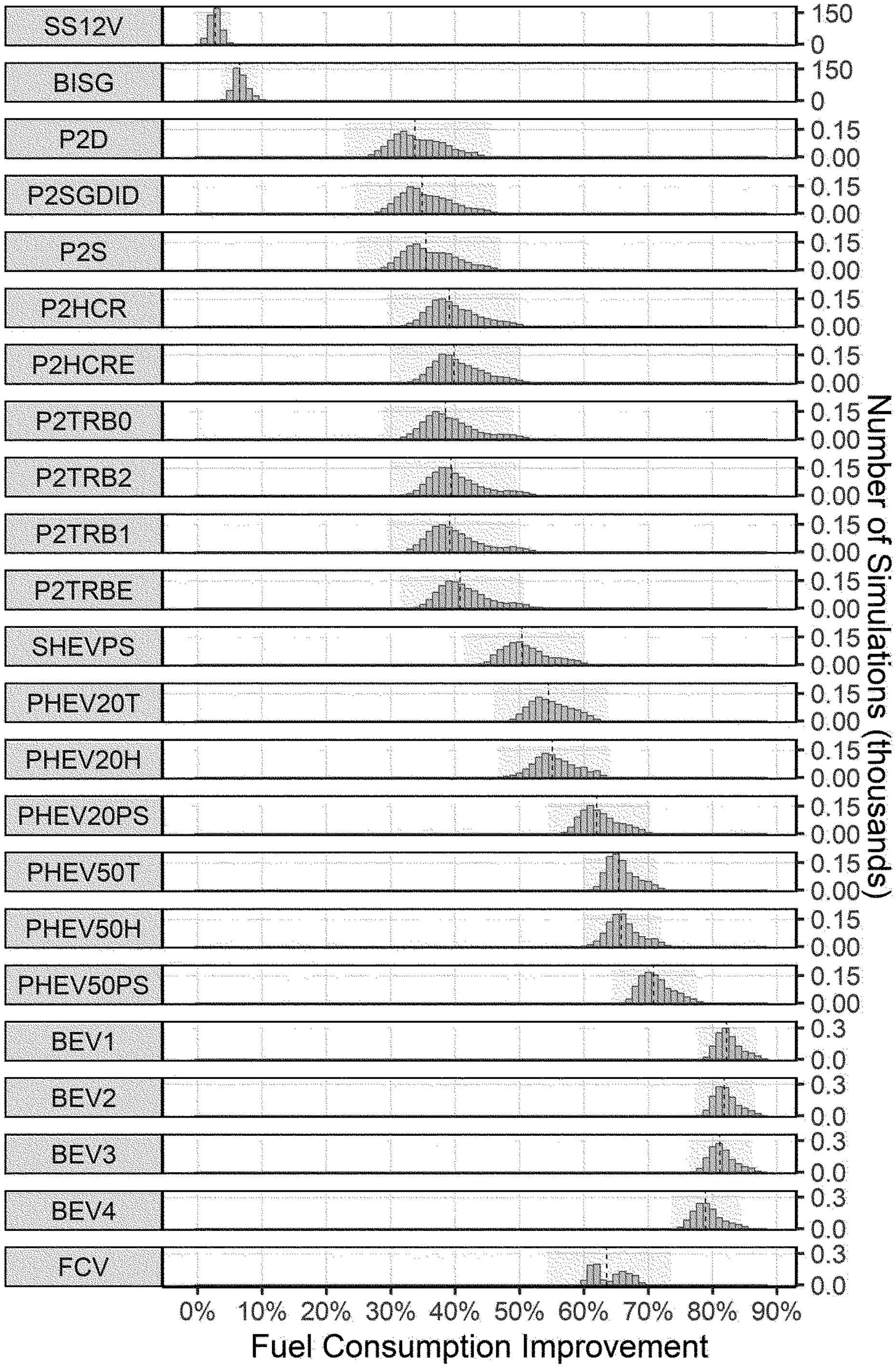

Figure II-24: Light-Duty Electrification Technology Effectiveness Values for All Vehicle Technology Classes (Unconstrained)

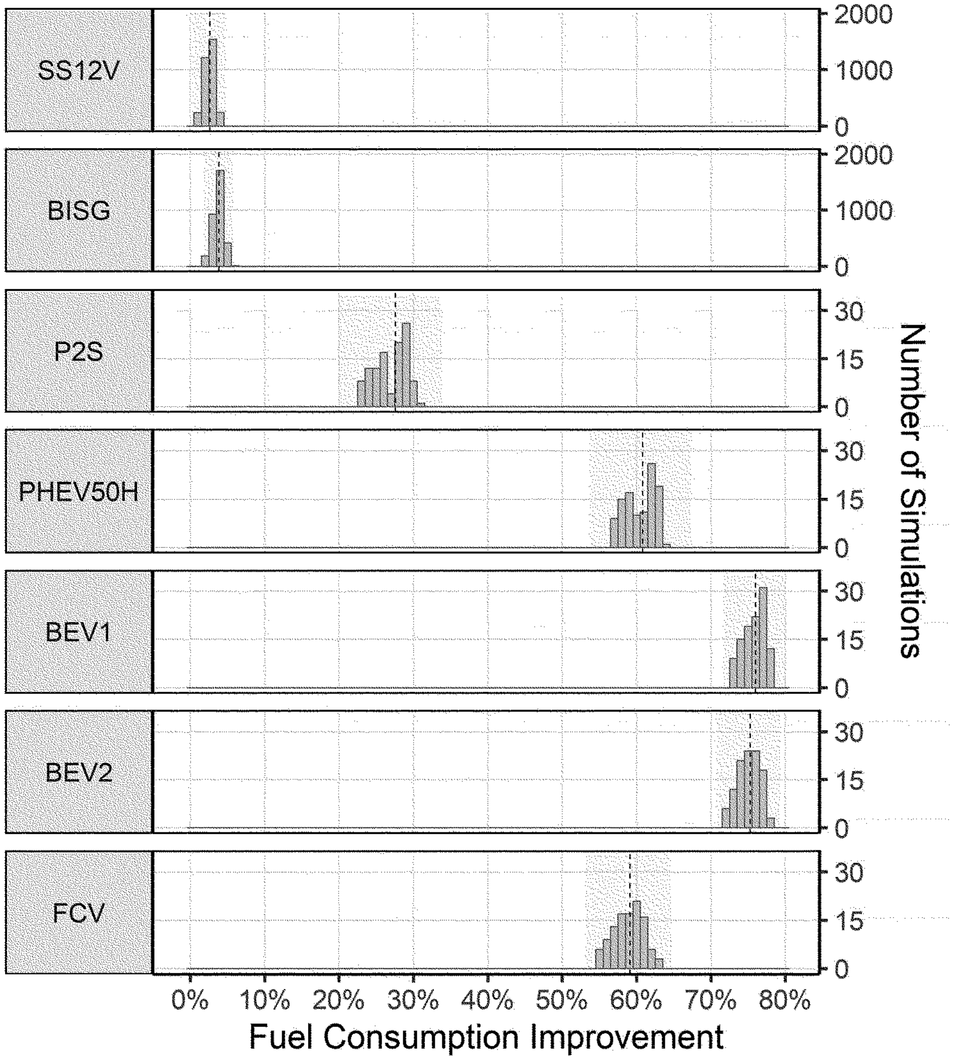

Figure II-25: Heavy-Duty Pick-up and Van (HDPUV) Electrification Technology Effectiveness Values for All Vehicle Technology Classes

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When the CAFE Model turns a vehicle powered by an ICE into an electrified vehicle, it must remove the parts and costs associated with the ICE (and, potentially, the transmission) and add the costs of a battery pack and other non-battery electrification components, such as the electric motor and power inverter. To estimate battery pack costs for this analysis, we need an estimate of how much battery packs cost now (*i.e.,* a ''base year'' cost), and estimates of how that cost could reduce over time (*i.e.,* the ''learning effect.''). The general concept of learning effects is discussed in detail in Section II.C and in Chapter 2 of the Draft TSD, while the specific LE we applied to battery pack costs in this analysis is discussed below. We estimate base year battery pack costs for most electrification technologies using BatPaC, which is an ANL model designed to calculate the cost of EV battery packs.

Traditionally, a user would use BatPaC to cost a battery pack for a single vehicle, and the user would vary factors such as battery cell chemistry, battery power and energy, battery pack interconnectivity configurations, battery pack production volumes, and/or charging constraints, just to name a few, to see how those factors would increase or decrease the cost of the battery pack. However, several hundreds of thousands of simulated vehicles in our analysis have electrified powertrains, meaning that we would have to run individual BatPaC simulations for each full vehicle simulation that requires a battery pack. This would have been computationally intensive and impractical. Instead, ANL staff builds ''lookup tables'' with BatPaC that provide battery pack manufacturing costs, battery pack weights, and battery pack cell capacities for vehicles with varying power requirements modeled in our large-scale simulation runs.

Just like with other vehicle technologies, the specifications of different vehicle manufacturer's battery packs are extremely diverse. We, therefore, endeavored to develop battery pack costs that reasonably encompass the cost of battery packs for vehicles in each technology class. Two BatPaC assumptions are of note when generating base year battery costs: (1)

battery cell chemistry and (2) battery plant production volume.

In conjunction with our partners at ANL working on the CAFE analysis Autonomie modeling, we referenced EV outlook reports,[304] [305] [306] vehicle teardown reports,[307] [308] and stakeholder discussions [309] to determine common battery pack chemistries for each modeled electrification technology. The CAFE Analysis Autonomie Documentation chapter titled ''Battery Performance and Cost Model—BatPac Examples from Existing Vehicles in the Market'' includes more detail about the reports referenced for this analysis.[310] For mild hybrids, we used the LFP-G [311] chemistry because power and energy requirements for mild hybrids are very low, the charge and discharge cycles (or need for increased battery cycle life) are high, and the battery raw materials are much less expensive than a nickel manganese cobalt (NMC)-based cell chemistry. We used NMC622-G [312] for all other electrified vehicle technology initial battery pack cost calculations. While we made this decision at the time of modeling based on the best available information, while also considering feedback on prior rules,[313] more recent data affirms that EV batteries using NMC622 cathode chemistries are still a significant part of the market.[314] We recognize there is ongoing research and development with battery cathode chemistries that may have the potential to reduce costs and increase battery capacity.[315] [316] [317] [318] In particular, we are aware of a recent shift by manufacturers to transition to lithium iron phosphate (LFP) chemistry-based battery packs as prices for materials used in battery cells fluctuate (see additional discussion below); however, we believe that based on available data,[319] NMC622 is more representative for our MY 2022 base year battery costs than LFP, and any additional cost reductions from manufacturers switching to LFP chemistry-based battery packs in years beyond 2022 are accounted for through LEs. As a reminder, in this analysis, we account for the potential cost savings for *future* battery cell chemistries using a learning rate applied to the battery pack DMC. As discussed above, the battery chemistry we use is intended to reasonably represent what is used in U.S. battery manufacturing in MY 2022, the DMC base year for our BatPaC calculations.

We also looked at vehicle sales volumes in MY 2022 to determine a reasonable base production volume assumption.[320] In practice, a single battery plant can produce packs using different cell chemistries with different power and energy specifications, as well as battery pack constructions with varying battery pack designs—different cell interconnectivities (to alter overall pack power end energy) and thermal management strategies—for the same base chemistry. However, in BatPaC, a battery plant is assumed to manufacture and assemble a specific battery pack design, and all cost estimates are based on one single battery plant manufacturing only that specific battery pack. For example, if a manufacturer has more than one BEV and each uses a specific battery pack design, a BatPaC user would include manufacturing volume assumptions for each design separately to represent each plant producing each specific battery pack. As a consequence, we examined battery pack designs for vehicles sold in MY 2022 to determine a reasonable manufacturing plant production volume assumption. We considered each assembly line designed for a specific battery pack and for a specific BEV as an individual battery plant. Since battery technologies are still evolving, it is likely to be some time before battery cells can be treated as commodity where the specific numbers of cells are used for varying battery pack applications and all other metrics remain the same.

Similar to previous rulemakings, we used BEV sales as a starting point to analyze potential base modeled battery manufacturing plant production volume assumptions. Since actual production data for specific battery manufacturing plants are extremely hard to obtain and the battery cell manufacturer is not always the battery pack manufacturer,[321] we calculated an

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[304] RhoMotion. 2023. Emerging Battery Technology Forum. Available at: *https://rhomotion.com/rho-motion-seminar-series-live-q1-2023-seminar-recordings.* (Accessed: May 31, 2023).

[305] Bibra, E. et al. 2022. Global EV Outlook 2022—Securing Supplies For an Electric Future. International Energy Agency. Available at: *https://iea.blob.core.windows.net/assets/ad8fb04c-4f75-42fc-973a-6e54c8a4449a/GlobalElectricVehicleOutlook2022.pdf.* (Accessed: May 31, 2023).

[306] Bloomberg New Energy Finance. 2023. Electric Vehicle Outlook 2023. Available at: *https://about.bnef.com/electric-vehicle-outlook/.* (Accessed: May 31, 2023).

[307] Hummel, P. et al. 2017. UBS Evidence Lab Electric Car Teardown—Disruption Ahead?. UBS. Available at: *https://neo.ubs.com/shared/d1ZTxnvF2k.* (Accessed: May 31, 2023).

[308] A2Mac1: Automotive Benchmarking. (Proprietary data). Available at: *https://portal.a2mac1.com/.* (Accessed: May 31, 2023).

[309] 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.

[310] CAFE Analysis Autonomie Documentation chapter titled ''Battery Performance and Cost Model—BatPac Examples from Existing Vehicles in the Market.''

[311] Lithium Iron Phosphate ($LiFePO_4$) cathode and Graphite anode.

[312] Lithium Nickel Manganese Cobalt Oxide ($LiNiMnCoO_2$) cathode and Graphite anode.

[313] Stakeholders had commented on both the 2020 and 2022 final rules that batteries using NMC811 chemistry had either recently come into or were imminently coming into the market, and therefore we should have selected NMC811 as the appropriate chemistry for modeling battery pack costs.

[314] Rho Motion. Seminar Series Live, Q1 2023—Seminar Recordings. ''Emerging Battery Technology Forum'' February 7, 2023. Available at: *https://rhomotion.com/rho-motion-seminar-series-live-q1-2023-seminar-recordings.* (Accessed: May 31, 2023). More specifically, the monthly weighted average global EV battery cathode chemistry across all vehicle classes shows that 19% use NMC622 and 20% use NMC811+, representing a fairly even split. Even though we considered domestic battery production rather than global battery production for the analysis supporting this proposal, NMC622 is still prevalent even at a global level. Note that this seminar video is no longer publicly available to non-subscribers.

[315] Slowik, P. et. al. 2022. Assessment of Light-Duty Electric Vehicle Costs and Consumer Benefits in the United States in the 2022–2035 Time Frame. International Council on Clean Transportation. Available at: *https://theicct.org/wp-content/uploads/2022/10/ev-cost-benefits-2035-oct22.pdf.* (Accessed: May 31, 2023).

[316] Batteries News. 2022. ''Solid-State NASA Battery Beats The Model Y 4680 Pack at Energy Density by Stacking all Cells in One Case.'' October 20, 2022. Available at: *https://batteriesnews.com/solid-state-nasa-battery-beats-model-y-4680-pack-energy-density-stacking-cells-one-case/.* (Accessed: February 1, 2023).

[317] Sagoff, J. 2023. Scientists develop more humane, environmentally friendly battery material. ANL. Available at: *https://www.anl.gov/article/scientists-develop-more-humane-environmentally-friendly-battery-material.* (Accessed: May 31, 2023).

[318] International Energy Agency. Global EV Outlook 2023. April 2023. Available at *https://www.iea.org/reports/global-ev-outlook-2023.* (Accessed: May 31, 2023).

[319] International Energy Agency. Global EV Outlook 2023. April 2023. Available at *https://www.iea.org/reports/global-ev-outlook-2023.* (Accessed: May 31, 2023). As of IEA's 2023 Global EV Outlook report, ''around 95% of the LFP batteries for electric LDVs went to vehicles produced in China, and BYD [a Chinese EV manufacturer] alone represents 50% of demand. Tesla accounted for 15%, and the share of LFP batteries used by Tesla increased from 20% in 2021 to 30% in 2022. Around 85% of the cars with LFP batteries manufactured by Tesla were manufactured in China, with the remainder being manufactured in the United States with cells imported from China. In total, only around 3% of electric cars with LFP batteries were manufactured in the United States in 2022.'' This is not to say that as of 2022 there were no current production or use of vehicle battery packs with LFP-based chemistries in the U.S., but rather that based on available data, we are more certain that NMC622 was a reasonable chemistry selection for our 2022 base year battery costs.

[320] See Chapter 2.2.1.1 of the Draft TSD for more information on data we use for MY 2022 sales volumes.

[321] Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States: 2010–2020, ANL/ESD–21/3.

average production volume per manufacturer metric to approximate BEV production volumes for this analysis. This metric was calculated by taking an average of all manufacturer's battery energy across all BEVs reported in vehicle manufacturer's PMY 2022 reports[322] and dividing by the averaged sales-weighted energy per-vehicle; the resulting volume was then rounded to the nearest 5,000. Manufacturers are not required to report gross battery pack sizes for the PMY report, so we estimated pack size for each vehicle based on publicly available data, like manufacturer's announcements. This process was repeated for all other electrified vehicle technologies. We believe this gave us a reasonable base year plant production volume—especially in the absence of actual production data—since the PMY data from manufacturers already includes accurate related data, such as vehicle model and sales information metrics.[323] An example calculation below, in Table II–14 and Equation II–7 and Equation II–8, outline how the sales-weighted energy per vehicle production volume estimates are calculated with Table II–14 showing several example BEV models, their production volumes, and pack energy that are representative of industry today.

TABLE II–14—EXAMPLE BEV MODEL BATTERY PACKS

Electrification level	Vehicle make	Vehicle model	Production volume	Battery pack energy
BEV	Make A	Model A1	70,000	80kWh
BEV	Make A	Model A2	3,000	100kWh
BEV	Make B	Model B1	4,000	90kWh
BEV	Make C	Model C1	18,000	70kWh

The average energy (E_{avg}) across all BEVs in the fleet is initially found. In this example, the average energy is calculated as the sum of the pack energy divided by the number of vehicle models:

$$E_{avg} = \frac{E_{Model\ A1} + E_{Model\ A2} + E_{Model\ B1} + E_{Model\ C1}}{N_{Vehicle\ models}}$$

$$= \frac{80kWh + 100kWh + 90kWh + 70kWh}{4}$$

$$= 85kWh\ average\ energy\ (example)$$

Equation II-7: Example Average BEV Energy Calculation

Next, the average production volume (P_{avg}) for this example was found via the sales weighted energy per vehicle by taking the product of a model's pack energy ($E_{Model\ xn}$) and production volume ($P_{Model\ xn}$) across all example vehicle models—with the sum of all models then divided by the average pack energy (E_{avg}), found from the previous equation:

---

[322] 49 CFR 537.7.

[323] NHTSA used publicly available range and pack size information and linked the information to vehicle models.

$$
\begin{aligned}
&P_{avg} \\
&= \frac{(E_{Model\,A1} * P_{Model\,A1}) + (E_{Model\,A2} * P_{Model\,A2}) + (E_{Model\,B1} * P_{Model\,B1}) + (E_{Model\,C1} * P_{Model\,C1})}{E_{avg}} \\
&= \frac{(80kWh * 70{,}000) + (100kWh * 3{,}000) + (90kWh * 4{,}000) + (70kWh * 18{,}000)}{85kWh} \\
&= 104{,}235.3 \approx 105{,}000\ average\ BEV\ production\ (THEORETICAL\ EXAMPLE\ ONLY)
\end{aligned}
$$

Equation II-8: Example Sales Weighted Energy Per Vehicle

Once the average BEV production (P_{avg}) was found, it is rounded to the nearest 5,000; for this example, the production volume is rounded up from 104,235.3 to 105,000 vehicles. This process was used to determine production volumes for each of the electrified powertrain technologies in the fleet. Our final battery manufacturing plant production volume assumptions for different electrification technologies are as follows: mild hybrid and strong hybrids are manufactured assuming 200,000 packs, PHEVs are manufactured assuming 20,000 packs, and BEVs are manufactured assuming 60,000 packs.

We believe it was reasonable to consider U.S. sales for purposes of this calculation rather than global sales based on the best available data we had at the time of modeling and based on our understanding of how manufacturers design BEVs for particular markets.[324] That said, we are interested in comments from manufacturers and other stakeholders on how vehicle and battery manufacturers take advantage of design overlap across markets to maintain cost reduction progress in battery technology. A manufacturer may have previously sold the same vehicle with different battery packs in two different markets, but as the outlook for battery materials and global economic events dynamically shift, manufacturers could take advantage of significant design overlap and other synergies like from vertical integration to introduce lower-cost battery packs in markets that it previously perceived had different design requirements.[325] To the extent that manufacturers' costs are based more closely on global volumes of battery packs produced, our base year battery pack *production volume* assumption could potentially be conservative; however, as discussed further below, our base year MY 2022 battery pack *costs* fall well within the range of reasonable estimates based on 2023 data. Again, we seek comment on this approach and the resulting base year cost estimates.

As mentioned above, our BatPaC lookup tables provide $/kWh battery pack costs based on vehicle power and energy requirements. As an example, a midsized SUV with mid-level road load reduction technologies (MASS, ROLL, and AERO), like the vehicle in the example in Section II.C, might require a 110–120kWh energy and 200–210kW power battery pack. From our base year BatPaC cost estimates, that vehicle might have a battery pack that costs around $123/kWh. Note that the total cost of a battery pack goes up the higher the power/energy requirements, however the cost per kWh goes down. This represents the cost of hardware that is needed in all battery packs but is deferred across more kW/kWh in larger packs, which reduces the per kW/kWh cost. Table II–15 shows an example of the BatPaC-based lookup tables for the BEV3 SUV through pickup technology classes.

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[324] As an example, a manufacturer might design a BEV to suit local or regional duty cycles (*i.e.,* how the vehicle is driven day-to-day) due to local geography and climate, customer preferences, affordability, supply constraints, and local laws. This is one factor that goes into chemistry selection, as different battery chemistries affect a vehicle's range capability, rate of degradation, and overall vehicle mass.

[325] As an example, some U.S. Tesla Model 3 and Model Y battery packs use a nickel cobalt aluminum (Lithium Nickel Manganese Cobalt Aluminum Oxide cathode with Graphite anode, commonly abbreviated as NCA)-based cell, while the same vehicles for sale in China use LFP-based packs. However, Tesla has introduced LFP-based battery packs to some Model 3 vehicles sold in the U.S., showing how manufacturers can take advantage of experience in other markets to introduce different battery technology in the United States. See Electric Vehicle Database. Tesla Model 3 Standard Range Plus LFP. Available at: *https://ev-database.uk/car/1320/Tesla-Model-3-Standard-Range-Plus-LFP.* (Accessed: May 31, 2023). See the Tesla Model 3 Owner's Manual for additional considerations regarding LFP-based batteries, at *https://www.tesla.com/ownersmanual/model3/en_jo/GUID-7FE78D73-0A17-47C4-B21B-54F641FFAEF4.html.*

Table II-15: Baseline (MY 2022) BEV3 $/kWh Battery Pack Costs, SUV to Pickup Technology Classes

$/kWh at Pack Level (Total Energy) for SUV to Pickup (LD & HDPUV) Vehicle Technology Class													
BEV3		Energy, kWh											
		30.0	50.0	70.0	90.0	120.0	140.0	160.0	180.0	200.0	250.0	300.0	350.0
Power, kW	20.0	$182	$151	$137	$129	$121	$118	$116	$114	$113	$110	$108	$106
	40.0	$183	$151	$137	$129	$121	$118	$116	$114	$113	$110	$108	$106
	60.0	$183	$151	$137	$129	$122	$118	$116	$114	$113	$110	$108	$106
	80.0	$184	$152	$137	$129	$122	$118	$116	$115	$113	$110	$108	$106
	100.0	$184	$152	$138	$129	$122	$119	$116	$115	$113	$110	$108	$106
	120.0	$185	$152	$138	$130	$122	$119	$117	$115	$113	$110	$108	$106
	140.0	$185	$153	$138	$130	$122	$119	$117	$115	$113	$110	$108	$106
	160.0	$186	$153	$138	$130	$122	$119	$117	$115	$113	$110	$108	$106
	180.0	$187	$154	$139	$130	$122	$119	$117	$115	$113	$110	$108	$107
	200.0	$187	$154	$139	$130	$123	$119	$117	$115	$113	$110	$108	$107
	240.0	$188	$155	$139	$131	$123	$119	$117	$115	$114	$110	$108	$107
	280.0	$191	$155	$140	$131	$123	$120	$117	$116	$114	$111	$108	$107
	320.0	$197	$156	$140	$131	$123	$120	$118	$116	$114	$111	$108	$107
	400.0	$208	$157	$141	$132	$124	$120	$118	$116	$114	$111	$109	$107

Note that the values in the table above should *not* be considered the total battery $/kWh costs that are used for vehicles in the analysis in future MYs. As detailed below, battery costs are also projected to decrease over time as manufacturers improve production processes, shift battery chemistries, or make other technological advancements. In addition, select modeled tax credits further reduce our estimated costs; additional discussion of those tax credits is located throughout this preamble, the Draft TSD, and PRIA.

The CAFE Analysis Autonomie Documentation details other specific assumptions that ANL used to simulate battery packs and their associated base year costs for the full vehicle simulation modeling, including updates to the battery management unit costs, and the range of power and energy requirements used to bound the lookup tables.[326] Please refer to the CAFE Analysis Autonomie Documentation and Chapter 3.3 of the Draft TSD for further information about how we used BatPaC to estimate base year battery costs. The full range of BatPaC-generated battery DMCs is located in ANL—Summary of Main Component Performance Assumptions_NPRM_2206. Note again that these charts represent the DMC using a dollar per kW/kWh metric; battery absolute costs used in the analysis by technology key can be found in the CAFE Model Battery Costs File.

For this analysis, our method of estimating future battery costs has three fundamental components: (1) an estimate of MY 2022 battery pack costs (*i.e.,* our base year costs generated in the BatPaC 5.0 model to estimate battery pack costs for specific vehicles, depending on factors such as pack size and power requirements, discussed above), and (2) future learning rates through 2050, and (3) the effect of changes in the cost of key minerals on battery pack costs, which are discussed below.

The concept of a learning curve was initially developed to describe cost reduction due to improvements in manufacturing processes from knowledge gained through experience in production; however, it has since been recognized that other factors make important contributions to cost reductions associated with cumulative production.[327] We discuss this concept further, in Section II.C.

For the last CAFE Model analysis, we estimated potential future reductions in battery pack costs,[328] based on an assessment of cost reductions due to battery pack production volume increases.[329] This production-volume-based learning rate clearly fell within the meaning of a ''learning curve'' because the cost reductions were based on improvements in manufacturing processes due to knowledge gained through experience in production. We also used BatPaC to examine how battery pack costs might change due to factors other than production volume increases, including chemistry changes and changes in manufacturing plant efficiency, while recognizing that BatPaC does include some cost reductions due to improvements in manufacturing processes, in particular

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[326] CAFE Analysis Autonomie Documentation chapter titled ''Battery Performance and Cost Model—Use of BatPac in Autonomie.''

[327] Wene, C. 2000. Experience Curves for Energy Technology Policy. International Energy Agency. Paris.

[328] Note that we use cost in the CAFE Model, however many sources also report price. We have tried to use the accurate term throughout this section, however, note that even within the same data source, cost and price may be used interchangeably. See Mauler, L., F. Duffner, W. Zeier and J. Leker. 2021. Battery cost forecasting: a review of methods and results with an outlook to 2050. *Energy and Environmental Science,* 4712–4739 (''However, details on company-specific prices, costs and profit margins are not publicly available and differences are difficult to assess.[] In battery literature both terms are frequently used interchangeable, a phenomenon reported earlier,[ ] which may be explained by different perspectives on the same value, since the price paid to a battery manufacturer represents the cost to the manufacturer of the final product.'').

[329] 87 FR 25819.

through assumed increases in the degree of plant automation.[330] Recognizing that battery pack costs for future years are inherently uncertain, we sought comment on our learning rates and also provided cost estimates from other sources against which to compare our estimates.[331] [332] Our conclusion after considering comments and publicly available information was that our estimates of how battery pack costs could reduce over time fell reasonably within the estimates of potential future battery pack cost estimates from other sources. However, we also received valuable information and feedback from commenters on sources of information about future battery costs estimates,[333] and concerns about factors that could potentially drive the future cost of battery packs up or down.[334]

In particular, a 2021 study by Mauler et al., ‘‘Battery cost forecasting: a review of methods and results with an outlook to 2050,’’ referenced above and by commenters during the last rule provided one of the most far-reaching examinations of battery cost literature to date. This comprehensive survey of 53 forecasts of battery pack and cell costs included studies based on four forecasting methods: learning, literature-based projections, expert elicitation, and bottom-up battery pack models.[335] Each study focused on a unique set of assumptions that may include battery plant size and location, the plant's production processes and overall cumulative production, battery cell and electrode designs, and material prices. The paper identifies and discusses these important considerations—making correlations between resulting cost differences across battery technology considerations and varying forecast periods between studies—and appropriately encapsulates the battery market within technological scope. Importantly, as discussed further below, the authors appropriately note the uncertainty associated with predicting lithium-ion battery (LIB) costs out through 2050.

The authors extracted 237 estimates from the 22 studies published over the previous 10 years that focused on LIB packs. They fitted a central tendency curve to the estimates as a function of time up to 2050.[336] The central tendency curve shows battery pack costs declining from $1,014/kWh in 2010 to $234/kWh in 2020. Costs in the fitted curve decline to $132/kWh in 2030, and progress lower to $109/kWh in 2035, and $92/kWh in 2040. The paper's authors present the fit curve with reference to survey battery prices from Bloomberg New Energy Finance (BNEF), one source of battery pack prices based on survey data. In the two articles referenced by Mauler et al. to provide comparison data for their fitted curve, BNEF cites battery pack prices at $176/kWh in 2018 declining to $94/kWh by 2024 (using observed historical values to calculate a ‘‘learning rate of around 18%. This means that for every doubling of cumulative volume, we observe an 18% reduction in price.’’),[337] and a more recent estimate of $137/kWh in 2020 declining to $101/kWh by 2023.[338] Mauler et al. note that ‘‘in the time period between 2015 and 2020, 90% of forecasted values are more pessimistic than observed prices. This indicates that forecasts in the examined literature have been on the pessimistic end in the past. Further, the persistent span of estimates above [$130/kWh, in the surveyed literature] throughout 2050 underlines the uncertainty associated with the prediction of LIB cost that will remain a key challenge in the future for researchers and companies in the field.’’ [339]

Much has happened since the last CAFE Model analysis and the battery cost forecasting paper summarized above. BNEF summarized that ‘‘[a]s demand continues to grow, battery producers and automakers are scrambling to secure access to key metals such as lithium and nickel, battling high prices and tight supply.’’ [340] Since the articles cited in the Mauler paper discussed above, BNEF has revised their battery pack price estimates for 2022 to $135/kWh,[341] and then revised their 2022 estimate again to $138/kWh.[342] BNEF attributed the increase in pack costs in part to the increase in mineral costs—specifically lithium carbonate—in addition to inflation and component cost increases.[343] However, BNEF also

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[330] See 24–26 TSD at 286–7 (citing Nelson, Paul A., Ahmed, Shabbir, Gallagher, Kevin G., and Dees, Dennis W. Modeling the Performance and Cost of Lithium-Ion Batteries for Electric-Drive Vehicles, Third Edition (ANL/CSE–19/2). Available at *https://publications.anl.gov/anlpubs/2019/03/150624.pdf.* (Accessed: May 31, 2023).) (‘‘As detailed in the BatPaC model documentation, the costs of materials, labor, and capital equipment in the model are based upon ANL's estimates of 2018 values, ‘[t]hus, if BatPaC is used to calculate the current costs of batteries at current production levels (say 30,000 all-electric (BEV) packs per year) we expect it to provide good estimates of current battery prices to OEMs. Estimates done for ten years in the future should be at production levels of 100,000 to 500,000 units per year, which will result in lower pack prices because of the assumed increase in the degree of plant automation.’ ’’).

[331] 87 FR 25818.

[332] 24–26 TSD at 313.

[333] See, *e.g.,* Mauler, L. et al. 2021. Battery Cost Forecasting: A Review of Methods and Results With an Outlook to 2050. Energy and Environmental Science: pp. 4712–4739.

[334] 87 FR 25819–20.

[335] Mauler, L. et al.. Battery Cost Forecasting: A Review Of Methods And Results With An Outlook To 2050. Energy and Environmental Science: pp. 4712–4739. Many of these selected studies focus on common-place LIB cathode chemistries for BEVs—such as lithium nickel manganese cobalt oxide (NMC), lithium nickel cobalt aluminum oxide (NCA), and lithium iron phosphate (LFP); however, some studies investigate the future-use of battery technologies such as solid-state (SSB) and lithium-sulfur (LSB), while other studies examine battery applications that more broadly coincide with HEVs, energy stationary storage (ESS), consumer electronics, and medical devices. Thirty of the forecasts were based on bottom-up battery models and sixteen used estimated learning curves.

[336] Figure 9 of Mauler et al., 2021, at 4715. The authors note: ‘‘Whenever values for multiple applications are reported, the forecast dedicated to electric vehicle batteries is preferred.’’ Costs appear to be in 2020 dollars, although this is not clearly stated in the text. The authors also ‘‘emphasize that this should not be considered as a literature-based forecast to 2050, but merely as a comprehensive picture of forecasted values from the past decade.’’

[337] BNEF. 2019. A Behind the Scenes Take on Lithium-ion Battery Prices. Last revised: March 5, 2019. Available at: *https://about.bnef.com/blog/behind-scenes-take-lithium-ion-battery-prices/.* (Accessed: May 31, 2023).

[338] BNEF. 2020. Battery Pack Prices Cited Below $100/kWh for the First Time in 2020, While Market Average Sits at $137/kWh. Last revised: December 16, 2020. Available at: *https://about.bnef.com/blog/battery-pack-prices-cited-below-100-kwh-for-the-first-time-in-2020-while-market-average-sits-at-137-kwh/.* (Accessed: May 31, 2023). Note that at the time of writing (2020), BNEF was of the opinion that ‘‘The path to achieving $101/kWh by 2023 looks clear, even if there will undoubtedly be hiccups, such as commodity price increases, along the way.’’).

[339] Mauler et al., at 4733.

[340] BNEF. 2022. The Race to Net Zero: The Pressures of the Battery Boom in Five Charts. Last revised: July 21, 2022. Available at: *https://about.bnef.com/blog/race-to-net-zero-the-pressures-of-the-battery-boom-in-five-charts/.* (Accessed: May 31, 2023).

[341] BNEF. 2022. The Race to Net Zero: The Pressures of the Battery Boom in Five Charts. Last revised: July 21, 2022. Available at: *https://about.bnef.com/blog/race-to-net-zero-the-pressures-of-the-battery-boom-in-five-charts/.* (Accessed: May 31, 2023).

[342] BNEF. 2022. Lithium-ion Battery Pack Prices Rise for First Time to an Average of $151/kWh. Last revised: Dec. 6, 2022. Available at: *https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/.* (Accessed: May 31, 2023); McKerracher, C. 2022. Rising Battery Prices Threaten to Derail the Arrival of Affordable Evs. Available at: *https://www.bloomberg.com/news/articles/2022-12-06/rising-battery-prices-threaten-to-derail-the-arrival-of-affordable-evs.* (Accessed: May 31, 2023). (‘‘To arrive at the average price, BNEF gathered almost 200 survey data points from buyers and sellers of lithium-ion batteries going into passenger Evs, commercial vehicles, buses and stationary storage applications. The headline figure is a volume-weighted average, so it hides a lot of variation by region and application. The lowest prices recorded were for electric buses and commercial vehicles in China at $131 per kWh. Average pack prices for fully electric passenger vehicles were $138 per kWh.’’).

[343] BNEF. 2022. Lithium-ion Battery Pack Prices Rise for First Time to an Average of $151/kWh. Last revised: Dec. 6, 2022. Available at: *https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/.* (Accessed: May 31, 2023).

noted that ''[t]he average battery price would have been even higher if not for the shift to lower-cost LFP batteries, which contain no nickel or cobalt.'' [344] The International Energy Agency's Global EV Outlook 2023 also used estimates from BNEF, citing a value of $150 for all LIB packs.[345]

In addition, the U.S. DOE updated modeling-based estimates of battery pack costs from using ANL's BatPaC model. Their updated estimates show 2022 values at $130/kWh of rated energy.[346] Separately, a 2022 analysis of future vehicle costs sponsored by the U.S. DOE with co-authors from ANL, Ford, GM, Electric Power Research Institute, the National Renewable Energy Laboratory, and Chevron compared predictions of future EV battery pack costs from 9 studies with 3 R&D targets set by DOE and US DRIVE.[347] They concluded that ''recent assessments of future BEV battery costs by governmental agencies, national laboratories, the NAS, academia, consulting firms, and automakers show this [dramatic decline in the costs of high-energy Li-ion batteries] trend is expected to continue in the future.'' [348]

For this analysis, instead of relying on our previous methodology of using the BatPaC model to estimate volume-based cost reductions for battery packs, we extracted estimated learning rates from the Mauler et al. study discussed above. Our learning rates are based on the year-over-year cost decreases shown in the Mauler et al. study; however, we modified the learning rate in two ways, discussed in turn.

First, we began Mauler's 2030–2035 estimated learning rate in MY 2022, as it better aligns with our MY 2022 BatPaC-based base year cost estimates and is reflected in the most recent BNEF survey data. To the extent that global EV battery production has grown more rapidly than the studies anticipated, it is reasonable to expect that learning in manufacturing processes, economies of scale, and technological progress have also been realized sooner than the projections anticipated. Assuming this is the case, future learning rates will be lower than the studies anticipated because battery manufacturing has moved farther down the learning curve than they anticipated.

Second, to reflect the combination of fluctuating mineral costs and an increase in demand, we hold the battery pack cost learning curve constant between MYs 2022 and 2025. This is a conservative assumption that is also employed by EPA in their proposal for light duty vehicles and medium duty vehicles beginning in MY 2027 at Section IV.C.2 and Draft Regulatory Impact Analysis Section 2.5.2.1.3. The assumption reflects increased lithium costs since 2020 that are not expected to decline appreciably to circa 2020 levels until additional capacity (mining, materials processing, and cell production) comes on-line,[349] although prices have already fallen from 2022 highs at the time of writing. We believe that a continuation of high prices for a few years followed by a decrease to near previous levels is reasonable because world lithium resources are more than sufficient to supply a global EV market and higher prices should continue to induce investment in lithium mining and refining.[350] [351] That said, we recognize the uncertainty in critical minerals prices into the near future. We seek comment on this representation of mineral costs in the learning curve, and any other feedback relevant to incorporating these considerations into our modeling framework.

Unlike our past production-based estimates for a battery learning curve, this learning curve methodology does not explicitly assume any particular battery chemistry is used, because the learning curve we use aggregates assumptions from several studies and uses some assumptions of our own. That said, we anticipate cell chemistry improvements will happen sometime during the middle or later part of this decade. We believe that during the rulemaking time frame, based on on-going research and discussions with stakeholders,[352] the industry will continue to employ lithium-ion NMC as the predominant battery cell chemistry for the near-term but will transition more fully to advanced high-nickel battery chemistries [353] like NMC811 or less-costly cell chemistries like LFP–G during the middle or end of the decade—*i.e.,* during the rulemaking timeframe. We acknowledge there are other battery cell chemistries currently being researched that reduce the use of cobalt, use solid opposed to liquid electrolyte, use of high silicone content anodes or lithium-metal anodes, or even eliminate use of lithium in the cell altogether; [354] [355] however, at this time, we do not have sufficient data to estimate cost for those advanced battery cell chemistries. Assuming lithium-ion NMC will continue to be used for the

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[344] *Id.*

[345] International Energy Agency, Global EV Outlook 2023, available at *https://www.iea.org/reports/global-ev-outlook-2023* (citing BloombergNEF, Lithium-ion Battery Prices Rise for First Time to an Average of $151/kWh, available at *https://about.bnef.com/blog/lithium-ion-battery-pack-prices-rise-for-first-time-to-an-average-of-151-kwh/*). Note that $151/kWh represents an average across multiple battery end-uses, while BNEF's estimates for battery electric vehicle packs in particular are $138/kWh on a volume-weighted average basis in 2022.

[346] ANL. 2022. BatPaC—A Spreadsheet Tool to Design a Lithium Ion Battery and Estimate Its Production Cost. Last revised: Mar. 8, 2022. Available at: *https://www.anl.gov/cse/batpac-model-software.* (Accessed: May 31, 2023). This estimate assumes a production scale of 100,000 units per year, however as discussed further below, our BatPaC-derived costs align extremely well with these DOE-estimated costs. See also, Cunningham, B. U.S. Department of Energy Vehicle Technologies Office 2023 Annual Merit Review. Overview: Batteries R&D, DOE Modeled Battery Pack Cost. June 12, 2023; VTO Fact of the Week #1272, Electric Vehicle Battery Pack Costs, which shows that 2022 costs are nearly 90% lower than in 2008, according to DOE Estimates (Jan. 9, 2023). Available at *https://www.energy.gov/eere/vehicles/articles/fotw-1272-january-9-2023-electric-vehicle-battery-pack-costs-2022-are-nearly.* (Accessed: May 31, 2023).

[347] Kelly, J. et al. 2022. Cradle-to-Grave Lifecycle Analysis of U.S. Light-Duty Vehicle-Fuel Pathways: A Greenhouse Gas Emissions and Economic Assessment of Current (2020) and Future (2030–2035) Technologies. ANL–22/27. ANL: Argonne, IL. p. 56.

[348] *Id.*

[349] Trading Economics. 2023. Lithium. Available at: *https://tradingeconomics.com/commodity/lithium* (Accessed: May 31, 2023).

[350] U.S. Geological Survey. 2023. Lithium Statistics and Information. Available at: *https://www.usgs.gov/centers/national-minerals-information-center/lithium-statistics-and-information.* (Accessed: May 31, 2023).

[351] Global lithium resources (''resources defined by U.S.G.S. as ''[a] concentration of naturally occurring solid, liquid, or gaseous material in or on the Earth's crust in such form and amount that economic extraction of a commodity from the concentration is currently or potentially feasible.'') are currently four times as large as global reserves (''reserves'' defined by U.S.G.S. as ''[t]hat part of the reserve base that could be economically extracted or produced at the time of determination.''), and both have grown over time as production has increased (Figure 3). Lithium resources are not evenly distributed geographically (Figure 4). According to 2021 USGS estimates, Bolivia (24%), Argentina (22%), Chile (11%), the United States (10%), Australia (8%) and China (6%) together hold four-fifths of the world's lithium resources.

[352] 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.

[353] Panayi, A. 2023. Into the Next Phase, the EV Market Towards 2030—The TWh year: The Outlook for the EV & Battery Markets in 2023. RhoMotion. Available at: *https://rhomotion.com/rho-motion-seminar-series-live-q1-2023-seminar-recordings.* (Accessed: May 31, 2023).

[354] Slowik, P. et. al. 2022. Assessment of Light-Duty Electric Vehicle Costs and Consumer Benefits in the United States in the 2022–2035 Time Frame. International Council on Clean Transportation. Available at: *https://theicct.org/wp-content/uploads/2022/10/ev-cost-benefits-2035-oct22.pdf.* (Accessed: May 31, 2023).

[355] Batteries News. 2022. Solid-State NASA Battery Beats The Model Y 4680 Pack at Energy Density by Stacking all Cells in One Case. Last revised: October 20, 2022. Available at: *https://batteriesnews.com/solid-state-nasa-battery-beats-model-y-4680-pack-energy-density-stacking-cells-one-case/.* (Accessed: May 31, 2023).

near and mid-term results in reasonable estimates that are comparable to other sources' cost projections, although we note that the outcome of a model should not be used to justify the input assumptions.

As there are inherent uncertainties in projecting future battery pack costs due to several factors, including the timing of the analysis used to support this proposal, we performed several battery-related cost sensitivity analyses. These include cases increasing and decreasing battery pack DMCs by 20%, cases increasing and decreasing the learning rate by 20%, and a case using the learning curve development methodology we used for the 2022 final rule for MYs 2024–2026 standards. These results are presented in Chapter 9 of the PRIA. One important point that these sensitivity case results emphasize is that because of NHTSA's inability to consider manufacturers building EVs in response to CAFE standards during standard-setting years (*i.e.,* MYs 2027–2032 for this proposal), net SCs and benefits do not change significantly between battery cost sensitivity cases, and similarly would not change significantly if much lower battery costs were used. We will continue to follow Federal and international reports on battery pack costs and seek additional comment on our battery cost estimates; we will update these costs for the final rule analysis if better data becomes available.

Additional discussion in Draft TSD Chapter 3 shows that our projected costs fall fairly well in the middle of the range of other costs projected by various studies and organizations for future years. Using the same approach as the rest of our analysis—that our costs should represent an average achievable performance across the industry—we believe that the battery DMCs with the learning curve applied provide a reasonable representation of potential future costs across the industry, based on the information available to us at the time of the analysis for this proposal was completed. Figure II–26 below shows how our reference and sensitivity case cost projections (for a 300-mile range BEV with a 70.1kWh battery pack) change over time using different base year and learning assumptions.

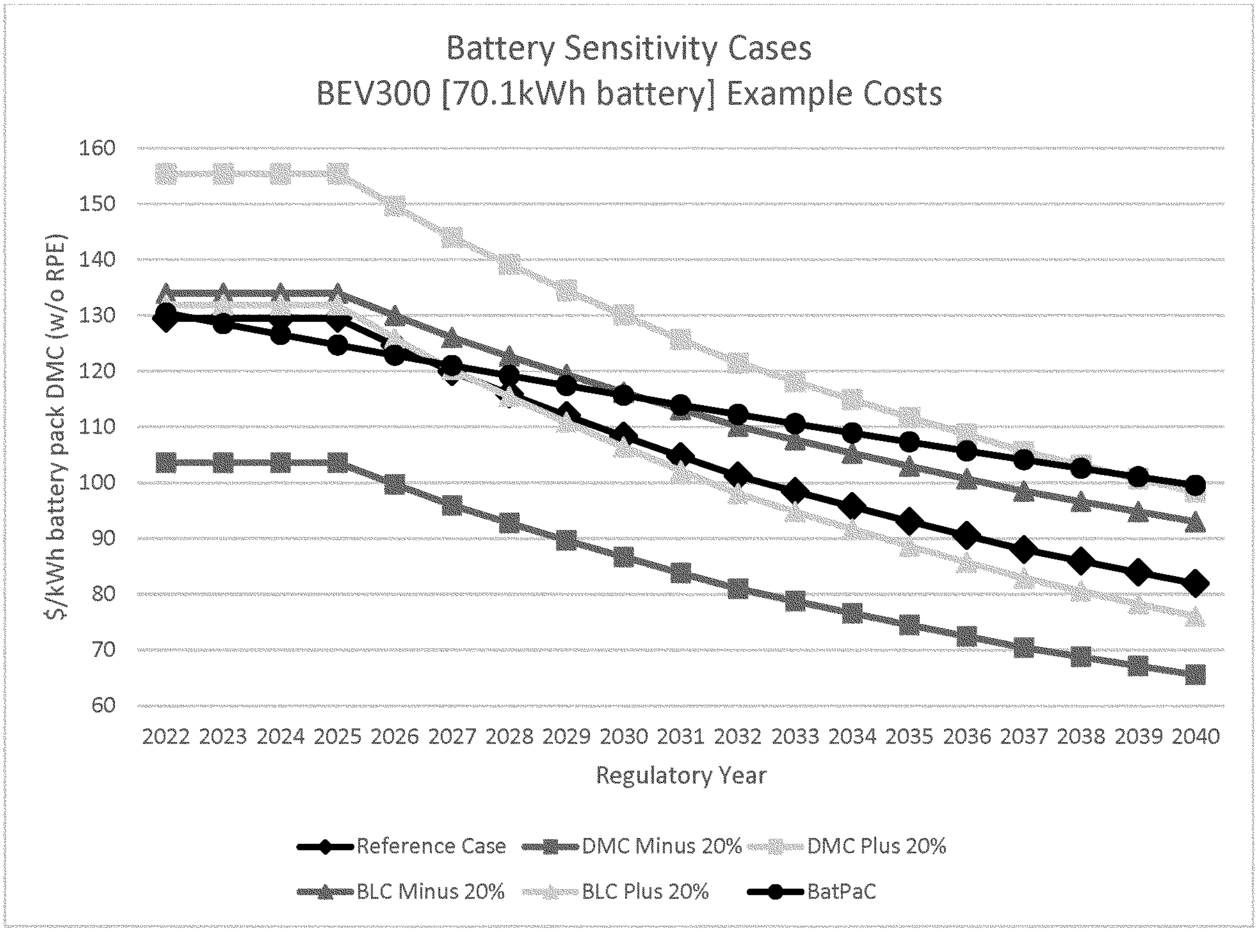

Figure II-26: Example Battery Costs for a BEV3 with a 70.1kWh Battery Pack

NHTSA also continues to coordinate with DOE and EPA on assumptions and methodology related to battery cost. During the interagency review process for EPA's Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles proposal, which shortly preceded the process for this proposal, EPA consulted with DOE to incorporate battery cost learning effects that reflect the effect of cumulative learning by considering the battery production required for a given projected BEV penetration. In its analysis, upon recommendation from DOE, EPA applied battery cost learning effects dependent on the cumulative GWh of battery pack production projected in each individual policy scenario, as described in Chapter 2.5.2.1.3 of the

EPA Draft Regulatory Impact Analysis (DRIA).[356] In other words, learning effects were more pronounced in policy scenarios resulting in higher rates of BEV penetration and, conversely, were less pronounced in policy scenarios resulting in lower rates of BEV penetration. Similar to the NHTSA analysis, the EPA cost/kWh also varies by pack size, with larger packs having a lower cost/kWh (see Chapter 2.5.2.1.2 of the EPA DRIA).[357] Because of the way in which EPA has thus parameterized its battery cost, which is dependent on cumulative volume production in a given policy scenario, a direct comparison to the NHTSA cost sensitivities shown in Figure II–27 is not straightforward. The cost/kWh of several different pack sizes, as implemented in the EPA analysis supporting the recent EPA proposal, are shown in Figure 30.

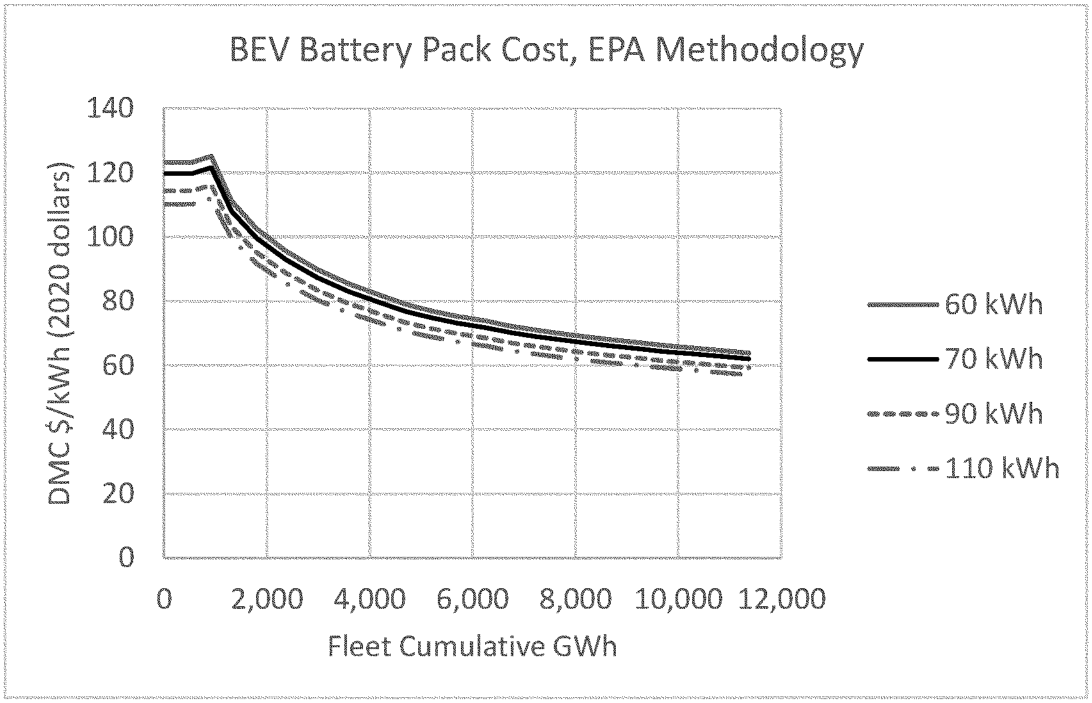

Figure II-27: Example Battery Costs Using the EPA Battery Cost Methodology[358]

In light of the timing of EPA's analysis relative to NHTSA's analysis, NHTSA was unable to consider the EPA approach for possible use in the current analysis. The costs developed by EPA as depicted in Figure II–27 above show the potential to reach significantly lower levels than most of the costs in NHTSA's battery sensitivity cases of Figure II–26, depending on the volume production associated with a given policy scenario and year. As previously noted, NHTSA continues to coordinate with DOE and EPA on battery cost assumptions and methodology, and in light of the battery costs and methodology published in the EPA LMDV proposal, NHTSA will consider this approach to estimating learning effects for use in the final rule analysis. Further analysis of battery costs similar to that proposed in EPA's LMDV proposal, including the possible adoption of EPA's cumulative volume-based learning approach, could result in significantly lower battery costs than assumed in this proposed rule analysis. NHTSA requests comment on the possibility of implementing for its final rule analysis EPA's cumulative volume-based learning approach, and on the methodology outlined in EPA's DRIA that EPA used to generate and validate the cumulative GWh battery pack production-based battery pack costs.

Recognizing that there is no way to validate costs for years that have not yet happened, we seek comment in particular from vehicle and battery manufacturers on any additional data they can submit (preferably publicly) to further the conversation about battery pack costs in the later part of this decade through the early 2030s. In addition, we seek comment on all aspects of our methodology for modeling base year and future year battery pack costs, and welcome data or other information that could inform our approach for the final rulemaking. We specifically seek comment on how the performance metrics may change in response to shifts in chemistries used in vehicle models driven by global policies affecting battery supply chain development, total global production and associated learning rates, and related sensitivity analyses.

While batteries and relative battery components are the biggest cost driver of electrification, non-battery electrification components, such as electric motors, power electronics, and wiring harnesses, also add to the total cost required to electrify a vehicle. Different electrified vehicles have

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[356] See U.S. EPA, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles Draft Regulatory Impact Analysis., EPA–420–D–23–003 (April 2023), Chapter 2.5.2.1.3.

[357] See U.S. EPA, Multi-Pollutant Emissions Standards for Model Years 2027 and Later Light-Duty and Medium-Duty Vehicles Draft Regulatory Impact Analysis., EPA–420–D–23–003 (April 2023), Chapter 2.5.2.1.2.

[358] Chart generated using EPA data, see *https://www3.epa.gov/otaq/ld/2023-03-14-22-42-30-ld-central-run-to2055.zip.*

variants of non-battery electrification components and configurations to accommodate different vehicle classes and applications with respective designs; for instance, some BEVs may be engineered with only one electric motor and some BEVs may be engineered with two or even four electric motors within their powertrain to provide all wheel drive function. In addition, some electrified vehicle types still include conventional powertrain components, like an ICE and traditional transmission.

For all electrified vehicle powertrain types, we group non-battery electrification components into four major categories: electric motors (or e-motors), power electronics (generally including the DC–DC converter, inverter, and power distribution module), charging components (charger, charging cable, and high voltage cables), and thermal management system(s). We further group the components into those comprising the electric traction drive system (ETDS), and all other components. Although each manufacturer's ETDS and power electronics vary between the same electrified vehicle types and between different electrified vehicle types, we consider the ETDS for this analysis to be comprised of the e-motor and inverter, power electronics, and thermal system.

When researching costs for different non-battery electrification components, we found that different reports vary in components considered and cost breakdown. This is not surprising, as vehicle manufacturers use different non-battery electrification components in different vehicles systems, or even in the same vehicle type, depending on the application. In order of the component categories discussed above, we examined the following cost teardown studies, as shown in Table II–16.

TABLE II–16—COST ESTIMATES FOR DIFFERENT ELECTRIFIED VEHICLE COMPONENTS, BY POWERTRAIN

Non-battery electrical components	EETT[359] roadmap report (2017$ in DMC year 2017)	UBS MY 2016 chevy bolt teardown (2017$ in DMC year 2017)	Assumptions	EPA-sponsored FEV report (updated 2021$ for analysis)
ETDS	$18/kW	$17.76/kW	Based on e-motor peak power.	$19.80/kW
On-Board Charger	no information provided.	85/kW	Based on vehicle requirement (7 kW for BEVs, 2 kW for PHEVs).	93.54/kW
DC to DC Converter	no information provided	90/kW	Based on converter rated power (2 kW).	100.94/kW
High Voltage Cables and Charging Cords for BEVs and PHEVs.	no information provided	450	Fixed cost rated for 360V	495.21
High Voltage Cables for Strong Hybrids.	no information provided	no information provided	Fixed cost	100.44

Using the best available estimate for each component from the different reports captures components in most manufacturer's systems but not all; we believe, however, that this is a reasonable metric and approach for this analysis, given the non-standardization of electrified powertrain designs and subsequent component specifications. Other sources we used for non-battery electrification component costs include an EPA-sponsored FEV teardown of a 2013 Chevrolet Malibu ECO with eAssist for some BISG component costs,[360] which we validated against a 2019 Dodge Ram eTorque system's publicly available retail price,[361] and the 2015 NAS report.[362] Broadly, our total BISG system cost, including the battery, fairly matches these other cost estimates.

As discussed in Section II.C, our technology costs account for three variables: retail price equivalence (RPE), which is 1.5 times the DMC, the technology learning curve, and the adjustment of the dollar value to 2021$ for this analysis. While HDPUVs have larger non-battery electrification componentry than LDVs, the cost calculation methodology is identical, in that the $/kW metric is the same, but the absolute costs are higher. As a result, HDPUVs and LDVs share the same non-battery electrification DMCs.

For the non-battery electrification component learning curves, in both the LD and HDPUV fleets, we used cost information from ANL's 2016 Assessment of Vehicle Sizing, Energy Consumption, and Cost through Large-Scale Simulation of Advanced Vehicle Technologies report.[363] The report provides estimated cost projections from the 2010 lab year to the 2045 lab year for individual vehicle components.[364] [365] We considered the component costs used in electrified vehicles, and determined the learning curve by evaluating the year over year cost change for those components. ANL published a 2020 and a 2022 version of the same report; however, those versions did not include a discussion of the high and low-cost estimates for the same components.[366] [367] Our learning estimates generated using the 2016 report align in the middle of these two ranges, and therefore we continue to apply the learning curve estimates based on the 2016 report. There are many sources that we could have picked to develop learning curves for non-battery electrification component costs, however given the uncertainty surrounding extrapolating costs out to

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[359] Electrical and Electronics Technical Team.

[360] Light Duty Vehicle Technology Cost Analysis 2013 Chevrolet Malibu ECO with eAssist BAS Technology Study, FEV P311264 (Contract no. EP–C–12–014, WA 1–9).

[361] Colwell, K.C. 2019. The 2019 Ram 1500 eTorque Brings Some Hybrid Tech, If Little Performance Gain, to Pickups. Last revised: Mar. 14, 2019. Available at: *https://www.caranddriver.com/reviews/a22815325/2019-ram-1500-etorque-hybrid-pickup-drive*. (Accessed: May 31, 2023).

[362] 2015 NAS report, at p. 305.

[363] Moawad, A. et al. 2016. Assessment of Vehicle Sizing, Energy Consumption and Cost Through Large Scale Simulation of Advanced Vehicle Technologies. ANL/ESD–15/28. Available at: *https://www.osti.gov/biblio/1245199*. (Accessed: May 31, 2023).

[364] ANL/ESD–15/28 at p. 116.

[365] DOE's lab year equates to five years after a model year, *e.g.,* DOE's 2010 lab year equates to MY 2015.

[366] Islam, E. et al. 2020. Energy Consumption and Cost Reduction of Future Light-Duty Vehicles through Advanced Vehicle Technologies: A Modeling Simulation Study Through 2050. ANL/ESD–19/10.

[367] Islam, E. et al. 2022. A Comprehensive Simulation Study to Evaluate Future Vehicle Energy and Cost Reduction Potential. ANL/ESD–22/6.

MY 2050, we believe these learning curves provide a reasonable estimate.

In summary, we calculate total electrified powertrain costs by summing individual component costs, which ensures that all technologies in an electrified powertrain appropriately contribute to the total system cost. We combine the costs associated with the ICE (if applicable) and transmission, non-battery electrification components like the electric machine, and battery pack to create a full-system cost. Chapter 3.3.5.4 of the Draft TSD presents the total costs for each electrified powertrain option, broken out by the components we discussed throughout this section. In addition, the chapter discusses where to find each of the component costs in the CAFE Model's various input files.

4. Road Load Reduction Paths

No car or truck uses energy (whether gas or otherwise) 100% efficiently when it is driven down the road. If the energy in a gallon of gas is thought of as a pie, the amount of energy ultimately available from that gallon to propel a car or truck down the road would only be a small slice. So where does the lost energy go? Most of it is lost due to thermal and frictional loses in the engine and drivetrain and drag from ancillary systems (like the air conditioner, alternator generator, various pumps, etc.). The rest is lost to what engineers call road loads. For the most part, road loads include wind resistance (or aerodynamics), drag in the braking system, and rolling resistance from the tires. At low speeds, aerodynamic losses are very small, but as speeds increases these loses rapidly become dramatically higher than any other road load. Drag from the brakes in most cars is practically negligible. ROLL losses can be significant: at low speeds ROLL losses can be more than aerodynamic losses. Whatever energy is left after these road loads are spent on accelerating the vehicle anytime a its speed increases. This is where reducing the mass of a vehicle is important to efficiency because the amount of energy to accelerate the vehicle is always directly proportional to a vehicle's mass. All else being equal, reduce a car's mass and better fuel economy is guaranteed. However, keep in mind that at freeway speeds, aerodynamics plays a more dominant role in determining fuel economy than any other road load or than vehicle mass.

We include three road load reducing technology paths in this analysis: the MR Path, Aerodynamic Improvements (AERO) Path, and ROLL Path. For all three vehicle technologies, we assign baseline fleet technologies and identify adoption features based on the vehicle's body style. The LD fleet body styles we include in the analysis are convertible, coupe, sedan, hatchback, wagon, SUV, pickup, minivan, and van. The HDPUV fleet body styles include chassis cab, cutaway, fleet SUV, work truck, and work van. Figure II–28 and Figure II–29 show the LD and HDPUV fleet body styles used in the analysis.

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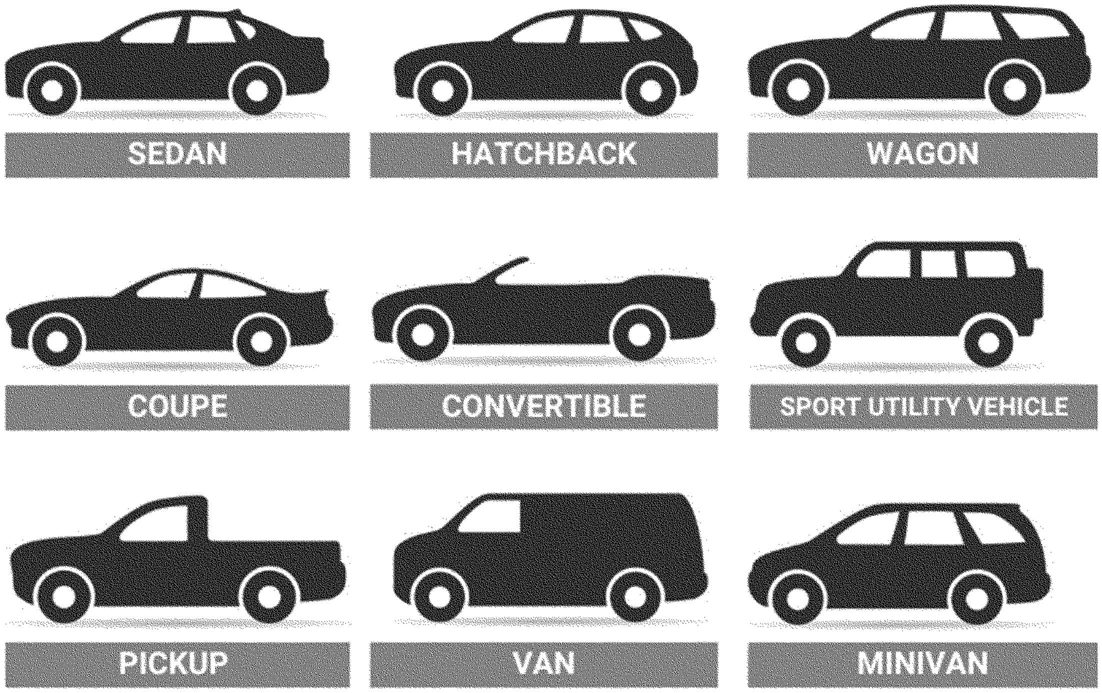

Figure II-28: LD Fleet Body Styles

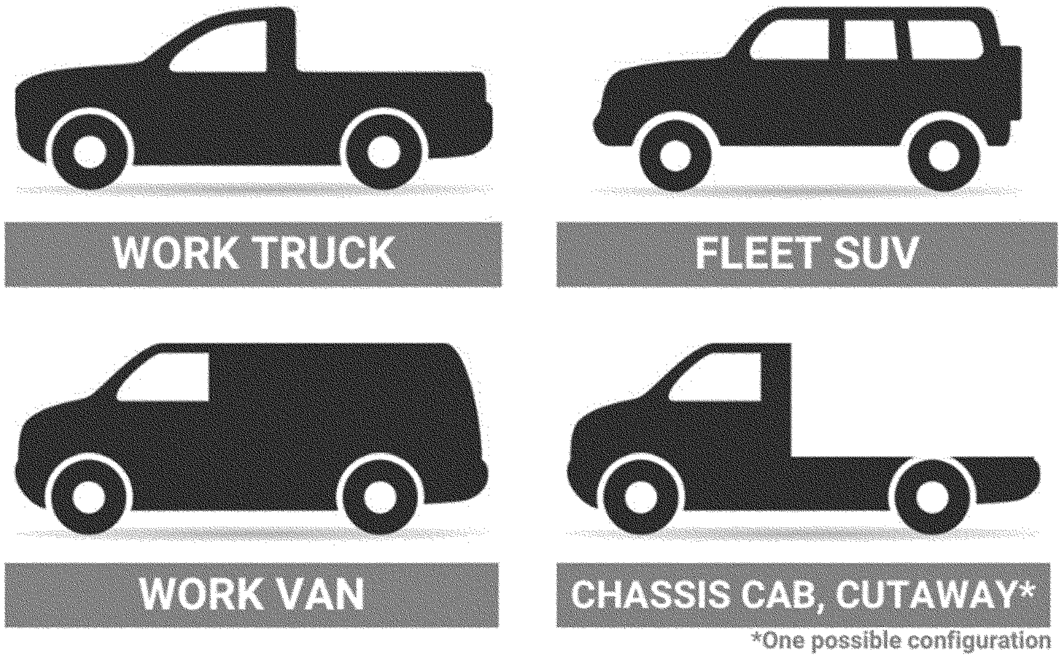

Figure II-29: HDPUV Fleet Body Styles[368]

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As expected, the road load forces described above operate differently based on a vehicle's body style, and the technology adoption features and effectiveness values reflect this. The following sections discuss the three Road Load Reduction Paths.

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[368] For this proposal, vehicles were divided between the LD and HDPUV fleets solely on their gross vehicle weight rating (GVWR) being above or below 8,500 lbs. We will revisit the distribution of vehicles in the final rule to include the distinction for MDPVs.

a. Mass Reduction

MR is a relatively cost-effective means of improving fuel economy, and vehicle manufacturers are expected to apply various MR technologies to meet fuel economy standards. Vehicle manufacturers can reduce vehicle mass through several different techniques, such as modifying and optimizing vehicle component and system designs, part consolidation, and adopting materials that are conducive to MR (advanced high strength steel (AHSS), aluminum, magnesium, and plastics including carbon fiber reinforced plastics).

For the LD fleet portion of this analysis, we considered five levels of MR technology (MR1–MR5) that include increasing amounts of advanced materials and MR techniques applied to the vehicle's glider.[369] The subsystems that may make up a vehicle glider include the vehicle body, chassis, interior, steering, electrical accessory, brake, and wheels systems. We accounted for mass changes associated with powertrain changes separately.[370] We considered two levels of MR (MR1—MR2) and a baseline (MR0) for the HDPUV fleet. We use fewer levels because vehicles within the HD fleets are built for a very different duty cycle[371] and tend to be larger and heavier. Moreover, there are different vehicle parameters, like towing capacity, that drive vehicle mass in the HD fleet rather than, for example, NVH (noise, vibration and harshness) performance in the LD fleet. Similarly, HDPUV MR is assumed to come from the glider,[372] and powertrain MR occurs during the Autonomie modeling. Our estimates of how manufacturers could reach each level of MR technology in the LD and HDPUV analyses, including a discussion of advanced materials and MR techniques, can be found in Chapter 3.4 of the Draft TSD.

We assigned baseline MR levels to vehicles in both the LD and HDPUV analysis fleets by using regression analyses that consider a vehicle's body design[373] and body style, in addition to several variables about the vehicle, like footprint, power, bed length (for pickup trucks), and battery pack size (if applicable), among other factors. We have been improving on the LD regression analysis since the 2016 Draft Technical Assessment Report (TAR) and continue to find that it reasonably estimates MR technology levels of vehicles in the analysis fleet. We developed a similar regression for the HDPUV fleet for this analysis using the factors described above and other applicable HDPUV attributes and found that it similarly appropriately assigns baseline MR technology levels. Chapter 3.4 of the Draft TSD contains a full description of the regression analyses used for each fleet and examples of results of the regression analysis for select vehicles.

There are several ways we ensure that the CAFE Model considers MR technologies like manufacturers might apply them in the real world. Given the degree of commonality among the vehicle models built on a single platform, manufacturers do not have complete freedom to apply unique technologies to each vehicle that shares the platform. While some technologies (*e.g.,* low rolling resistance tires) are very nearly ''bolt-on'' technologies, others involve substantial changes to the structure and design of the vehicle, and therefore often necessarily affect all vehicle models that share that platform. In most cases, MR technologies are applied to platform level components and therefore the same design and components are used on all vehicle models that share the platform. Each vehicle in the analysis fleet is associated with a specific platform. A platform ''leader'' in the analysis fleet is a vehicle variant of a given platform that has the highest level of MR technology in the analysis fleet. As the model applies technologies, it will ''level up'' all variants on a platform to the highest level of MR technology on the platform. For example, if a platform leader is already at MR3 in MY 2022, and a ''follower'' starts at MR0 in MY 2022, the follower will get MR3 at its next redesign (unless the leader is redesigned again before that time, and further increases the MR level associated with that platform, then the follower would receive the new MR level).

In addition to leader-follower logic for vehicles that share the same platform, we also restrict MR5 technology to platforms that represent 80,000 vehicles or fewer. The CAFE Model will not apply MR5 technology to platforms representing high volume sales, like a Chevrolet Traverse, for example, where hundreds of thousands of units are sold per year. We use this particular adoption feature and the 80,000-unit threshold in particular, to model several relevant considerations. First, we assume that MR5 would require a significant amount of carbon fiber technology.[374] There is high global demand from a variety of industries for a limited supply of carbon fibers; specifically, aerospace, military/defense, and industrial applications demand most of the carbon fiber currently produced. Today, only roughly 10 percent of the global dry fiber supply goes to the automotive industry, which translates to the global supply base only being able to support approximately 70,000 cars.[375] In addition, the production process for carbon fiber is significantly different than for traditional vehicle materials. We use this adoption feature as a proxy for stranded capital (*i.e.,* when manufacturers amortize research, development, and tooling expenses over many years) from leaving the traditional processes, and to represent the significant paradigm change to tooling

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[369] Note that in the previous analysis, there was a sixth level of mass reduction available as a pathway to compliance. For this analysis, this pathway was removed because it relied on extensive use of carbon fiber composite technology to an extent that is only found in purpose-built racing cars and a few hundred road legal sports cars costing hundreds of thousands of dollars. Draft TSD Chapter 3.4 provides additional discussion on the decision to include five mass reduction levels in this analysis.

[370] Glider mass reduction can sometimes enable a smaller engine while maintaining performance neutrality. Smaller engines typically weigh less than bigger ones. We captured any changes in the resultant fuel savings associated with powertrain mass reduction and downsizing via the Autonomie simulation. Autonomie calculates a hypothetical vehicle's theoretical fuel mileage using a mass reduction to the vehicle curb weight equal to the sum of mass savings to the glider plus the mass savings associated with the downsized powertrain.

[371] HD vans that are used for package delivery purposes are frequently loaded to GVWR. However, LD passenger cars are never loaded to GVWR. Operators of HD vans have an economic motivation to load their vehicles to GVWR. In contrast studies show that between 38% and 82% of passenger cars are used soley to transport their drivers. (Bureau of Transportation Studies, 2011, FHWA Publication No. FHWA–PL–18–020, 2019).

[372] We also assumed that an HDPUV glider comprises 71 percent of a vehicle's curb weight, based on a review of mass reduction technologies in the 2010 Transportation Research Board and National Research Council's ''Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles.'' See Transportation Research Board and National Research Council. 2010. Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles. Washington, DC: The National Academies Press. At page 120–121. Available at: *https://nap.nationalacademies.org/12845/.* (Accessed: May 31, 2023).

[373] The body design categories we used are 3-box, 2-box, HD pickup, and HD van. A 3-box can be explained as having a box in the middle for the passenger compartment, a box in the front for the engine and a box in the rear for the luggage compartment. A 2-box has a box in front for the engine and then the passenger and luggage box are combined into a single box.

[374] See the Final TSD for CAFE Standards for MYs 2024–2026, and Chapter 3.4 of the Draft TSD accompanying this rulemaking for more information about carbon fiber.

[375] Sloan, J. 2020. Carbon Fiber Suppliers Gear up for Next Generation Growth. Available at: *https://www.compositesworld.com/articles/carbon-fiber-suppliers-gear-up-for-next-gen-growth.* (Accessed: May 31, 2023).

and equipment that would be required to support molding carbon fiber panels. There are no other adoption features for MR in the LD analysis, and no adoption features for MR in the HDPUV analysis.

In the Autonomie simulations, MR technology is simulated as a percentage of mass removed from the specific subsystems that make up the glider. The mass of subsystems that make up the vehicle's glider is different for every technology class, based on glider weight data from the A2Mac1 database [376] and two NHTSA-sponsored studies that examined light-weighting a passenger car and light truck. We account for MR from powertrain improvements separately from glider MR. Autonomie considers several components for powertrain MR, including engine downsizing, and, fuel tank, exhaust systems, and cooling system light-weighting.[377] With regard to the LDV fleet, the 2015 NAS report suggested an engine downsizing opportunity exists when the glider mass is light-weighted by at least 10 percent. The 2015 NAS report also suggested that 10 percent light-weighting of the glider mass alone would boost fuel economy by 3 percent and any engine downsizing following the 10 percent glider MR would provide an additional 3 percent increase in fuel economy.[378] The NHTSA light-weighting studies applied engine downsizing (for some vehicle types but not all) when the glider weight was reduced by 10 percent. Accordingly, the analysis limits engine resizing to several specific incremental technology steps; important for this discussion, engines in the analysis are only resized when MR of 10 percent or greater is applied to the glider mass, or when one powertrain architecture replaces another architecture. For the HDPUV analysis, we do not allow engine downsizing at any MR level. This is because HDPUV designs are sized with the maximum GVWR and GCWR in mind, as discussed earlier in this section. We are objectively controlling the vehicles' utility and performance by this method in Autonomie. For example, if more MR technology is applied to a HD van, the payload capacity increases while maintaining the same maximum GVWR and GCWR.[379] The lower laden weight enables these vehicles to improve fuel efficiency by increased capacity. A summary of how the different MR technology levels improve fuel consumption is shown in Figure II–30, Figure II–31, and Figure II–32 below.

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[376] A2Mac1: Automotive Benchmarking. Available at: *https://portal.a2mac1.com/*. (Accessed: May 31, 2023). The A2Mac1 database tool is widely used by industry and academia to determine the bill of materials (a list of the raw materials, sub-assemblies, parts, and quantities needed to manufacture an end-product) and mass of each component in the vehicle system.

[377] Although we do not acount for mass reduction in transmissions, we do reflect design improvements as part of mass reduction when going from, for example, an older AT6 to a newer AT8 that has similar if not lower mass.

[378] National Research Council. 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. The National Academies Press: Washington DC. Available at: *https://doi.org/10.17226/21744*. (Accessed: May 31, 2023).

[379] Transportation Research Board and National Research Council. 2010. Technologies and Approaches to Reducing the Fuel Consumption of Medium- and Heavy-Duty Vehicles. *The National Academies Press:* Washington, DC. p. 116. Available at: *https://nap.nationalacademies.org/12845/*. (Accessed: May 31, 2023).

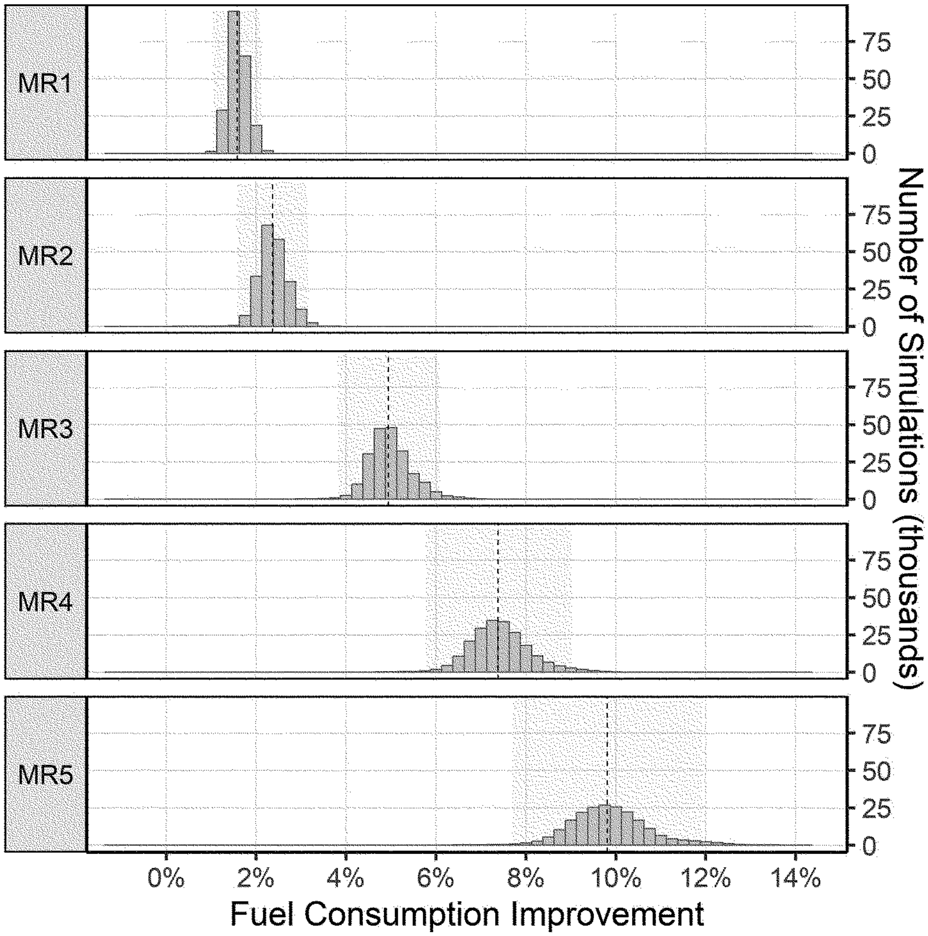

Figure II-30: Light-Duty Mass Reduction Technology Effectiveness Values for All Vehicle Technology Classes (Unconstrained)

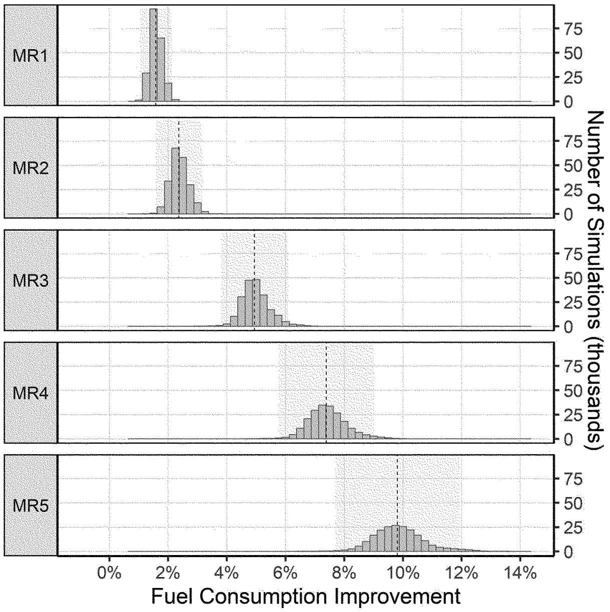

Figure II-31: Light-Duty Mass Reduction Technology Effectiveness Values for All Vehicle Technology Classes (Standard Setting)

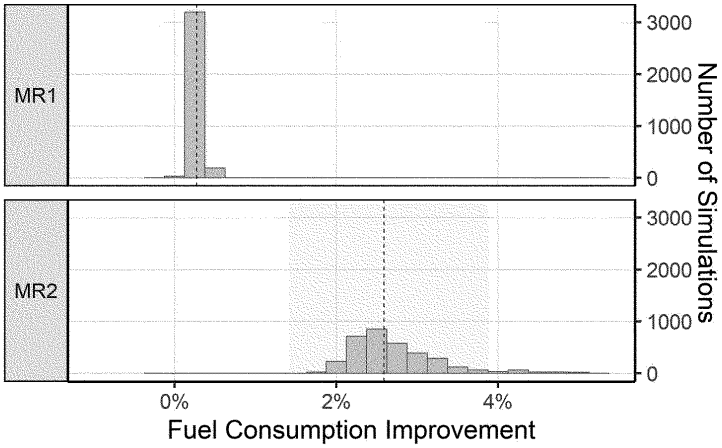

Figure II-32: HDPUV Mass Reduction Technology Effectiveness Values for All Technology Classes

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Our MR costs are based on two NHTSA light-weighting studies—the teardown of a MY 2011 Honda Accord and a MY 2014 Chevrolet Silverado pickup truck[380]—and the 2021 NAS report.[381] The costs for MR1–MR4 rely on the light-weighting studies, while the cost of MR5 references the carbon fiber costs provided in the 2021 NAS report. The same cost curves are used for the HDPUV analysis, however, we used linear interpolation to shift the HDPUV MR2 curve (by roughly a factor of 20) to account for the fact that MR2 in the HDPUV analysis represents a different level than MR2 in the LD analysis. Unlike the other technologies in our analysis that have a fixed technology cost (for example, it costs about $3,000 to add a AT10L3 transmission to a LD SUV or pickup truck in MY 2027), the cost of MR is calculated on a dollar per pound saved basis based on a vehicle's starting weight. Put another way, for a given vehicle platform, a baseline mass is assigned using the aforementioned regression model. The amount of mass to reach each of the five levels of MR is calculated by the CAFE Model based on this baseline number and then multiplied by the dollar per pound saved figure for each of the five MR levels. The dollar per pound saved figure increases at a nearly linear rate going from MR0 to M4. However, this figure increases steeply going from MR4 to MR5 because the technology cost to realize the associated mass savings level is an order of magnitude larger. This dramatic increase is reflected by all three studies we relied on for MR costing, and we believe that it reasonably represents what manufacturers would expect to pay for including increasing amounts of carbon fiber on their vehicles. For the HDPUV analysis, there is also a significant cost increase from MR1 to MR2. This is because the MR going from MR1 to MR2 in the HDPUV fleet analysis is a larger step than going from MR1 to MR2 for the LD fleet analysis—5% to 7.5% off the glider compared to 1.4% to 13%. More MR demands higher costs.

Like past analyses, we considered several options for MR technology costs. Again, we determined that the NHTSA-sponsored studies accounted for significant factors that we believe are important to include our analysis, including materials considerations (material type and gauge, while considering real-world constraints such as manufacturing and assembly methods and complexity), safety (including the Insurance Institute for Highway Safety's (IIHS) small overlap tests), and functional performance (including towing and payload capacity, noise, vibration, and harshness (NVH)+, and gradeability in the pickup truck study).

b. Aerodynamic Improvements

The energy required for a vehicle to overcome wind resistance, or more formally what is known as aerodynamic drag, ranges from minimal at low speeds to incredibly significant at highway speeds.[382] Reducing a vehicle's aerodynamic drag is, therefore, an effective way to reduce the vehicle's fuel consumption. Aerodynamic drag is characterized as proportional to the frontal area (A) of the vehicle and a factor called the coefficient of drag (C_d). The coefficient of drag (C_d) is a dimensionless value that represents a moving object's resistance against air, which depends on the shape of the object and flow conditions. The frontal area (A) is the cross-sectional area of the vehicle as viewed from the front. Aerodynamic drag of a vehicles is often expressed as the product of the two values, C_dA, which is also known as the drag area of a vehicle. The force imposed by aerodynamic drag increases with the square of vehicle velocity, accounting for the largest contribution to road loads at higher speeds.[383]

Manufacturers can reduce aerodynamic drag either by reducing the drag coefficient or reducing vehicle frontal area, which can be achieved by passive or active aerodynamic technologies. Passive aerodynamics refers to aerodynamic attributes that are inherent to the shape and size of the vehicle. Passive attributes can include the shape of the hood, the angle of the windscreen, or even overall vehicle ride height. Active aerodynamics refers to technologies that variably deploy in response to driving conditions. Example of active aerodynamic technologies are grille shutters, active air dams, and

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[380] DOT HS 811 666, Singh, H., Final Report, Mass Reduction for Light-Duty Vehicles for Model Years 2017–2025, 2012; DOT HS 812 487, Singh, H., Davies, J., Kramer, D. Fisher, A., Paramasuwom, M., Mogal, V., . . . and Ganesan, V., Mass Reduction for Light-Duty Vehicles for Model Years 2017–2025, 2018.

[381] This analysis applied the cost estimates per pound derived from passenger cars to all passenger car segments, and the cost estimates per pound derived from full-size pickup trucks to all light-duty truck and SUV segments. The cost estimates per pound for carbon fiber (MR5) were the same for all segments.

[382] 2015 NAS Report, at 207.

[383] See, *e.g.,* Pannone, G. 2015. Technical Analysis of Vehicle Load Reduction Potential for Advanced Clean Cars, Final Report. April 2015. Available at: *https://ww2.arb.ca.gov/sites/default/files/2020-04/13_313_ac.pdf* (Accessed: May 31, 2023). The graph on page 20 shows how at higher speeds the aerodyanmic force becomes the dominant load force.

active ride height adjustment. Manufacturers may employ both passive and active aerodynamic technologies to improve aerodynamic drag values.

There are four levels of aerodynamic improvement (over the baseline AERO0) available in the LD analysis (AERO5, AERO10, AERO15, AERO20), and two levels of improvements available for the HDPUV analysis (AERO10, AERO20). There are fewer levels available for the HDPUV analysis because HDPUVs have less diversity in overall vehicle shape; prioritization of vehicle functionality forces a boxy shape and limits incorporation of many of the ''shaping''—based aerodynamic technologies, such as smaller rear-view mirrors, body air flow, rear diffusers, and so on. Refer back to Figure II–28 and Figure II–29 for a visual of each body style considered in the LD and HDPUV analyses.

Each AERO level associates with 5, 10, 15, or 20 percent aerodynamic drag improvement values over a baseline computed for each vehicle body style. These levels, or bins, respectively correspond to the level of aerodynamic drag reduction over the baseline, *e.g.,* ''AERO5'' corresponds to the 5 percent aerodynamic drag improvement value over the baseline, and so on. While each level of aerodynamic drag improvement is technology agnostic—that is, manufacturers can ultimately choose how to reach each level by using whatever technologies work for the vehicle—we estimated a pathway to each technology level based on data from a NRC of Canada-sponsored wind tunnel testing program. The program included an extensive review of production vehicles utilizing aerodynamic drag improvement technologies, and industry comments.[384] [385] Our example pathways for achieving each level of aerodynamic drag improvements is discussed in Chapter 3.5 of the Draft TSD.

We assigned baseline aerodynamic drag reduction technology levels based on vehicle body styles.[386] We computed an average coefficient of drag based on vehicle body styles, using coefficient of drag data from the MY 2015 analysis fleet for the LD analysis, and data from the MY 2019 Chevy Silverado and MY 2020 Ford Transit and the MY 2022 Ford e-Transit for cargo vans for the HDPUV analysis. Different body styles offer different utility and have varying levels of baseline form drag. This analysis considers both frontal area and body style as unchangeable utility factors affecting aerodynamic forces; therefore, the analysis assumes all reduction in aerodynamic drag forces come from improvement in the drag coefficient. Then we used drag coefficients for each vehicle in the baseline fleet to establish a baseline aerodynamic technology level for each vehicle. We compared the vehicle's drag coefficient to the calculated drag coefficient by body style mentioned above, to assign baseline levels of aerodynamic drag reduction technology. We were able to find most vehicles' drag coefficients in manufacturer's publicly available specification sheets, however in cases where we could not find that information, we used engineering judgment to assign the baseline technology level.

We also look at vehicle body style and vehicle horsepower to determine which types of vehicles can adopt different aerodynamic technology levels. For the LD analysis, AERO15 and AERO20 cannot be applied to minivans, and AERO20 cannot be applied to convertibles, pickup trucks, and wagons. We also do not allow application of AERO15 and AERO20 technology to vehicles with more than 780 horsepower. There are two main types of vehicles that inform this threshold: performance ICE vehicles and high-power BEVs. In the case of the former, we recognize that manufacturers tune aerodynamic features on these vehicles to provide desirable downforce at high speeds and to provide sufficient cooling for the powertrain, rather than reducing drag, resulting in middling drag coefficients despite advanced aerodynamic features. Therefore, manufacturers may have limited ability to improve aerodynamic drag coefficients for high performance vehicles with ICEs without reducing horsepower. Only 4,047 units of sales volume in the baseline fleet include limited application of aerodynamic technologies due to ICE vehicle performance.[387]

In the case of high-power BEVs, the 780-horsepower threshold is set above the highest peak system horsepower present on a BEV in the 2020 fleet. We originally set this threshold based on vehicles in the MY 2020 fleet in parallel with the 780-horsepower ICE limitation. For this analysis, the restriction does not have any functional effect because the only BEVs that have above 780-horsepower in the MY 2022 analysis fleet—the Tesla Model S and X Plaid, and variants of the Lucid Air—are already assigned AERO20 as a baseline technology state and there are no additional levels of AERO technology left for those vehicles to adopt. Note that these high horsepower BEVs have extremely large battery packs to meet both performance and range requirements. These bigger battery packs make the vehicles heavier, which means they do not have the same downforce requirements as a similarly situated high-horsepower ICE vehicle. Broadly speaking, BEVs have different aerodynamic behavior and considerations than ICE vehicles, allowing for features such as flat underbodies that significantly reduce drag.[388] BEVs are therefore more likely to achieve higher AERO levels, so the horsepower threshold is set high enough that it does not restrict AERO15 and AERO20 application. BEVs that do not currently use high AERO technology levels are generally bulkier (*e.g.,* SUVs or trucks) or lower budget vehicles.

There are no additional adoption features for aerodynamic improvement technologies in the HDPUV analysis. We limited the range of technology options for reasons discussed above, but both AERO technology levels are available to all HDPUV body styles.

Figure II–33, Figure II–34, and Figure II–35 show the potential fuel consumption improvement from the baseline AERO0 technology. For example, the AERO20 values shown represent the range of potential fuel consumption improvement values that could be achieved through the replacement of AERO0 technology with AERO20 technology for every technology key that is not restricted from using AERO20. We use the change in fuel consumption values between entire technology keys, and not the individual technology effectiveness values. Using the change between whole technology keys captures the

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[384] Larose, G. et al. 2016. Evaluation of the Aerodynamics of Drag Reduction Technologies for Light-duty Vehicles—a Comprehensive Wind Tunnel Study. SAE International Journal of Passenger Cars—Mechanical Systems 9(2): pp. 772–784. Available at: *https://doi.org/10.4271/2016-01-1613.* (Accessed: May 31, 2023).

[385] Larose, G. et al. 2016. Evaluation of the Aerodynamics of Drag Reduction Technologies for Light-duty Vehicles—a Comprehensive Wind Tunnel Study. SAE International Journal of Passenger Cars—Mechanical Systems 9(2): pp. 772–784. Available at: *https://doi.org/10.4271/2016-01-1613.* (Accessed: May 31, 2023).

[386] These assignments do not necessarily match the body styles that manufacturers use for marketing purposes. Instead, we make these assignments based on engineering judgment and the categories used in our modeling, considering how this affects a vehicle's AERO and vehicle technology class assignments.

[387] See the Market Data Input File.

[388] 2020 EPA Automotive Trends Report, at p. 227.

complementary or non-complementary interactions among technologies.

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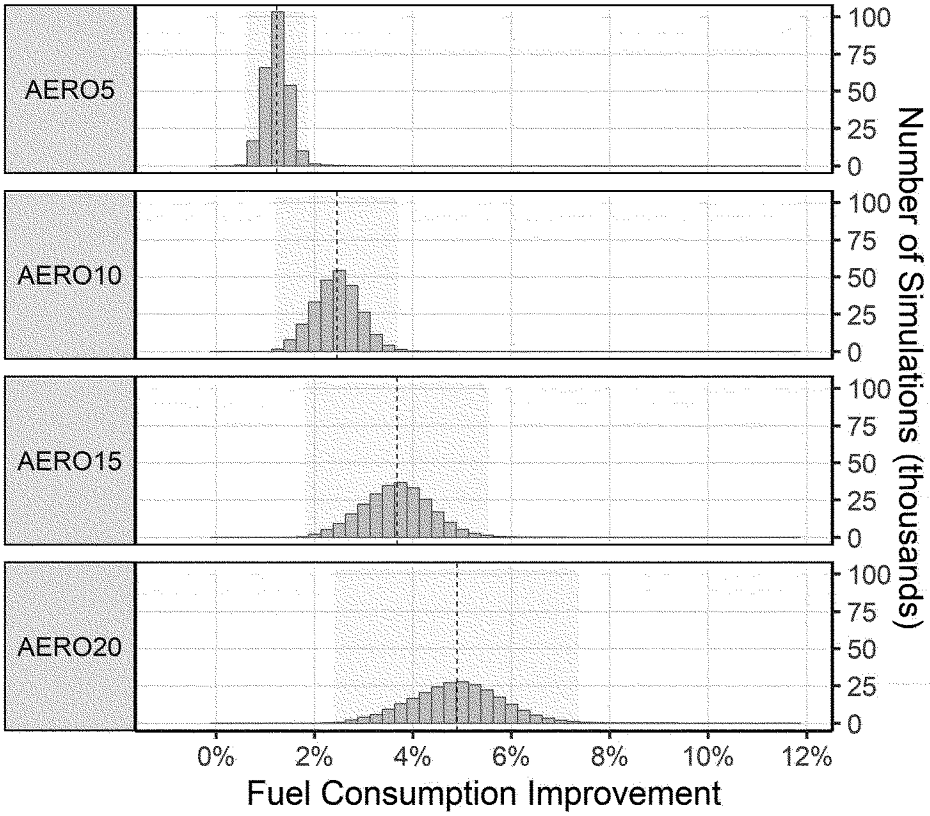

Figure II-33: Light-Duty AERO Technology Effectiveness Values for All Vehicle Technology Classes (Unconstrained)

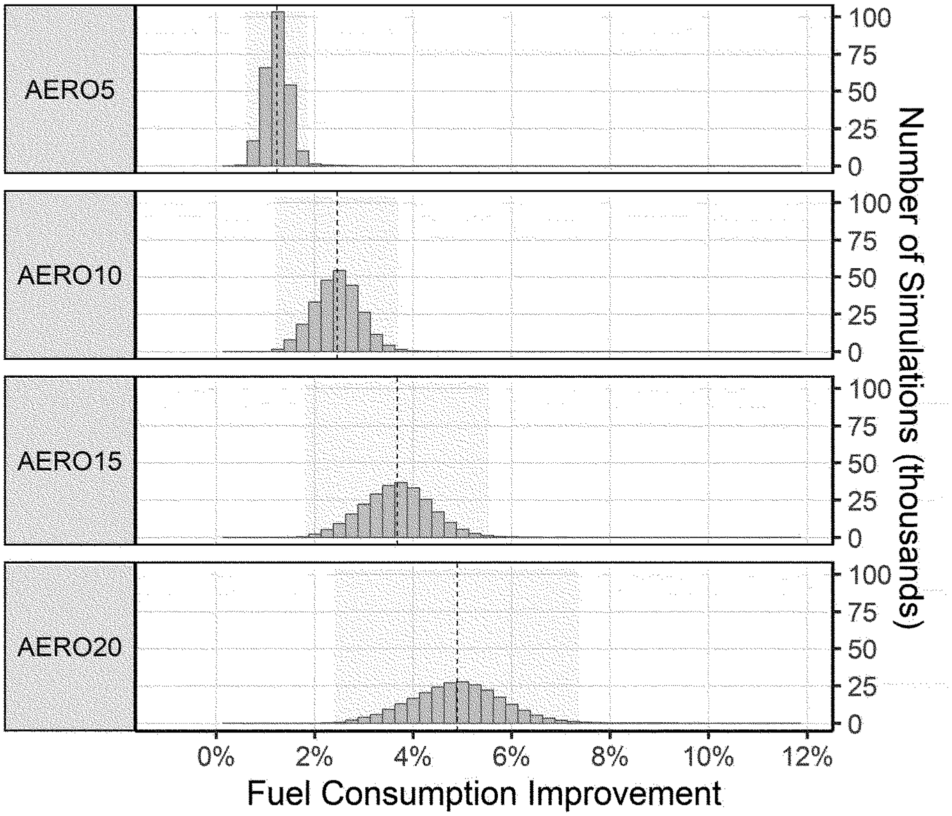

Figure II-34: Light-Duty AERO Technology Effectiveness Values for All Vehicle Technology Classes (Standard Setting)

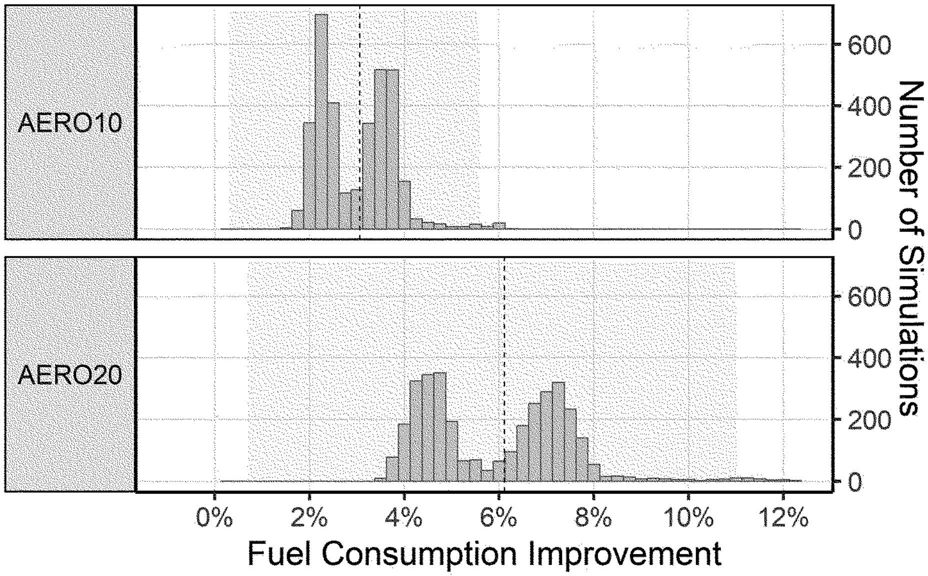

Figure II-35: HDPUV AERO Technology Effectiveness Values for All Vehicle Technology Classes

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We carried forward the established AERO technology costs previously used in the 2020 final rule and again into the MY 2024–2026 standards analysis,[389] and updated those costs to the dollar-year used in this analysis. For LD AERO improvements, the cost to achieve AERO5 is relatively low, as manufacturers can make most of the improvements through body styling changes. The cost to achieve AERO10 is higher than AERO5, due to the addition of several passive aerodynamic technologies, and consecutively the cost to achieve AERO15 and AERO20 are much higher than AERO10 due to use of both passive and active aerodynamic technologies. The two AERO technology levels available for HDPUVs are similar in technology type and application to LDVs in the same technology categories, specifically light trucks. Because of this similarity, and unlike other technology areas that are required to handle higher loads or greater wear, aerodynamics technologies can be almost directly ported between fleets. As a result, there is no difference in technology cost between LD and HDPUV fleets for this analysis. The cost estimates are based on CBI submitted by the automotive industry in advance of the 2018 CAFE NPRM, and on our assessment of manufacturing costs for specific aerodynamic technologies. See the 2018 PRIA for discussion of the cost estimates.[390] We received no additional comments from stakeholders regarding the costs established in the 2018 PRIA during the MY 2024–2026 standards analysis and continued to use the established costs for this analysis. Draft TSD Chapter 3.5 contains additional discussion of aerodynamic improvement technology costs, and costs for all technology classes across all MYs are in the CAFE Model's Technologies Input File.

c. Low Rolling Resistance Tires

Tire rolling resistance burns additional fuel when driving. As a car or truck tire rolls, at the point the tread touches the pavement, the tire flattens-out to create what tire engineers call the contact patch. The rubber in the contact patch deforms to mold to the tiny peaks and valleys of the payment. The interlock between the rubber and these tiny peaks and valleys creates grip. Every time the contact patch leaves the road surface as the tire rotates, it must recover to its original shape and then as the tire goes all the way around it must create a new contact patch that molds to a new piece of road surface. However, this molding and repeated re-molding action takes energy. Just like when a person stretches a rubber band it takes work, so does deforming the rubber and the tire to form the contact patch. When thinking about the efficiency of driving a car down the road, this means that not all the energy produced by a vehicle's engine can go into propelling the vehicle forward. Instead, some small, but appreciable, amount goes into deforming the tire and creating the contact patch repeatedly. This also explains why tires with low pressure have higher rolling resistance than properly inflated tires. When the tire pressure is low, the tire deforms more to create the contact patch which is the same as stretching the rubber farther in the analogy above. The larger deformations burn up even more energy and results in worse fuel mileage. Lower-rolling-resistance tires have characteristics that reduce frictional losses associated with the energy dissipated mainly in the deformation of the tires under load, thereby improving fuel economy.

We use three levels of low rolling resistance tire technology for LDVs and two levels for HDPUVs. Each level of low rolling resistance tire technology reduces rolling resistance by 10 percent from an industry-average baseline rolling resistance coefficient (RRC) value of 0.009.[391] While the industry-average baseline RRC is based on information from LDVs, we also determined that baseline is appropriate for HDPUVs. RRC data from a NHTSA-sponsored study shows that similar vehicles across the LD and HDPUV categories have been able to achieve similar RRC improvements. See Chapter 3.6 of the Draft TSD for more information on this comparison. Table II–17 shows the LD and HDPUV low rolling resistance technology options and their associated RRC.

TABLE II–17—TIRE ROLLING RESISTANCE TECHNOLOGIES AND THEIR ASSOCIATED ROLLING RESISTANCE COEFFICIENT (RRC)

Technology	Rolling resistance coefficient (RRC) (N/N)
ROLL0	0.0090
ROLL10	0.0081
ROLL20	0.0072
ROLL30	0.0063

We have been using ROLL10 and ROLL20 in the last several CAFE Model analyses. New for this analysis is ROLL30 for the LD fleet. In past rulemakings, we did not consider ROLL30 due to lack of widespread commercial adoption of ROLL30 tires in the fleet within the rulemaking timeframe, despite commenters' argument on availability of the technology on current vehicle models and possibility that there would be additional tire improvements over the next decade.[392] Comments we received during the comment period for the last CAFE rule also reflected the application of ROLL30 by OEMs, although they discouraged considering the technology due to high cost and possible wet traction reduction. With increasing use of ROLL30 application by OEMs,[393] [394] [395] and material selection making it possible to design low rolling resistance independent of tire wet grip (discussed in detail in Chapter 3.6 of the Draft TSD), we now consider ROLL30 as a viable future technology during this rulemaking period. We believe that the tire industry is in the process of moving automotive manufacturers towards higher levels of rolling resistance technology in the vehicle fleet. We believe that at this time, the emerging tire technologies that would achieve 30 percent improvement in rolling resistance, like changing tire profile, stiffening tire walls, or adopting improved tires along with active chassis control, among other technologies, will be available for commercial adoption in

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[389] See the FRIA accompanying the 2020 final rule, Chapter VI.C.5.e.

[390] See the PRIA accompanying the 2018 NPRM, Chapter 6.3.10.1.2.1.2 for a discussion of these cost estimates.

[391] See Technical Analysis of Vehicle Load Reduction by CONTROLTEC for California Air Resources Board (April 29, 2015). We determined the industry-average baseline RRC using a CONTROLTEC study prepared for the CARB, in addition to considering CBI submitted by vehicle manufacturers prior to the 2018 LD NPRM analysis. The RRC values used in this study were a combination of manufacturer information, estimates from coast down tests for some vehicles, and application of tire RRC values across other vehicles on the same platform. The average RRC from surveying 1,358 vehicle models by the CONTROLTEC study is 0.009. The CONTROLTEC study compared the findings of their survey with values provided by the U.S. Tire Manufacturers Association for original equipment tires. The average RRC from the data provided by the U.S. Tire Manufacturers Association is 0.0092, compared to the average of 0.009 from CONTROLTEC.

[392] NHTSA–2018–0067–11985.

[393] Docket No. NHTSA–2021–0053–0010, Evaluation of Rolling Resistance and Wet Grip Performance of OEM Stock Tires Obtained from NCAP Crash Tested Vehicles Phase One and Two, Memo to Docket—Rolling Resistance Phase One and Two.

[394] Technical Analysis of Vehicle Load Reduction by CONTROLTEC for California Air Resources Board (April 29, 2015).

[395] NHTSA DOT HS 811 154.

the fleet during this rulemaking timeframe.

However, we did not consider ROLL30 for the HDPUV fleet, for several reasons. We do not believe that HDPUV manufacturers will use ROLL30 tires because of the significant added cost for the technology while they would see more fuel efficiency benefits from powertrain improvements. As discussed further below, our cost estimates for ROLL30 technology—which incorporate both technology and materials costs—are approximately double the costs of ROLL20. In addition, a significant majority of the HDPUV fleet currently employs no low rolling resistance tire technology. We believe that HDPUV manufacturers will still move through ROLL10 and ROLL20 technology in the rulemaking timeframe. That said, we welcome any data or feedback from stakeholders showing a pathway to ROLL30 (*i.e.,* vehicles that can achieve a RRC value of 0.0063) for HDPUVs.

Assigning low rolling resistance tire technology to the baseline fleet is difficult because RRC data is not part of tire manufacturers' publicly released specifications, and because vehicle manufacturers often offer multiple wheel and tire packages for the same nameplate. Consistent with previous rules, we used a combination of CBI data, data from a NHTSA-sponsored ROLL study, and assumptions about parts-sharing to assign tire technology in the baseline fleet. A slight majority of vehicles (52.9%) in the baseline LD fleet do not use any ROLL improvement technology, while 16.2% of baseline vehicles use ROLL10 and 24.9% of baseline vehicles use ROLL20. Only 6% of vehicles in the baseline LD fleet use ROLL30. Most (74.5%) vehicles in the HDPUV fleet do not use any ROLL improvement technology, and 3.0% and 22.5% use ROLL10 and ROLL20, respectively.

The CAFE Model can apply ROLL technology at either a vehicle refresh or redesign. We recognize that some vehicle manufacturers prefer to use higher RRC tires on some performance cars and SUVs. Since most of performance cars have higher torque, to avoid tire slip, OEMs prefer to use higher RRC tires for these vehicles. Like the aerodynamic technology improvements discussed above, we applied ROLL technology adoption features based on vehicle horsepower and body style. All vehicles in the LD and HDPUV fleets that have below 350hp can adopt all levels of ROLL technology.

Table II–18 shows that all LDVs under 350hp can adopt ROLL technology, and as vehicle hp increases, fewer vehicles can adopt the highest levels of ROLL technology. Note that ROLL30 is not available for vehicles in the HDPUV fleet not because of an adoption feature, but because it is not included in the ROLL technology pathway.

TABLE II–18—WHEN CAN ROLL TECHNOLOGY BE APPLIED?

Technology	Light Duty				HDPUV			
Engine horsepower (hp)	<350	≥350	≥405	≥500	<350	≥350	≥405	≥500
ROLL0	All body styles.	All body styles.	All body styles.	All body styles.	All body styles.	All body styles.	All body styles.	All body styles.
ROLL10	All body styles.	All body styles.	All body styles.	—Pickup truck.	All body styles.	All body styles.	All body styles.	—Work truck.
ROLL20	All body styles.	All body styles.	—Pickup truck. —SUV —Van —Minivan	No body styles.	All body styles.	All body styles.	—Work truck. —Work van —Fleet SUV —Chassis Cab. —Cutaway	No body styles.
ROLL30	All body styles.	—Pickup truck. —Sport Utility. —Van —Minivan	No body styles.	No body styles.	All body styles.	N/A	N/A	N/A.

Figure II–36, Figure II–37, and Figure II–38 show how effective the different levels of ROLL technology are at improving vehicle fuel consumption.

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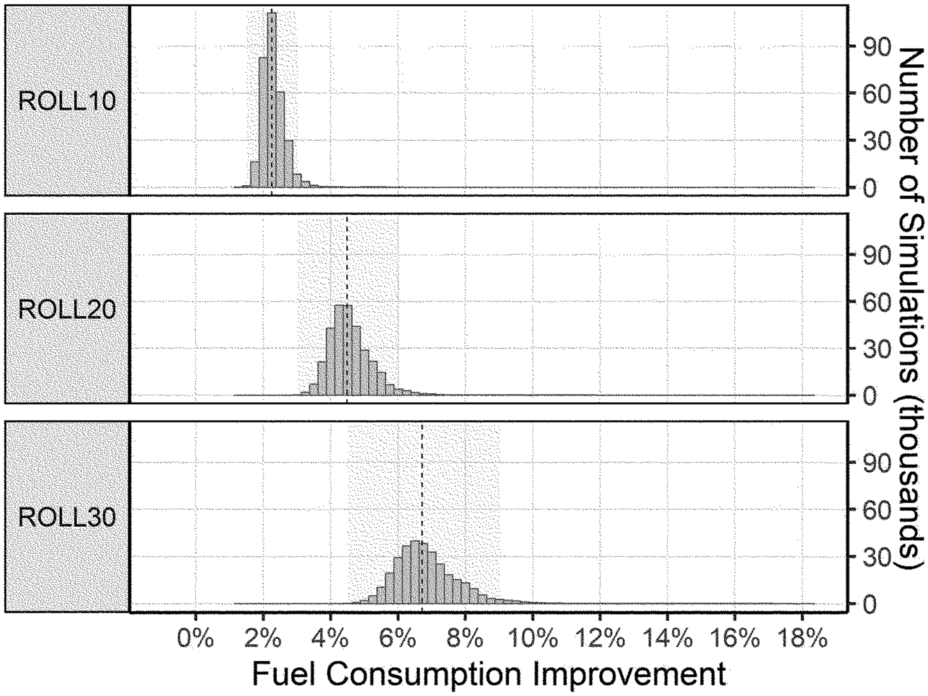

Figure II-36: Light-Duty Roll Technology Effectiveness Values for All Vehicle Technology Classes (Standard Setting)

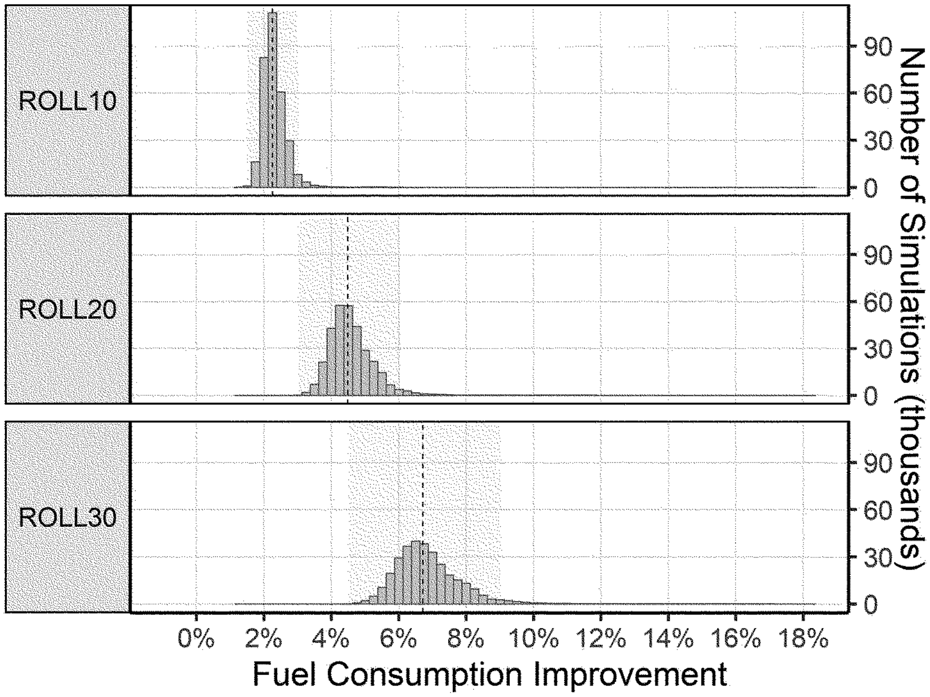

Figure II-37: Light-Duty Roll Technology Effectiveness Values for All Vehicle Technology Classes (Unconstrained)

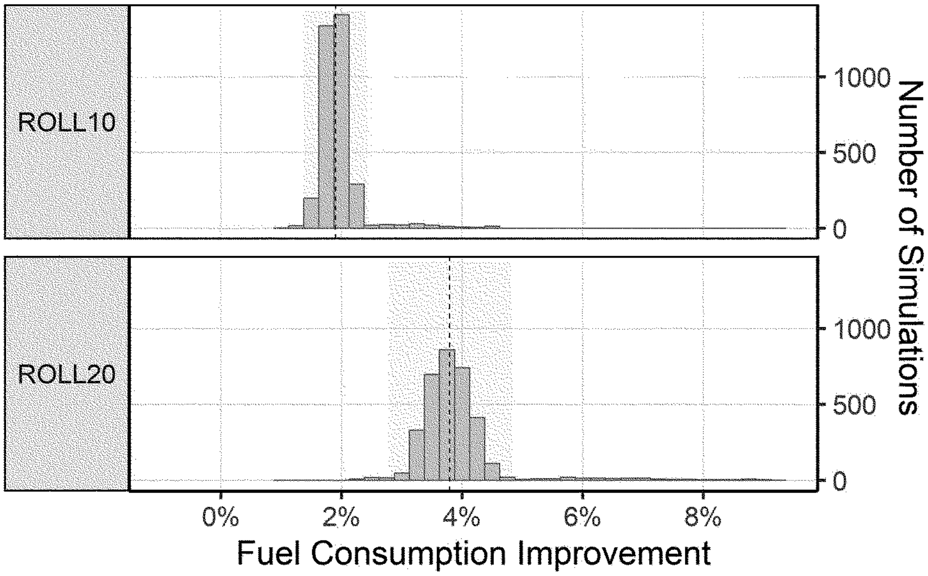

Figure II-38: HDPUV Roll Technology Effectiveness Values for All Vehicle Technology Classes

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DMCs and learning rates for ROLL10 and ROLL20 are the same as prior analyses,[396] but are updated to the dollar-year used in this analysis. In the absence of ROLL30 DMCs from tire manufacturers, vehicle manufacturers, or studies, to develop the DMC for ROLL30 we extrapolated the DMCs for ROLL10 and ROLL20. We seek comment on this approach, and if we receive updated information from tire or vehicle manufacturers, or other studies, we will update it for future analyses. In addition, we used the same DMCs for the LD and HDPUV analyses. This is because the original cost of a potentially heavier or sturdier HDPUV tire is already accounted for in the baseline MSRP of a HDPUV in our baseline, and the DMC represents the added cost of the improved tire technology. In addition, as discussed above, LD and HDPUV tires are often interchangeable. We believe that the added cost of each tire technology accurately represents the price difference that would be experienced by the different fleets. ROLL technology costs are discussed in detail in Chapter 3.6 of the Draft TSD, and ROLL technology costs for all vehicle technology classes can be found in the CAFE Model's Technologies Input File.

5. Simulating AC Efficiency and Off-Cycle Technologies

Off-cycle and AC efficiency technologies can provide fuel economy benefits in real-world vehicle operation, but the traditional 2-cycle test procedures (*i.e.,* FTP and HFET) used to measure fuel economy cannot fully capture those benefits.[397] Off-cycle technologies can include, but are not limited to, thermal control technologies, high-efficiency alternators, and high-efficiency exterior lighting. As an example, manufacturers can claim a benefit for thermal control technologies like active seat ventilation and solar reflective surface coating, which help to regulate the temperature within the vehicle's cabin—making it more comfortable for the occupants and reducing the use of low-efficiency heating, ventilation, and air-conditioning (HVAC) systems. AC efficiency technologies are technologies that reduce the operation of or the loads on the compressor, which pressurizes AC refrigerant. The less the compressor operates or the more efficiently it operates, the less load the compressor places on the engine or battery storage system, resulting in better fuel efficiency. AC efficiency technologies can include, but are not limited to, blower motor controls, internal heat exchangers, and improved condensers/evaporators.

Vehicle manufacturers have the option to generate credits for off-cycle technologies and improved AC systems under the EPA's CO_2 program and receive a fuel consumption improvement value (FCIV) equal to the value of the benefit not captured on the 2-cycle test under NHTSA's CAFE program. The FCIV is not a ''credit'' in the NHTSA CAFE program—unlike, for example, the statutory overcompliance credits prescribed in 49 U.S.C. 32903—but FCIVs increase the reported fuel economy of a manufacturer's fleet, which is used to determine compliance. EPA applies FCIVs during determination of a fleet's final average

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[396] See NRC/NAS Special Report 286, Tires and Passenger Vehicle Fuel Economy: Informing Consumers, Improving Performance (2006); Corporate Average Fuel Economy for MY 2011 Passenger Cars and Light Trucks, Final Regulatory Impact Analysis (March 2009), at V–137; Joint Technical Support Document: Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards (April 2010), at 3–77; Draft Technical Assessment Report: Midterm Evaluation of Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards for Model Years 2022–2025 (July 2016), at 5–153 and 154, 5–419. In brief, the estimates for ROLL10 are based on the incremental $5 value for four tires and a spare tire in the NAS/NRC Special Report and confidential manufacturer comments that provided a wide range of cost estimates. The estimates for ROLL20 are based on incremental interpolated ROLL10 costs for four tires (as NHTSA and EPA believed that ROLL20 technology would not be used for the spare tire), and were seen to be generally fairly consistent with CBI suggestions by tire suppliers.

[397] See 49 U.S.C 32904(c) (''The Administrator shall measure fuel economy for each model and calculate average fuel economy for a manufacturer under testing and calculation procedures prescribed by the Administrator. The Administrator shall use the same procedures for passenger automobiles the Administrator used for model year 1975 (weighted 55 percent urban cycle and 45 percent highway cycle), or procedures that give comparable results.'').

fuel economy reported to NHTSA.[398] We only calculate and apply FCIVs at a manufacturer's fleet level, and the improvement is based on the volume of the manufacturer's fleet that contains qualifying technologies.

We currently do not model AC efficiency and off-cycle technologies in the CAFE Model like we model other vehicle technologies, for several reasons. Each time we add a technology option to the CAFE Model's technology pathways we increase the number of Autonomie simulations by approximately a hundred thousand. This means that to add just five AC efficiency and five off-cycle technology options would double our Autonomie simulations to around two million total simulations. In addition, 40 CFR 600.512–12 does not require manufacturers to submit information regarding AC efficiency and off-cycle technologies on individual vehicle models in their FMY reports to EPA and NHTSA.[399] In their FMY reports, manufacturers are only required to provide information about AC efficiency and off-cycle technology application at the fleet level. However, starting with MY 2023, manufacturers are required to submit AC efficiency and off-cycle technology data to NHTSA in the new CAFE Projections Reporting Template for PMY, MMY and supplementary reports. Once we begin evaluating manufacturer submissions in the CAFE Projections Reporting Template we may reconsider in future analyses how off-cycle and AC efficiency technologies are evaluated in the analysis. However, developing a robust methodology for including off-cycle and AC efficiency technologies in the analysis depends on manufacturers giving us robust data.

Instead, the CAFE Model applies predetermined AC efficiency and off-cycle benefits to each manufacturer's fleet after the CAFE Model applies traditional technology pathway options. The CAFE Model attempts to apply pathway technologies and AC efficiency and off-cycle technologies in a way that both minimizes cost and allows the manufacturer to meet a given level of CAFE standard without over or under complying. The predetermined benefits that the CAFE Model applies for AC efficiency and off-cycle technologies are based on EPA's 2022 Trends Report and CBI compliance data from vehicle manufacturers. We started with each manufacturer's latest reported values and extrapolated the values to the regulatory cap on benefits that manufacturers are allowed to claim, considering each manufacturer's fleet composition (*i.e.,* passenger cars versus light trucks) and historic AC efficiency and off-cycle technology use. In general, data shows that manufacturers apply less off-cycle technology to passenger cars than pickup trucks, and our input assumptions reflect that. Additional details about how we determined AC efficiency and off-cycle technology application rates are discussed Chapter 3.7 of the Draft TSD.

New for this analysis, we also developed a methodology for considering BEV AC efficiency and off-cycle technology application. We did this because the analytical ''no-action'' baseline against which we measure the costs and benefits of our standards includes an appreciable number of BEVs. Because BEVs are not equipped with a traditional engine or transmission, they cannot benefit from off-cycle technologies like engine idle start-stop, active transmission and engine warm-up, and high efficiency alternator technologies. However, BEVs still benefit from technologies like high efficiency lighting, solar panels, active aerodynamic improvement technologies, and thermal control technologies. We calculated the maximum off-cycle benefit that the model could apply for each manufacturer and each MY based on off-cycle technologies that could be applied to BEVs and the percentage of BEVs in each manufacturer's fleet. Note that we do not include PHEVs in this calculation, because they still use a conventional engine and transmission. We discuss additional details and assumptions for this calculation in Chapter 3.7 of the Draft TSD.

Note that we do not model AC efficiency and off-cycle technology benefits for HDPUVs. We have received petitions for off-cycle benefits for HDPUVs from manufacturers, but to date, none have been approved.

Because the CAFE Model applies AC efficiency and off-cycle technology benefits independent of the technology pathways, we must account for the costs of those technologies independently as well. We generated costs for these technologies on a dollars per gram of CO_2 per mile ($ per g/mi) basis, as AC efficiency and off-cycle technology benefits are applied in the CAFE Model on a gram per mile basis (as in the regulations). Like the last CAFE analysis, we used data from EPA's Proposed Determination TSD and the 2012 Joint NHTSA/EPA TSD, updated to 2018$ with an indirect cost markup and relatively flat learning rate applied. We did not have time to update these costs to 2021$, but will do so for the final rule, and we expect the impact to be minimal. Additional details and assumptions used for A/C Efficiency and off-cycle costs is discussed in Chapter 3.7 of the Draft TSD.

E. Consumer Responses to Manufacturer Compliance Strategies

The previous subsections in Section II have so far discussed how manufacturers might respond to changes to the standards. While the technology analysis is informative of the different compliance strategies available to manufactures, the tangible costs and benefits that accrue because of the standards are dependent on how consumers respond to the decisions made by manufacturers. Many, if not most, of the benefits and costs resulting from changes to standards are private benefits that accrue to the buyers of new vehicles, produced in the MYs under consideration. These benefits and costs largely flow from the changes to vehicle ownership and operating costs that result from improved fuel economy, and the cost of the technology required to achieve those improvements. The remaining benefits are also derived from how consumers use—or do not use—vehicles. Since they are not borne directly by the consumer who purchases or operates the new vehicle, we categorize these as ''external'' benefits, even if they do not necessarily meet the economic definition of an externality. The next few subsections walk through how the analysis models how consumers respond to changes to vehicles implemented by manufacturers to respond to the CAFE and HDPUV FE standards. NHTSA seeks comment on the following discussion.

1. Macroeconomic and Consumer Behavior Assumptions

This proposal includes a comprehensive economic analysis of the impacts of the proposed standards. Most of the effects measured are influenced by macroeconomic conditions that are exogenous to the agency's influence. For example, fuel prices are mainly determined by global supply and demand, and yet they partially determine how much fuel efficiency technology manufacturers will apply to U.S. vehicles, how much consumers are willing to pay for a new vehicle, the amount of travel in which all users engage, and the value of each gallon saved from higher standards. Constructing these forecasts requires robust projections of macroeconomic variables that span the timeframe of the analysis, including real GDP, consumer

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[398] 49 U.S.C. 32904. Under EPCA, the Administrator of the EPA is responsible for calculating and measuring vehicle fuel economy.

[399] 40 CFR 600.512–12.

confidence, U.S. population, and real disposable personal income.

The analysis presented along with this proposal employs fuel price forecasts developed by the EIA's NEMS. EIA is an agency within the U.S. DOE which collects, analyzes, and disseminates independent and impartial energy information to promote sound policymaking, efficient markets, and public understanding of energy and its interaction with the economy and the environment. EIA uses NEMS to produce its AEO, which presents forecasts of future fuel prices, among many other energy-related variables. The analysis uses the 2022 EIA forecasts of fuel prices and electricity prices.

The analysis also uses IHS Markit Global Insight forecasts of U.S. population, GDP, total number of households, and disposable personal income. We chose to use these estimates as they are the same estimates employed by EIA to construct their AEO projections. The agency uses a forecast of consumer confidence to project sales from the IHS Markit Global Insight long-term macroeconomic model.

While these macroeconomic assumptions are important inputs to the analysis, they are also subject to the most uncertainty—particularly over the full lifetimes of the vehicles affected by this proposed rule. The agency uses low and high cases from the AEO as bounding cases for fuel price sensitivity analyses. The purpose of the sensitivity analyses, discussed in greater detail in Chapter 9 of the PRIA, is not to posit a more credible future state of the world than the central case assumes—we assume the central case is the most likely future state of the world—but rather to measure the degree to which important outcomes can change under different assumptions about fuel prices.

The first year simulated in this analysis is 2022, though it is based on observational data (rather than forecasts) to the greatest extent possible. The elements of the analysis that rely most heavily on the macroeconomic inputs—aggregate demand for VMT, new vehicle sales, used vehicle retirement rates—all reflect the continued return to pre-pandemic growth rates (in all the regulatory alternatives). See Chapter 4.1 of the Draft TSD for a more complete discussion of the macroeconomic assumptions made for the analysis.

Another key assumption that permeates throughout the analysis is how much consumers are willing to pay for fuel economy. Increased fuel economy offers vehicle owners savings through reduced fuel expenditures throughout the lifetime of a vehicle. If buyers fully value the savings in fuel costs that result from driving (and potentially re-selling) vehicles with higher fuel economy and manufacturers supply all improvements in fuel economy that buyers demand, market-determined levels of fuel economy would reflect both the cost of improving it and the private benefits from doing so. In that case, regulations on fuel economy would only be necessary to reflect environmental or other benefits other than to buyers themselves. But if consumers instead undervalue future fuel savings or are otherwise unable to purchase their optimal levels of fuel economy due to market failures, they will underinvest in fuel economy and manufacturers would spend too little on fuel-saving technology (or deploy its energy-saving benefits to improve vehicles' other attributes). In that case, more stringent fuel economy standards could lead manufacturers to adopt improvements in fuel economy that not only reduce external costs from producing and consuming fuel to appropriate levels but also improve consumer welfare.

Increased fuel economy offers vehicle owners significant potential savings. The analysis shows that the value of prospective fuel savings exceeds manufacturers' technology costs to comply with the preferred alternatives for HDPUVs and light trucks discounted at 3 percent, and the fuel savings for passenger automobiles pays back a significant portion of the upfront costs. It would seem reasonable to assume that well-informed vehicle shoppers, if without time constraints or other barriers to rational decision-making, will recognize the full value of fuel savings from purchasing a model that offers higher fuel economy, since they would enjoy an equivalent increase in their disposable income and the other consumption opportunities it affords them; or for commercial operators, higher fuel efficiency would free up additional capital for either higher profits or additional business ventures. If consumers did value the full amount of fuel savings, more fuel-efficient vehicles would functionally be less costly for consumers to own when considering both their initial purchase prices and subsequent operating costs, thus making the models that manufacturers are likely to offer under stricter alternatives more attractive than those available under the No-Action Alternative.

Recent econometric research is divided between studies concluding that consumers value most or all of the potential savings in fuel costs from driving higher-mpg vehicles, and those concluding that consumers significantly undervalue expected fuel savings. More circumstantial evidence appears to show that consumers do not fully value the expected lifetime fuel savings from purchasing higher-mpg models. Although the average fuel economy of new light vehicles reached an all-time high in MY 2021 of 25.4 mpg,[400] this is still significantly below the fuel economy of the fleet's most efficient vehicles that are readily available to consumers.[401] Manufacturers have repeatedly informed the agency that consumers only value between 2 to 3 years-worth of fuel savings when making purchasing decisions. And in the last CAFE rulemaking, the Environmental Defense Fund commented with a Consumer Reports article indicating that 64 percent of consumers ranked fuel economy as extremely or very important, and viewed fuel economy as the attribute that has the most room for improvement, but only 29% of those same respondents would be willing to pay for technology that paid back over a period in excess of 3 years with the average consumer willing to pay for fuel economy that recouped the upfront costs between 2 and 3 years.[402]

The potential for 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." This appearance of such a gap, between the level of energy efficiency that would minimize consumers' overall expenses and what they actually purchase, is typically based on engineering calculations that compare the initial cost for providing higher energy efficiency to the discounted present value of the resulting savings in future energy costs. There has long been an active debate about why such a gap might arise and whether it actually exists. Economic theory predicts that economically rational individuals will purchase more energy-efficient products only if the savings in future energy costs they offer promise to offset their higher initial costs.

On the other hand, behavioral economics has documented numerous situations in which the decision-making of consumers differs in important ways from the from the predictions of the standard model of rational consumer behavior, especially for choices under

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[400] See EPA 2022 Automotive Trends Report at 5. Available at *https://www.epa.gov/system/files/documents/2022-12/420r22029.pdf.* (Accessed: May 31, 2023).

[401] *Id.* At 9.

[402] 87 FR 25856.

uncertainty.[403] 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 generally differ from that shown on fuel economy labels, potential buyers may be uncertain how much they will actually drive a new vehicle, future resale prices may be uncertain, and future fuel prices are highly uncertain. Recent research indicates that typical consumers exhibit several behavioral departures from the rational economic model, 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.[404] 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. 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 net present savings, 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.[405]

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. 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 NHTSA's estimates of the impacts of raising 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.

The analysis assumes that potential buyers value only the undiscounted savings in fuel costs from purchasing a higher-mpg model they expect to realize over the first 30 months (*i.e.,* 2.5 years) they own it. NHTSA feels that 30 months is supported by the totality of present literature and is consistent with manufacturer assumptions about consumer demand. Depending on the DR buyers are assumed to apply, this amounts to 25–30% of the expected savings in fuel costs over its entire lifetime. These savings would offset only a fraction of the expected increase in new vehicle prices that NHTSA estimates will be required for manufacturers to recover their increased costs for making required improvements to fuel economy. NHTSA seeks comment on whether 30 months of undiscounted fuel savings is an appropriate measure for the analysis of consumer willingness to pay for fuel economy. The assumption also has important implications for other outcomes of the model, including for VMT, safety, and air pollution emissions projections, and NHTSA has included a handful of sensitivity cases to examine the impacts of higher and lower payback periods on the analysis. If commenters believe a different amount of time should be used for the payback assumption, it would be most helpful to NHTSA if commenters could define the amount of time, provide an explanation of why that amount of time is preferable, and provide any data or information on which the amount of time is based. These concepts are explored more thoroughly in Chapter 4.2.1.1 of the Draft TSD and Chapter 2.4 of the PRIA.

It is possible that commercial operators, to the extent they act as profit-maximizing entities could value the tradeoff between long-term fuel savings and upfront capital differently than the average non-commercial consumer. However, both commercial and non-commercial consumers may face their own set of market failures and other constraints that may prevent them from purchasing in an un-regulated market the level of fuel efficiency that may maximize their private net benefits. Additionally, the CAFE Model is unable to distinguish between these two types of purchasers. Given this constraint, NHTSA believes that using the same payback period for the HDPUV fleet as for the LD fleet made sense. Similar to the LD analysis, the agency is including several sensitivity cases testing alternative payback assumptions for HDPUVs.

2. Fleet Composition

The composition of the on-road fleet—and how it changes in response to the standards—determines many of the costs and benefits of the proposal. For example, how much fuel the LD fleet consumes is dependent on the number and efficiency of new vehicles sold, older (and less efficient) vehicles retired, and how much those vehicles are driven.

Until the 2020 final rule, all previous CAFE rulemaking analyses used static fleet forecasts that were based on a combination of manufacturer compliance data, public data sources, and proprietary forecasts (or product plans submitted by manufacturers). When simulating compliance with regulatory alternatives, those analyses projected identical sales and retirements across the alternatives, for each manufacturer down to the make/model level—where the exact same number of each model variant was assumed to be sold in a given MY under both the least stringent alternative (typically the baseline) and the most stringent alternative considered (intended to represent ''maximum technology'' scenarios in some cases).

However, a fleet forecast is unlikely to be representative of a broad set of regulatory alternatives with significant variation in the cost of new vehicles. Several commenters on previous regulatory actions and peer reviewers of the CAFE Model encouraged consideration of the potential impact of fuel efficiency standards on new vehicle

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[403] *e.g.* Dellavigna, S. 2009. Psychology and economics: Evidence from the field. *Journal of Economic Literature.* 47(2): pp. 315–372.

[404] Satisficing is when a consumer finds a solution that meets enough of their requirements instead of searching for a vehicle that optimizes their utility.

[405] For a discussion of these potential market failures, *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.

prices and sales, the changes to compliance strategies that those shifts could necessitate, and the downstream impact on vehicle retirement rates. In particular, the continued growth of the utility vehicle segment causes changes within some manufacturers' fleets as sales volumes shift from one region of the footprint curve to another, or as mass is added to increase the ride height of a vehicle on a sedan platform to create a crossover utility vehicle, which exists on the same place of the footprint curve as the sedan upon which it might be based.

The analysis accompanying this proposal, like the 2020 and 2022 rulemakings, dynamically simulates changes in the vehicle fleet's size, composition, and usage as manufacturers and consumers respond to regulatory alternatives, fuel prices, and macroeconomic conditions. The analysis of fleet composition is comprised of two forces, how new vehicle sales—the flow of new vehicles into the registered population—change in response to regulatory alternatives, and the influence of economic and regulatory factors on vehicle retirement (otherwise known as scrappage). Below are brief descriptions of how the agency models sales and scrappage. For a full explanation, refer to Chapter 4.2 of the Draft TSD. Particularly given the broad uncertainty discussed in Chapter 4.2 of the Draft TSD, NHTSA seeks comment on the discussion below and the associated discussions in the TSD, on the internal structure of the sales and scrappage modules, and whether and how to change the sales and scrappage analyses for the final rule.

a. Sales

For the purposes of regulatory evaluation, the relevant sales metric is the difference between alternatives rather than the absolute number of sales in any of the alternatives. As such, the sales response model currently contains three parts: a nominal forecast that provides the level of sales in the baseline (based upon macroeconomic inputs, exclusively), a price elasticity that creates sales differences relative to that No-Action alternative in each year, and a fleet share model that produces differences in the passenger car and light truck market share in each alternative. For a more detailed description of these three parts, see Chapter 4.2 of the Draft TSD.

The current baseline sales module reflects the idea that total new vehicle sales are primarily driven by conditions in the economy that are exogenous to the automobile industry. Over time, new vehicle sales have been cyclical—rising when prevailing economic conditions are positive (periods of growth) and falling during periods of economic contraction. While the kinds of changes to vehicle offerings that occur as a result of manufacturers' compliance actions exert some influence on the total volume of new vehicle sales, they are not determinative. Instead, they drive the kinds of marginal differences between regulatory alternatives that the current sales module is designed to simulate—more expensive vehicles, generally, reduce total sales but only marginally.

The first component of the sales response model is the nominal forecast, which is a function with a small set of macroeconomic inputs that determines the size of the new vehicle market in each CY in the analysis for the baseline. It is of some relevance that this statistical model is intended only as a means to project a baseline sales series for LDVs. The nominal forecast model does not include prices and is not intended for statistical inference around the question of price response in the new vehicle market. NHTSA's projection oscillates by MY at the beginning of the analysis before settling on a constant trend in the 2030s. This result seems consistent with the continued response to the pandemic and to supply chain challenges. NHTSA's projections for most MYs fall between AEO 2021 and 2022 forecasts, which were run as sensitivity cases. NHTSA will continue to monitor macroeconomic data and new vehicle sales and update its baseline forecast as appropriate.

The baseline HDPUV fleet is modeled differently. NHTSA considered using a statistical model drawn from the LD specification to project new HDPUV sales but reasoned that the mix of HDPUV buyers and vehicles was sufficiently different that an alternative approach was required. Due to a lack of historical and future data on the changing customer base in the HDPUV market (*e.g.,* the composition of commercial and personal users) and uncertainty around vehicle classification at the LDV and HDPUV margin, NHTSA chose to rely on an exogenous forecast path from the AEO to project sales. To align with the technology used to create the model fleet, NHTSA used compliance data from multiple MYs to estimate aggregate sales for MY 2022 and then applied year-over-year growth rates taken from the AEO forecast to project aggregate sales for subsequent MYs. Since the first year of the analysis, MY 2022, was constructed using compliance data spanning nearly a decade, the aggregate number of sales for the simulated fleet in MY 2022 was lower than the MY 2022 AEO forecast. To align with the AEO projections, the agency applied an upward adjustment to the HDPUV growth rate of 2 percent for MYs 2023–2025, and 2.5 percent for MYs 2026–2028. Instead of adjusting the fleet size to match AEO's in MY2022, the agency elected to phase-in the increase in growth rates over a span of years to reflect that HDPUV production may continue to face supply constraints resulting from the COVID pandemic in the near future but should return to normal sometime later in the decade. NHTSA seeks comment on this approach, and whether it should implement an approach similar to how NHTSA models LDV sales.

The second component of the sales response model captures how price changes affect the number of vehicles sold. NHTSA applies a price elasticity to the percentage change in average price (in each year). The price change does not represent an increase/decrease over the last observed year, but rather the percentage change relative to the baseline for that year. In the baseline, the average price is defined as the observed new vehicle price in 2022 (the last historical year before the simulation begins) plus the average regulatory cost associated with the No-Action Alternative for each MY.[406] The central analysis in this proposal simulates multiple programs simultaneously (CAFE and HDPUV FE final standards, EPA final GHG standards, ZEV, and the California Framework Agreement), and the regulatory cost includes both technology costs and civil penalties paid for non-compliance (with CAFE standards) in a MY. We also subtract any IRA tax credits that a vehicle may qualify for from the regulatory costs.[407] Because the elasticity assumes no perceived change in the quality of the product, and the vehicles produced under different regulatory scenarios have inherently different operating costs, the price metric must account for this difference. The price to which the elasticity is applied in this analysis represents the residual price change *between scenarios* after accounting for

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[406] The CAFE Model currently operates as if all costs incurred by the manufacturer as a consequence of meeting regulatory requirements, whether those are the cost of additional technology applied to vehicles in order to improve fleetwide fuel economy or civil penalties paid when fleets fail to achieve their standard, are ''passed through'' to buyers of new vehicles in the form of price increases.

[407] For additional details about how we model tax credits, see Section II.C.5b above.

2.5 years' worth of fuel savings to the new vehicle buyer.

The price elasticity is also specified as an input, and for this analysis the agency assumes an elastic response of −0.4—meaning that a five percent increase in the average price of a new vehicle produces a two percent decrease in total sales. As explained in Chapter 4.2.1.2 of the Draft TSD, NHTSA selected this elasticity because of the totality of present evidence. NHTSA seeks comment on this assumption and has included several sensitivity cases testing alternative values.

The third and final component of the sales model, which only applies to the LD fleet, is the dynamic fleet share module (DFS). Some commenters to previous rules noted that the market share of SUVs continues to grow, while conventional passenger car body-styles continue to lose market share. For instance, in the 2012 final rule, the agencies projected fleet shares based on the continuation of the baseline standards (MYs 2012–2016) and a fuel price forecast that was much higher than the realized prices since that time. As a result, that analysis assumed passenger car body-styles comprising about 70 percent of the new vehicle market by 2025. The reality, however, has been quite different; in 2021, passenger cars represented only 22% of new vehicle sales.[408] Since the 2020 rule, NHTSA has incorporated a DFS into the CAFE Model in an attempt to address these market realities.

For the 2020 and 2022 rulemakings, NHTSA used a DFS model crafted from two functions from the NEMS used for the 2017 AEO to independently estimate the share of passenger cars and light trucks, respectively, given average new market attributes (fuel economy, horsepower, and curb weight) for each group and current fuel prices, as well as the prior year's market share and prior year's attributes. The two independently estimated shares are then normalized to ensure that they sum to one. However, as the agency explained in the 2022 final rulemaking, that approach had several drawbacks including the model having counterintuitive signs, the exclusion a variable for price, and an overestimation of the fleet share of passenger automobile as currently observed.[409]

For this proposal, NHTSA has revised its approach to modeling the DFS. The baseline fleet share projection is derived from the agency's own compliance data for the 2022 fleet, and the 2022 AEO projections for later MYs. To reconcile differences in the initial 2022 shares, NHTSA projected the fleet share forward using the annual changes from 2022 predicted by AEO and applied these to the agency's own compliance fleet shares for MY 2022.[410] The fleet is distributed across two different body-types: ''cars'' and ''light trucks.'' While there are specific definitions of ''passenger cars'' and ''light trucks'' that determine a vehicle's regulatory class, the distinction used in this phase of the analysis is more simplistic. All body-styles that are commonly considered a car—sedans, coupes, convertibles, hatchbacks, and station wagons—are defined as ''cars'' for the purpose of determining fleet share. Everything else—SUVs, smaller SUVs (crossovers), vans, and pickup trucks—are defined as ''light trucks''—even though they may not be treated as such for compliance purposes.

These shares are applied to the total industry sales derived in the first stage of the sales response. This produces total industry volumes of car and light truck body styles. Individual model sales are then determined from there based on the following sequence: (1) individual manufacturer shares of each body style (either car or light truck) times the total industry sales of that body style, then (2) each vehicle within a manufacturer's volume of that body-style is given the same percentage of sales as appear in the 2022 fleet. This implicitly assumes that consumer preferences for particular styles of vehicles are determined in the aggregate (at the industry level), but that manufacturers' sales shares of those body styles are consistent with MY 2022 sales. Within a given body style, a manufacturer's sales shares of individual models are also assumed to be constant over time. This approach implicitly assumes that manufacturers are currently pricing individual vehicle models within market segments in a way that maximizes their profit. Without more information about each OEM's true cost of production and operation, fixed and variables costs, and both desired and achievable profit margins on individual vehicle models, there is no basis to assume that strategic shifts within a manufacturer's portfolio will occur in response to standards.

Similar to the second component of the sales module, the DFS then applies an elasticity to the change in price between alternatives and the No-Action Alternative to determine the change in fleet share. NHTSA uses the net regulatory cost differential (costs minus fuel savings) in a logistic model to capture the changes in fleet share between passenger cars and light trucks, with a price coefficient of −0.000042. NHTSA selected this methodology and price coefficient based on academic literature.[411] When the total regulatory costs of passenger automobiles minus fuel savings exceeds that of light-trucks, the market share of light-trucks will rise relative to passenger automobiles. For example, a $100 net regulatory cost increase in passenger automobiles relative to light trucks would produce a ~.1% shift in market share towards light trucks assuming light trucks initially represented 60% of the fleet. NHTSA seeks comment on how it is modeling the DFS in this proposal, and more specifically seeks input to the elasticity NHTSA is using.

The approach for this proposal to modeling changes in fleet share addresses several key concerns raised by NHTSA in its prior rulemaking. There are no longer any counterintuitive signs, and the model now directly considers the impacts of changes in price. While the model applies fuel savings in determining the relative changes in prices between passenger cars and light-trucks, the current approach does not explicitly consider the utility of fuel economy when determining the respective market share of passenger automobiles and light trucks. In prior rules, NHTSA has speculated that the rise in light-truck market share may be attributable to the increased utility that light-trucks provide their operators, and as the fuel economy between the different body-styles diminished, light-trucks have become an even more attractive option. As explained in a docket memo, NHTSA has been unable to create a comprehensive model that includes the variables in NEMS, price, and fuel economy that behaves appropriately. NHTSA is considering applying an elasticity to the changes in fuel economy directly to capture this change in utility. NHTSA seeks comment on whether this alternative approach is appropriate.

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[408] See Bureau of Transportation Statistics. 2023. National Transportation Statics. Table 1–17. Avaliable at: *https://www.bts.gov/content/new-and-used-passenger-car-sales-and-leases-thousands-vehicles.* (Accessed May 31, 2023).

[409] 84 FR 25861 (May 2, 2022).

[410] For example if AEO PC share grows from 40 percent in one year to 50 percent in the next (25 percent growth), and our compliance PC share in that year is 44 percent then the predicted share in the next year would be 55 percent (11 points or 25 percent higher).

[411] The agency describes this literature review and the calibrated logit model in more detail in the accompanying docket memo ''Calibrated Estimates for Projecting Light-Duty Fleet Share in the CAFE Model''.

b. Scrappage

New and used vehicles are substitutes. When the price of a good's substitute increases/decreases, the demand curve for that good shifts upwards/downwards and the equilibrium price and quantity supplied also increases/decreases. Thus, increasing the quality-adjusted price of new vehicles will result in an increase in equilibrium price and quantity of used vehicles. Since, by definition, used vehicles are not being ''produced'' but rather ''supplied'' from the existing fleet, the increase in quantity must come via a reduction in their scrappage rates. Practically, when new vehicles become more expensive, demand for used vehicles increases (and they become more expensive). Because used vehicles are more valuable in such circumstances, they are scrapped at a lower rate, and just as rising new vehicle prices push marginal prospective buyers into the used vehicle market, rising used vehicle prices force marginal prospective buyers of used vehicles to acquire older vehicles or vehicles with fewer desired attributes. The effect of fuel economy standards on scrappage is partially dependent on how consumers value future fuel savings and our assumption that consumers value only the first 30 months of fuel savings when making a purchasing decision.

Many competing factors influence the decision to scrap a vehicle, including the cost to maintain and operate it, the household's demand for VMT, the cost of alternative means of transportation, and the value that can be attained through reselling or scrapping the vehicle for parts. A car owner will decide to scrap a vehicle when the value of the vehicle minus the cost to maintain or repair the vehicle is less than the value as scrap metal. In other words, the owner gets more value from scrapping the vehicle than continuing to drive it, or from selling it. Typically, the owner that scraps the vehicle is not the original vehicle owner.

While scrappage decisions are made at the household level, NHTSA is unaware of sufficient household data to sufficiently capture scrappage at that level. Instead, NHTSA uses aggregate data measures that capture broader market trends. Additionally, the aggregate results are consistent with the rest of the CAFE Model as the model does not attempt to model how manufacturers will price new vehicles; the model instead assumes that all regulatory costs to make a particular vehicle compliant are passed onto the purchaser who buys the vehicle.

The most predictive element of vehicle scrappage is ''engineering scrappage.'' This source of scrappage is largely determined by the age of a vehicle and the durability of a specific MY vintage. NHTSA uses proprietary vehicle registration data from IHS/Polk to estimate vehicle age and durability. Other factors include fuel economy and new vehicle prices. For historical data on new vehicle transaction prices, NHTSA uses National Automobile Dealers Association (NADA) Data.[412] The data consist of the average transaction price of all LDVs; since the transaction prices are not broken-down by body style, the model may miss unique trends within a particular vehicle body style. The transaction prices are the amount consumers paid for new vehicles and exclude any trade-in value credited towards the purchase. This may be particularly relevant for pickup trucks, which have experienced considerable changes in average price as luxury and high-end options entered the market over the past decade. Future models will further consider incorporating price series that consider the price trends for cars, SUVs and vans, and pickups separately. The other source of vehicle scrappage is from cyclical effects, which the model captures using forecasts of GDP and fuel prices.

Vehicle scrappage follows a roughly logistic function with age—that is, when a vintage is young, few vehicles in the cohort are scrapped, as they age, more and more of the cohort are retired and the instantaneous scrappage (the rate at which vehicles are scrapped) reaches a peak, and then scrappage declines as vehicles enter their later years as fewer and fewer of the cohort remains on the road. The analysis uses a logistic function to capture this trend of vehicle scrappage with age. The data show that the durability of successive MYs generally increases over time, or put another way, historically newer vehicles last longer than older vintages. However, this trend is not constant across all vehicle ages—the instantaneous scrappage rate of vehicles is generally lower for later vintages up to a certain age, but increases thereafter so that the final share of vehicles remaining converges to a similar share remaining for historically observed vintages.[413] NHTSA uses fixed effects to capture potential changes in durability across MYs, and to ensure that vehicles approaching the end of their life are scrapped in the analysis, NHTSA applies a decay function to vehicles after they reach age 30. The macroeconomic conditions variables discussed above are included in the logistic model to capture cyclical effects. Finally, the change in new vehicle prices projected in the model (technology costs minus 30 months of fuel savings and any tax credits passed through to the consumer) are included, which generates differing scrappage rates across the alternatives.

For this proposal, NHTSA modeled the retirement of HDPUVs similarly to pick-up trucks. The amount of data for HDPUVs is significantly smaller than for the LD fleet and drawing meaningful conclusions from the small sample size is difficult. Furthermore, the two regulatory classes share similar vehicle characteristics and are likely used in similar fashions, hence NHTSA believes that the vehicles will follow a similar scrappage schedule. Commercial HDPUVs may endure harsher conditions during their useful life such as more miles in tough operating conditions, which may impact their retirement schedules. We believe that many light-trucks likely endure the same rigor and are represented in the light-truck segment of the analysis; however, NHTSA recognizes that the intensity or proportionality of heavy use in the HDPUV fleet may exceed that of light trucks and seeks comment from the public on how to capture that use in a statistically-significant fashion either within the existing framework or an alternative approach.

In addition to the variables included in the scrappage model, NHTSA considered several other variables that likely either directly or indirectly influence scrappage in the real world, including maintenance and repair costs, the value of scrapped metal, vehicle characteristics, the quantity of new vehicles purchased, higher interest rates, and unemployment. These variables were excluded from the model either because of a lack of underlying data or modeling constraints. Their exclusion from the model is not intended to diminish their importance, but rather highlights the practical constraints of modeling intricate decisions like scrappage.

For additional details on how NHTSA modeled scrappage, see Chapter 4.2.2 of the Draft TSD. NHTSA seeks comments on its approach to modeling scrappage.

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[412] The data can be obtained from NADA. For reference, the data for MY 2020 may be found at *https://www.nada.org/nadadata/.*

[413] Examples of why durability may have changed are new automakers entering the market or general changes to manufacturing practices like switching some models from a car chassis to a truck chassis.

3. Changes in Vehicle Miles Traveled (VMT)

In the CAFE Model, VMT is the product of average usage per vehicle in the fleet and fleet composition, which is itself a function of new vehicle sales and vehicle retirement decisions. These three components—average vehicle usage, new vehicle sales, and older vehicle scrappage—jointly determine total VMT projections for each alternative. VMT directly influences many of the various effects of fuel economy standards that decision-makers consider in determining what levels of standards to set. For example, the value of fuel savings is a function of a vehicle's efficiency, miles driven, and fuel price. Similarly, factors like criteria pollutant emissions, congestion, and fatalities are direct functions of VMT. For a more detailed description of how NHTSA models VMT, see Chapter 4.3 of the Draft TSD.

It is NHTSA's 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 standards, 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). Based on the structure of the CAFE Model, the combined effect of the sales and scrappage responses could create small percentage differences in total VMT across the range of regulatory alternatives if steps are not taken to constrain VMT. Because VMT is related to many of the costs and benefits of the program, even small magnitude differences in VMT across alternatives can have meaningful impacts on the incremental net benefits. Furthermore, since decisions about alternative stringencies look at the incremental costs and benefits across alternatives, it is more important that the analysis capture the variation of VMT across alternatives than to accurately project total VMT within a scenario. NHTSA seeks comment on whether non-rebound VMT should be constrained across the LD fleet, or if it would be more appropriate to model VMT changing with fleet size.

To ensure that travel demand remains consistent across the different regulatory scenarios for the LD fleet, the CAFE Model begins with a model of aggregate VMT developed by Federal Highway Administration (FHWA) that is used to produce their annual VMT forecasts. These estimates provide the aggregate VMT of all MYs and body styles for any given CY and are the same across regulatory alternatives for each year in the analysis. NHTSA seeks comment on whether it should continue to constrain aggregate, non-rebound VMT across alternatives. NHTSA is considering removing the constraint on VMT. While as noted above, this will produce some differences in non-rebound VMT across the alternatives, we believe that the differences will be minor and will reflect households either reducing or dropping out of the personal vehicle market as they seek to reduce travel costs through alternative modes of transportation.

Since vehicles of different ages and body styles carry different costs and benefits, to account properly for the average value of consumer and societal costs and benefits associated with vehicle usage under various alternatives, it is necessary to partition miles by age and body type. NHTSA created ''mileage accumulation schedules'' using IHS-Polk odometer data to construct mileage accumulation schedules as an initial estimate of how much a vehicle expected to drive at each age throughout its life.[414] NHTSA uses simulated new vehicle sales, annual rates of retirement for used vehicles, and the mileage accumulation schedules to distribute VMT across the age distribution of registered vehicles in each CY to preserve the non-rebound VMT constraint.

FHWA does not produce an annual VMT forecast for HDPUVs. Without an annual forecast, NHTSA is unable to constrain VMT for HDPUVs similar to the LD fleet. Instead, VMT is built exclusively through the vehicle accumulation schedules. For the aforementioned reasons, we believe that the change in VMT that results from changes in fleet composition and size are reasonable. NHTSA seeks comment on this assumption, and alternatively asks commenters to identify an independent forecast of HDPUV VMT that may be used as a constraint.

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 (as measured by VMT) to increase when their fuel economy is improved and, as a result, the cost per mile (CPM) of driving declines. Establishing more stringent standards than the baseline level will lead to comparatively higher fuel economy for new cars and light trucks, and increase fuel efficiency for HDPUVs, thus decreasing the amount of fuel consumed and increasing the amount of travel in which new vehicle owners engage. NHTSA recognizes that the value selected for the rebound effect influences overall costs and benefits associated with the regulatory alternatives under consideration as well as the estimates of lives saved under various regulatory alternatives, and that the rebound estimate, along with fuel prices, technology costs, and other analytical inputs, is part of the body of information that agency decision-makers have considered in determining the appropriate levels of the standards in this proposal. We also note that the rebound effect diminishes the economic and environmental benefits associated with increased fuel efficiency.

NHTSA conducted a review of the literature related to the fuel economy rebound effect, which is extensive and covers multiple decades and geographic regions. The totality of evidence, without categorically excluding studies on grounds that fail to meet certain criteria, and evaluating individual studies based on their particular strengths, suggests that a plausible range for the rebound effect is 10–50 percent. This range implies that, for example, a 10 percent reduction in vehicles' fuel CPM would lead to an increase of 1–5 percent in the number of miles they are driven annually. The central tendency of this range appears to be at or slightly above its midpoint, which is 30 percent. Considering only those studies that NHTSA believes are derived from extremely robust and reliable data, employ identification strategies that are likely to prove effective at isolating the rebound effect, and apply rigorous estimation methods, suggests a range of approximately 10–45 percent, with most of the estimates falling in the 15–30 percent range.

That said, a case can also be made to support values of the rebound effect in the 5–15 percent range. Both economic theory and empirical evidence suggest that the rebound effect has been declining over time due to factors such as increasing income (which raises the value of travelers' time), progressive smaller reductions in fuel costs in response to continuing increases in fuel economy, and slower growth in car ownership and the number of license holders. Lower estimates of the rebound effect estimates are associated with recently published studies that rely on U.S. data, measure vehicle use using

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[414] The mileage accumulations schedules are constructed with content supplied by IHS Markit; Copyright © R.L. Polk & Co., 2018. All rights reserved.

actual odometer readings, control for the potential endogeneity of fuel economy, and estimate the response of vehicle use to variation in fuel economy itself rather than to fuel cost per distance driven or fuel prices. Accordingly, greater weight to these studies suggests that the rebound effect is more likely to be in the 5–15 percent range.

NHTSA selected a rebound effect of 10% for its analysis of both LD and HDPUV fleets because it was well-supported by the totality of the evidence. It is rarely possible to identify whether estimates of the rebound effect in academic literature apply specifically to household vehicles, LDVs, or another category, and different nations classify trucks included in NHTSA's HDPUV category in varying ways, so NHTSA has assumed the same value for LDVs and HDPUVs.

We also examine the sensitivity of estimated impacts to values of the rebound ranging from 5 percent to 15 percent to account for the uncertainty surrounding the rebound value. NHTSA seeks comment on the above discussion, and whether to consider a different value for the rebound effect for the final rule analysis for either the LD or HDPUV analyses.

In order to calculate total VMT *with* rebound, the CAFE Model applies the price elasticity of VMT (taken from the FHWA forecasting model) to the full change in CPM and the initial VMT schedule but applies the (user defined) rebound parameter to the incremental percentage change in CPM between the non-rebound and full CPM calculations to the miles applied to each vehicle during the reallocation step that ensured adjusted non-rebound VMT matched the non-rebound VMT constraint.

The approach in the model is a combination of top-down (relying on the FHWA forecasting model to determine total LD VMT in a given CY), and bottom-up (where the composition and utilization of the on-road fleet determines a base level of VMT in a CY, which is constrained to match the FHWA model). While a joint household consumer choice model—if one could be developed adequately and reliably to capture the myriad circumstances under which families and individuals make decisions relating to vehicle purchase, use, and disposal—would reflect decisions that are made at the household level, it is not obvious, or necessarily appropriate, to model the national program at that scale in order to produce meaningful results that can be used to inform policy decisions.

The most useful information for policymakers relates to national impacts of potential policy choices. No other element of the rulemaking analysis occurs at the household level, and the error associated with allocating specific vehicles to specific households over the course of three decades would easily dwarf any error associated with the estimation of these effects in aggregate. We have attempted to incorporate estimates of changes to the new and used vehicle markets at the highest practical levels of aggregation and worked to ensure that these effects produce fleetwide VMT estimates that are consistent with the best, current projections given our economic assumptions. While future work will always continue to explore approaches to improve the realism of CAFE and HDPUV FE policy simulations, there are important differences between small-scale econometric studies and the kind of flexibility that is required to assess the impacts of a broad range of regulatory alternatives over multiple decades. To assist with creating even more precise estimates of VMT, NHTSA requests comment on alternative approaches to simulate VMT demand. See Chapter 4.3 of the Draft TSD for a complete accounting of how NHTSA models VMT.

4. Changes to Fuel Consumption

NHTSA uses the fuel economy and age and body-style VMT estimates to determine changes in fuel consumption. NHTSA divides the expected vehicle use by the anticipated mpg to calculate the gallons consumed by each simulated vehicle, and when aggregated, the total fuel consumed in each alternative.

F. Simulating Emissions Impacts of Regulatory Alternatives

This proposal includes various fuel-saving technologies, which produce additional co-benefits. These co-benefits include reduced vehicle emissions during operation as well as reduced upstream emissions during petroleum extraction, transportation and refining, and finally fuel transportation, storage, and distribution. This section has a detailed discussion, particularly for the main standard-setting inputs and assumptions, on the development and evolution of input parameters for criteria pollutants, GHGs, and air toxics emissions and the resulting potential human health effects.

The rule implements an emissions inventory methodology for estimating emissions impacts. Vehicle emissions inventories are often described as three-legged stools, comprised of vehicle activity (*i.e.,* miles traveled, hours operated, or gallons of fuel burned), population (or number of vehicles), and EFs. An emissions factor is a representative rate that attempts to relate the quantity of a pollutant released to the atmosphere per unit of activity. For this rulemaking, like past rules, activity levels (both miles traveled and fuel consumption) are generated by the CAFE Model while the EFs have been incorporated from other Federal models.

The following section briefly discusses the methodology the CAFE Model uses to track vehicle activity and populations, and how we generate the emissions factors that relate that vehicle activity to criteria pollutant, GHG, and air toxics emissions impacts. This section also details how we estimate these emissions could adversely affect human health, especially from criteria pollutants known to cause poor air quality. Further description of how the health impacts of criteria pollutant emissions can vary and how these emission damages have been monetized and incorporated into the rule can be found in Chapter 6.2.2 of the Draft TSD and the Draft EIS accompanying this analysis.

For transportation applications, upstream emissions are generated between the point of energy feedstock extraction to the vehicle's fuel tank or energy storage system; in lifecycle analysis this is often referred to as well-to-tank emissions. Downstream emissions are primarily comprised of what is emitted through the vehicle's exhaust but would also include other emissions generated during vehicle use and inactivity (called 'soaking'), including hydrofluorocarbons leaked from AC systems. This would encompass, for example, particulate matter (PM) from brake and tire wear (BTW) as well as volatile organic compounds (VOCs) from evaporative emissions during refueling and as the vehicle's engine remains off and the fuel onboard permeates from its tank. Downstream emissions are commonly known as tank-to-wheel emissions and cumulative fuel cycle emissions are called well-to-wheel emissions in lifecycle analysis.

The CAFE Model tracks vehicle populations and activity levels to produce estimates of the effects of different levels of CAFE standards. Tracking vehicle populations begins with the baseline fleet or analysis fleet, and estimates of each vehicle's fuel type (*e.g.,* gasoline, diesel, electricity), fuel economy, and number of units sold in the U.S. As fuel-economy-improving technology is added to vehicles in the baseline fleet in each subsequent MY, the CAFE Model estimates annual rates at which new vehicles are purchased, driven,[415] and subsequently scrapped. The model uses estimates of vehicles remaining in service in each year and the amount those vehicles are driven (*i.e.,* activity levels) to calculate the quantities of each type of fuel or energy, including gasoline, diesel, and electricity, that vehicles in the fleet consume in each year. The quantities of travel and fuel consumption estimated for the cross section of MYs and CYs constitutes a set of ''activity levels'' based on which the model calculates emissions. The model does so by multiplying activity levels by EFs.

EFs measure the mass of each greenhouse or criteria pollutant emitted per vehicle-mile of travel, gallon of fuel consumed, or unit of fuel energy content. We generate EFs for the following regulated criteria pollutants and GHGs: carbon monoxide (CO), VOCs, nitrogen oxides (NO_X), sulfur oxides (SO_X), particulate matter with 2.5-micron (µm) diameters or less ($PM_{2.5}$); CO_2, methane (CH_4), and nitrous oxide (N_2O).[416] In this rulemaking, upstream EFs are on a fuel volume basis and downstream EFs are on a distance basis. Simply stated, the rulemaking's upstream emission inventory is the product of the per-gallon EF and the corresponding number of gallons of gasoline or diesel, or amount of electricity, the vehicle consumes. Similarly, the downstream emission inventory is the product of the per-mile EF and the appropriate miles traveled estimate. The only exceptions are that tailpipe SO_X and CO_2 also use a per-gallon EF in the CAFE Model. EVs do not produce combustion-related emissions,[417] however, EV upstream electricity emissions are also accounted for in the CAFE Model inputs. Upstream and downstream EFs and subsequent inventories were developed independently from separate data sources, as discussed further below.

We estimated upstream EFs using the GREET 2022 Model,[418] which is a lifecycle emissions model developed by the U.S. DOE's ANL. Like past CAFE analyses, we used GREET 2022 to calculate emissions factors for the following four upstream emission processes for gasoline, E85, and diesel: (1) petroleum extraction, (2) petroleum transportation, (3) petroleum refining, and (4) fuel transportation, storage, and distribution (TS&D), for the years 2022 through 2050 in five-year intervals. We consider conventional crude oil, oil sands, and shale oils in the gasoline and diesel EF calculations and follow assumptions consistent with the GREET Model for ethanol blending. Based on our assumption that any reduction in fuel consumption within the United States leads to an equal sized increase in gasoline exports, we currently do not project changes in upstream emissions resulting from feedstock extraction and fuel production outside the U.S. We realize that reduced domestic fuel consumption may to lead to some reduction in global fuel supply over the longer term even if U.S. fuel production remains unaffected in the near term (as we argue is likely to be the case), and we are considering if and how to incorporate this effect in our Final Rule. Doing so would involve projecting the long run effects of changes to domestic fuel economy and fuel efficiency standards on global demand, prices, and output of refined transportation fuels and feedstocks used to produce them. We seek comment on the most suitable methods for conducting this analysis, and on our underlying analysis and assumptions about the likely effects of changes in domestic gasoline consumption on U.S. gasoline imports and exports as well as the global supply and demand.

We also used GREET 2022 to estimate upstream electricity EFs. GREET 2022 projects a national default mix for electricity generation (often simply called the grid mix) for transportation from the latest AEO data available, in this case from 2022. The CAFE Model utilizes a single upstream electricity EF for transportation use and does not differentiate by process, based on GREET EFs for electricity as a transportation fuel. A detailed description of how we used GREET 2022 to generate upstream EFs is located in Chapter 5 of the Draft TSD.

We understand that AEO 2023 became available after NHTSA completed its analysis for this proposal, and that AEO 2023 projects a higher grid mix for renewable-based electricity generation, which would reduce upstream emissions associated with additional electricity generation as a potential result of more stringent CAFE standards. We intend to employ updated estimates of power sector emissions in our final rule, which could be based on the latest-available versions of AEO and GREET, and we seek comment on making these updates. Other grid mixes with higher penetrations of renewables are presented as sensitivity cases in the PRIA and do provide some context about what our analysis would look like using a grid mix with a higher penetration of renewables. We seek comment on these sensitivity cases and which national grid mix forecast may best represent the latest market conditions and policies, such as the Inflation Reduction Act. We also seek comments on other forecasts to consider, including EPA's Integrated Planning Model for the post-IRA 2022 reference case for the final rulemaking,[419] and the methodology used to generate alternate forecasts.

We estimated non-CO_2 downstream EFs for gasoline, E85, diesel, and CNG[420] using the MOtor Vehicle Emission Simulator (MOVES3) model,[421] which is a regulatory highway emissions inventory model developed by the EPA's National Vehicle and Fuel Emissions Laboratory. We generated downstream CO_2 EFs based on the carbon content (*i.e.,* the fraction of each fuel type's mass that is carbon) and mass density per unit of the specific type of fuel. The CAFE Model calculates CO_2 vehicle-based emissions associated with vehicle operation of the surviving on-road fleet by multiplying the number of gallons of a specific fuel consumed by the CO_2 emissions factor for the associated fuel type. More specifically, the number of gallons of a particular fuel is multiplied by the carbon content

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[415] The procedures the CAFE Model uses to estimate annual VMT for individual car and light truck models produced during each model year over their lifetimes and to combine these into estimates of annual fleet-wide travel during each future CY, together with the sources of its estimates of their survival rates and average use at each age, are described in detail in Draft TSD Chapters 4.2 and 4.3. The data and procedures the CAFE Model employs to convert these estimates of VMT to fuel and energy consumption by individual model, and to aggregate the results to calculate total consumption and energy content of each fuel type during future CYs, are also described in detail in that same section.

[416] There is also HFC leakage from air conditioner systems, but these emissions are not captured in our analysis.

[417] BEVs do not produce any combustion-based emissions while PHEVs only produce combustion-based emissions during use of conventional fuels. Utilization factors typically define how much real-world operation occurs while using electricity versus conventional fuels.

[418] U.S. DOE, Energy Systems and Infrastructure Analysis.2022. Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model. Last Revised: Oct. 11, 2022. Available at: *https://greet.es.anl.gov/.* (Accessed: May 31, 2023).

[419] See documentation of US EPA, Post-IRA 2022 Reference Case, *https://www.epa.gov/power-sector-modeling/post-ira-2022-reference-case.*

[420] BEVs and FCEVs do not generate any combustion-related emissions.

[421] To ensure that the MOVES default database aligned with the most current CAFE standards, we removed assumptions associated with the Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule from 2020 that was withdrawn, and replaced those assumptions with changes from the MY 2024–2026 Rule finalized in 2022. We modified parameters related to future fleet increases in stringency and rebound effects of vehicle miles traveled.

and the mass density per unit of that fuel type, and then the ratio of CO_2 emissions generated per unit of carbon consumed during the combustion process is applied.[422] Draft TSD Chapter 5.3 goes into detail about how we generated the downstream emissions factors used in this analysis.

With stringent LDV standards already in place for PM from vehicle exhaust, particles from brake and tire wear (BTW) are becoming an increasingly important component of PM emission inventories. To put the impact of future BTW PM emissions in perspective, for a gasoline-fueled passenger car's $PM_{2.5}$ emissions (from vehicle exhaust, brake wear, and tire wear),[423] BTW will constitute a slight majority of $PM_{2.5}$ emissions in 2020 and after. Similarly, for light trucks, BTW will become a majority of $PM_{2.5}$ in 2035. In particular, brake wear from cars and light trucks will account for up to 40 percent of their $PM_{2.5}$ inventories by 2050. Previous CAFE rulemakings have not modeled the indirect impacts to BTW emissions due to changes in fuel economy and VMT. This rulemaking considers $PM_{2.5}$ from the vehicle's exhaust, brakes, and tires.

As with downstream emissions factors, we generated BTW EFs using EPA's MOVES3 model.[424] Due to limited BTW measurements, MOVES does not vary BTW factors by vehicle MY, fuel type, or powertrain. Instead, MOVES brake wear is dependent on vehicle weight-based regulatory classes and operating behavior derived primarily from vehicle speed and acceleration. On the other hand, tire wear is dependent on the weight-based MOVES regulatory classes and operations strictly based on vehicle speed. Unlike the CAFE Model's downstream EFs, the BTW estimates were averaged over all vehicle MYs and ages for a single grams-per-mile value by regulatory class.

There is some evidence that average vehicle weight will differ by fuel type and powertrain, particularly EVs with extended-range battery packs, which are often heavier than a comparable gasoline- or diesel-powered vehicle.[425] These weight increases due to electrification are likely to result in additional tire wear. However, regenerative braking often extends their useful life and reduces associated brake wear,[426] but the additional mass from heavier batteries might increase BTW emissions overall.[427] [428] Further BTW field studies are needed to better understand how differences in vehicle fuel and powertrain type are likely to impact $PM_{2.5}$ emissions from BTW. For the time being, the CAFE Model's BTW inputs are differentiated by fuel type but have equivalent values across gasoline, diesel, and electricity. Given the degree to which $PM_{2.5}$ inventories are expected to shift from vehicle exhaust to BTW in the near future, we assert that it is better to have some BTW estimates—even if imperfect—than not to include them at all, as was the case in prior CAFE rulemakings. We seek comment on this updated approach and additional data sources that could be used to update the BTW estimates.

The CAFE Model computes select health impacts resulting from three criteria pollutants: NO_X, SO_X, and $PM_{2.5}$. Out of the six criteria pollutants currently regulated, NO_X, SO_X, and $PM_{2.5}$ are known to be emitted regularly from mobile sources and have the most adverse effects to human health. These health impacts include several different morbidity measures, as well as a mortality estimate, and are measured by the number of instances predicted to occur per ton of emitted pollutant. The CAFE Model reports total health impacts by multiplying the estimated tons of each criteria pollutant—generated using the process described above—by the corresponding health incidence per ton value. Broadly speaking, a health incidence per ton value is the morbidity and mortality estimates linked to an additional ton of an emitted pollutant; these can also be referred to as benefit per ton values where there are monetized reduced health incidences related to a reduced ton of emissions (discussed further in Section II.G).

The health incidence per ton values in this analysis reflect the differences in health impacts arising from the five upstream emission source sectors that we use to generate upstream emissions (petroleum extraction, petroleum transportation, refineries, fuel transportation, storage and distribution, and electricity generation). We carefully examined how each upstream source sector is defined in GREET 2022 (the model we use to generate upstream EFs, as described above) to appropriately map the emissions estimates to data on health incidences from criteria pollutant emissions. As the health incidences for the different source sectors are all based on the emission of one ton of the same pollutants, NO_X, SO_X, and $PM_{2.5}$, the differences in the incidence per ton values arise from differences in the geographic distribution of the pollutants, a factor which affects the number of people impacted by the pollutants.[429]

Like past CAFE analyses, we relied on publicly available reports from EPA to estimate health incidence per ton values for each upstream source. We used several EPA reports to generate the upstream health incidence per ton values, as different EPA reports provided more up-to-date estimates for different sectors based on newer air quality modeling. These EPA reports use a reduced-form benefit-per-ton (BPT) approach to inform the assessment of health impacts. In this approach, the $PM_{2.5}$-related BPT values are the total monetized human health benefits (the sum of the economic value of the reduced risk of premature death and illness) that are expected from reducing one ton of directly-emitted $PM_{2.5}$ or $PM_{2.5}$ precursor such as NO_X or Sulfur Dioxide (SO_2). We note, however, that the complex, non-linear photochemical processes that govern ozone formation prevent us from developing reduced-form ozone, ambient NO_X, or other air toxic BPT values. This is an important limitation to recognize when using the BPT approach. We include additional discussion of uncertainties in the BPT approach in Chapter 5.4.3 of the Draft TSD. That said, we believe that the BPT approach provides a reasonable estimate

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[422] Chapter 3, Section 4 of the CAFE Model Documentation provides additional description for calculation of CO_2 downstream emissions with the model.

[423] $PM_{2.5}$ is particulate matter of diameters less than 2.5 microns.

[424] US EPA, Office of Transportation and Air Quality. 2020. Brake and Tire Wear Emissions from Onroad Vehicles in MOVES3. Assessment and Standards Division. pp. 1–48. Available at: *https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P1010M43.pdf.* (Accessed May 31, 2023).

[425] Cooley, B. 2022. America's New Weight Problem: Electric Vehicles. CNET. Published: Jan. 28, 2022. Available at: *https://www.cnet.com/roadshow/news/americas-new-weight-problem-electric-cars.* (Accessed: May 31, 2023).

[426] Bondorf, L. et al. 2023. Airborne Brake Wear Emissions from a Battery Electric Vehicle. Atmosphere 14(3): pp. 488. Available at: *https://doi.org/10.3390/atmos14030488.* (Accessed: May 31, 2023).

[427] US EPA, Office of Transportation and Air Quality. 2022 Brake Wear Particle Emission Rates and Characterization. Available at: *https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P1013TSX.txt.* (Accessed: May 31, 2023).

[428] McTurk, E. 2022. Do Electric Vehicles Produce More Tyre and Brake Pollution Than Their Petrol and Diesel Equivalents?. RAC. Available at: *https://www.rac.co.uk/drive/electric-cars/running/do-electric-vehicles-produce-more-tyre-and-brake-pollution-than-petrol-and/.* (Accessed: May 31, 2023).

[429] EPA. 2018. Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors. Office of Air and Radiation and Office of Air Quality Planning and Standards. Research Triangle Park, NC. pp. 1–108. Available at: *https://www.epa.gov/sites/production/files/2018-02/documents/sourceapportionmentbpttsd_2018.pdf.* (Accessed: May 31, 2023).

of how different CAFE stringencies may impact public health. The BPT methodology and data sources are unchanged from the 2022 CAFE rule, and stakeholders generally agreed that estimates of the benefits of $PM_{2.5}$ reductions were improved from prior analyses based on our emissions-related health impacts methodology updated for that rule.[430]

The reports we relied on for health incidences and BPT estimates include EPA's 2018 technical support document, Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors (referred to here as the 2018 EPA source apportionment TSD),[431] a 2018 oil and natural gas sector paper written by EPA staff (Fann et al.), which estimates health impacts for this sector in the year 2025,[432] and a 2019 paper from EPA (Wolfe et al.) that computes monetized per ton damage costs for mobile sources in several categories, based on vehicle type and fuel type.[433] Some CAFE Model upstream emissions components do not correspond to any one EPA source sector in available literature, so we used a weighted average of different source sectors to generate those values. Data we used from each paper for each upstream source sector are discussed in detail in Chapter 5.4 of the Draft TSD.

The CAFE Model follows a similar process for computing health impacts resulting from downstream emissions as it does for calculating health impacts from upstream emissions. We used the Wolfe et al. paper to compute monetized damage costs per ton values for several on-road mobile sources categories based on vehicle type and fuel type. Wolfe et al. did not report incidences per ton, but that information was obtained through communications with EPA staff. Additional information about how we generated downstream health estimates is discussed in Chapter 5.4 of the Draft TSD.

We are aware that EPA recently updated its estimated benefits for reducing $PM_{2.5}$ from several sources,[434] but those sources do not include mobile sources. After discussion with EPA staff, we retained the $PM_{2.5}$ incidence per ton values from the last CAFE analysis for consistency with the current mobile source emissions estimates. If any additional information becomes available before the final rule analysis, we will consult with EPA staff and may update values where applicable.

G. Simulating Economic Impacts of Regulatory Alternatives

The following sections describe NHTSA's approach for measuring the economic costs and benefits that would result from establishing alternative standards for future MYs. The measures that NHTSA uses are important considerations, because as OMB Circular A–4 states, benefits and costs reported in regulatory analyses must 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. For CAFE and fuel efficiency standards, those include vehicle manufacturers, buyers of new vehicles, owners of used vehicles, and suppliers of fuel, all of whose behavior is likely to respond in complex ways to the level of standards that DOT establishes for future MYs.

It is also important to report the benefits and costs of this proposed action in a format that conveys useful information about how those impacts are generated, while also distinguishing the economic consequences for private businesses and households from the action's effects on the remainder of the U.S. economy. A reporting format will accomplish this objective to the extent that it clarifies *who* incurs the benefits and costs of the proposed action, while also showing how the economy-wide or ''social'' benefits and costs of the proposed action are composed of direct effects on vehicle producers, buyers, and users, plus the indirect or ''external'' benefits and costs it creates for the general public.

Table II–19 lists the economic benefits and costs analyzed in conjunction with this proposal, and where to find explanations for what we measure, why we include it, how we estimate it, and the estimated value for that specific line item. The table also shows how the different elements of the analysis piece together to inform NHTSA's estimates of private and external costs and benefits.[435]

TABLE II–19—BENEFITS AND COSTS RESULTING FROM NHTSA'S PROPOSED REGULATORY ACTION[436]

Entry	Section of preamble discussion	Chapter of draft TSD modeling explanation	Chapter of PRIA discussion	Chapter of PRIA results
Private Costs				
Technology Costs to Increase Fuel Economy.	II.G.1.a(1)	Chapter 6.1	Chapter 7.1.1	Chapters 8.2.3.1 and 8.3.3.1.
Increased Maintenance and Repair Costs.	II.G.3		Chapter 7.1.1	
Sacrifice in Other Vehicle Attributes	II.G.3		Chapters 7.1.1 and 9.2.3.10.	Chapters 9.2.3.9 and 9.2.3.10.
Consumer Surplus Loss from Reduced New Vehicle Sales.	II.G.1.a(2)	Chapter 6.1.2	Chapter 7.1.4	Chapters 8.2.2.3, 8.2.3.2, 8.3.2.3 and 8.3.3.2.
Safety Costs Internalized by Drivers	II.H.3	Chapter 7.4	Chapters 7.1.5, 8.5.5	Chapters 8.2.4.5 and 8.3.4.5.
Subtotal—Internal Costs				Sum of above entries.

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[430] CBD et al., Docket No. NHTSA–2021–0053–1572, at 5.

[431] EPA. 2018. Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors. Office of Air and Radiation and Office of Air Quality Planning and Standards. Research Triangle Park, NC. pp. 1–108. Available at: *https://19january2017snapshot.epa.gov/benmap/estimating-benefit-ton-reducing-pm25-precursors-17-sectors_.html.* (Accessed: May 31, 2023).

[432] Fann, N. et al. 2018. Assessing Human Health $PM_{2.5}$ and Ozone Impacts from U.S. Oil and Natural Gas Sector Emissions in 2025. Environmental Science & Technology, 52(15): pp. 8095–8103. (*hereinafter* Fann et al.).

[433] Wolfe, P. et al. 2019.). Monetized Health Benefits Attributable To Mobile Source Emission Reductions Across The United States In 2025. The Science of the Total Environment, 650(Pt 2). pp. 2490–2498. (*hereinafter* Wolfe et al.). Health incidence per ton values corresponding to this paper were sent by EPA staff.

[434] U.S. EPA. 2023. Estimating the Benefit per Ton of Reducing Directly-Emitted $PM_{2.5}$, $PM_{2.5}$ Precursors and Ozone Precursors from 21 Sectors. Last updated: Jan. 2023. Available at: *https://www.epa.gov/benmap/estimating-benefit-ton-reducing-directly-emitted-pm25-pm25-precursors-and-ozone-precursors.* (Accessed: May 31, 2023).

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

TABLE II–19—BENEFITS AND COSTS RESULTING FROM NHTSA'S PROPOSED REGULATORY ACTION [436]—Continued

Entry	Section of preamble discussion	Chapter of draft TSD modeling explanation	Chapter of PRIA discussion	Chapter of PRIA results
External and Government Costs				
Congestion and Noise Costs from Rebound-Effect Driving.	II.G.2.a(1)	Chapter 6.2.3	Chapter 7.2.2	Chapters 8.2.4.3 and 8.3.4.3.
Safety Costs Not Internalized by Drivers.	II.H.1 and II.H.2.	Chapter 7	Chapters 7.1.5, 8.5.5	Chapters 8.2.4.5 and 8.3.4.5.
Loss in Fuel Tax Revenue	II.G.2.a(2)	Chapters 6.1.3, 6.2	Chapter 7.3.1	Chapters 8.2.4.6 and 8.3.4.6.
Subtotal—External Costs				Sum of above entries.
Social Costs				Sum of private and external costs.
Private Benefits				
Savings in Retail Fuel Costs [437]	II.G.1.b(1)	Chapter 6.1.3	Chapter 7.3.1	Chapters 8.2.2.2, 8.2.2.3, and 8.3.2.2, 8.3.2.3.
Benefits from Additional Driving	II.G.1.b(3)	Chapter 6.1.5	Chapter 7.2.1	Chapters 8.2.3.2 and 8.3.3.2.
Less Frequent Refueling	II.G.1.b(2)	Chapter 6.1.4	Chapter 8.4.2	Chapters 8.2.2.3 and 8.3.2.3.
Subtotal—Private Benefits				Sum of above entries.
External and Government Benefits				
Reduction in Petroleum Market Externality.	II.G.2.b(3)	Chapter 6.2.4	Chapter 7.3.2	Chapters 8.2.4.4 and 8.3.4.4.
Climate Benefits	II.G.2.b(1)	Chapter 6.2.1	Chapters 8.5.1	Chapters 8.2.4.1 and 8.3.4.1.
Health Benefits	II.G.2.b(2)	Chapter 6.2.2	Chapters 8.5.2	Chapters 8.2.4.2 and 8.3.4.1.
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.

NHTSA reports the costs and benefits of proposed standards for LDVs and HDPUVs separately. While the effects are largely the same for the two fleets our fuel economy and fuel efficiency programs are separate, and NHTSA makes independent determinations of the maximum feasible standards for each fleet.

A standard function of regulatory analysis is to evaluate tradeoffs between impacts that occur at different points in time. Many Federal regulations involve costly upfront investments that generate future benefits in the form of reductions in health, safety, or environmental damages. To evaluate these tradeoffs, the analysis must account for the social rate of time preference—the broadly observed social preference for benefits that occur sooner versus those that occur further in the future. This is accomplished by discounting impacts that occur further in the future more than impacts that occur sooner.

OMB Circular A–4 affirms the appropriateness of accounting for the social rate of time preference in regulatory analyses and recommends DRs of 3 and 7 percent for doing so. The recommended 3 percent DR was chosen to represent the ''consumption rate of interest'' approach, which discounts future costs and benefits to their present values using the rate at which consumers appear to make tradeoffs between current consumption and equal consumption opportunities when deferred to the future. OMB Circular A–4 reports an inflation-adjusted or ''real'' rate of return on 10-year Treasury notes of 3.1 percent between 1973 and its 2003 publication date and interprets this as approximating the rate at which society is indifferent between consumption today and in the future. The 7 percent rate reflects the opportunity cost of capital approach to discounting, where the DR approximates the forgone return on private investment if the regulation were to divert resources from capital formation. 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 percent rate is the appropriate rate. However, NHTSA reports both the 3 and 7 percent rates for transparency and completeness On April 6, 2023, OMB issued a request for comment on proposed updates to Circular A–4.[438] OMB specifically sought comment on whether to change its guidance on DRs.[439] DOT will consider modifying the DRs used in this analysis if OMB issues a revision to Circular A–4 ahead of the final rule.

For a complete discussion of the methodology employed and the results, see Chapter 6 of the Draft TSD and Chapter 8 of the PRIA, respectively. The safety implications of the proposal—including the monetary impacts—are

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[436] This table presents the societal costs and benefits. Costs and benefits that affect only the consumer analysis, such as sales taxes, insurance costs, and reallocated VMT, are purposely ommited from this table. See Chapters 8.2.3 and 8.3.3 of the PRIA for consumer-specific costs and benefits.

[437] 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.

[438] 88 FR 20915 (April 7, 2023).

[439] See Preamble: Proposed OMB Circular No. A–4. Regulatory Analysis. Page 17. Avaliable at: *https://www.whitehouse.gov/wp-content/uploads/2023/04/DraftCircularA-4Preamble.pdf.* (Accessed May 31, 2023).

reserved for Section II.H. NHTSA seeks comment on the following discussion.

1. Private Costs and Benefits

a. Costs to Consumers

(1) Technology Costs

The technology applied to meet the proposed standards would increase the cost to produce new cars, light trucks and HDPUVs. Within this analysis, manufacturers are assumed to transfer these costs to the consumers who purchase vehicles offering higher fuel economy. While NHTSA recognizes that some manufacturers may defray their regulatory costs for meeting increased CAFE and fuel efficiency standards through more complex pricing strategies or by accepting lower profits, NHTSA lacks sufficient insight into manufacturers' pricing strategies to confidently model alternative approaches. Thus, we simply assume that manufacturers raise the prices of models whose fuel economy they elect to improve sufficiently to recover their increased costs for doing so. The technology costs are incurred by manufacturers and then passed onto consumers. While we include the effects of IRA tax credits in our modeling of consumer responses to the standards, the effect of the tax credit is an economic transfer where the costs to one party are exactly offset by benefits to another and have no impact on the net benefits of the proposal. NHTSA could include IRA tax credits as a reduction in the technology costs for manufacturers and purchasing prices in our cost-benefit accounting, tax credits are a transfer from the government to private parties, and as such have no net effect on the benefits or costs of the proposed rule. As such, the line item included in the tables summarizing the cost of technology throughout this proposal should be considered pre-tax unless otherwise noted.

See Section III.C.6 of this preamble and Chapter 2.5 of the Draft TSD for more details.

(2) Consumer Sales Surplus

Consumers who forgo purchasing a new vehicle because of the increase in the price of new vehicles' prices caused by more stringent standards will experience a decrease in welfare. The collective welfare loss to these ''potential'' new vehicle buyers is measured by their foregone consumer surplus.

Consumer surplus is a fundamental economic concept and represents the net value (or net benefit) a good or service provides to consumers. It is measured as the difference between what a consumer is willing to pay for a good or service and its market price. OMB Circular A–4 explicitly identifies consumer surplus as a benefit that should be accounted for in cost-benefit analysis. For instance, OMB Circular A–4 states the ''net reduction in total surplus (consumer plus producer) is a real cost to society,'' and elsewhere recommends that consumer surplus values be monetized ''when they are significant.''

Accounting for the limited portion of lifetime fuel savings that the average new vehicle buyer values, and holding all else equal, higher average prices should depress new vehicle sales and by extension reduce consumer surplus. The inclusion of the effects on the proposal on consumer surplus is not only consistent with OMB guidance, but with other parts of this regulatory analysis. For instance, we calculate the increase in consumer surplus associated with increased driving that results from the lower CPM of driving under more stringent regulatory alternatives, as discussed in Section II.G.1.b(3). The surpluses associated with sales and additional mobility are inextricably linked, as they capture the direct costs and benefits to purchasers of new vehicles. The sales surplus captures the welfare loss to consumers when they forego purchasing new vehicles because of higher prices, while the consumer surplus associated with additional driving measures the benefit of the increased mobility it provides.

NHTSA estimates the loss of sales surplus based on the change in quantity of vehicles projected to be sold, after adjusting for quality improvements attributable to higher fuel economy or fuel efficiency. For additional information about consumer sales surplus, see Chapter 6.1.2 of the Draft TSD. NHTSA seeks comment on our methodology for the consumer sales surplus.

(3) Ancillary Costs of Higher Vehicle Prices

Some costs of purchasing and owning a new or used vehicle increase in proportion to its purchase price or market value. At the time of purchase, the price of the vehicle combined with the state-specific tax rate determine the sales tax paid. Throughout the lifetime of the vehicle, the residual value of the vehicle—which is determined by its initial purchase price, age, and accumulated usage—determine value-related registration fees and insurance premiums. The analysis assumes that the transaction price is a fixed share of the MSRP, which allows calculation of these factors as shares of MSRP. As the standards influence the price of vehicles, these ancillary costs will also increase. For a detailed explanation of how NHTSA estimates these costs, see Chapter 6.1.1 of the Draft TSD.

These costs are included in the consumer per-vehicle cost-benefit analysis but not in the societal cost-benefit analysis, because they are assumed to be transfers from consumers to government agencies or to reflect actuarially ''fair'' insurance premiums. We seek comment on this approach and our methodology for calculating these costs.

In previous proposals and final rules, NHTSA also included the costs of financing vehicle purchases as an ancillary cost to consumers. However, as we noted in the 2022 final rule, the availability of vehicle financing offers a benefit to consumers by spreading out the costs of additional fuel economy technology over time. Thus, we no longer include financing as a cost to consumers. We seek comment on this assumption.

b. Benefits to Consumers

(1) Fuel Savings

The primary benefit to consumers of increasing standards is the savings in future fuel costs that accrue to buyers and subsequent owners of new vehicles. The value of fuel savings is calculated by multiplying avoided fuel consumption by retail fuel prices. Each vehicle of a given body style is assumed to be driven the same amount in each year of its lifetime as all those of comparable age and body style. The ratio of that cohort's annual VMT to its fuel efficiency produces an estimate of its yearly fuel consumption. The difference between fuel consumption in the No-Action Alternative, and in each regulatory alternative, represents the gallons (or energy content) of fuel saved.

Under this assumption, our estimates of fuel consumption from increasing the fuel economy or fuel efficiency of each individual model depend only on how much its fuel economy or efficiency is increased, and do not reflect whether its actual use differs from other models of the same body type. Neither do our estimates of fuel consumption account for variation in how much vehicles of the same body type and age are driven each year, which appears to be significant (see Chapter 4.3.1.2 of the Draft TSD). Consumers save money on fuel expenditures at the average retail fuel price (fuel price assumptions are discussed in detail in Chapter 4.1.2 of the Draft TSD), which includes all taxes and represents an average across octane blends. For gasoline and diesel, the included taxes reflect both the Federal tax and a calculated average state fuel tax. Expenditures on alternative fuels (E85 and electricity, primarily) are also included in the calculation of fuel expenditures, on which fuel savings are based. However, since alternative fuel technology is not applied to meet the proposed standards, the majority of the costs associated with operating alternative fuels net to zero. And while the included taxes net out of the social benefit cost analysis (as they are a transfer), consumers value each gallon saved at retail fuel prices including any additional fees or taxes they pay.

Chapter 6.1.3 of the Draft TSD provides additional details. In the TSD, NHTSA considers the possibility that several of the assumptions made about vehicle use could lead to misstating the benefits of fuel savings. NHTSA notes that these assumptions are necessary to model fuel savings and likely have minimal impact to the accuracy of the analysis for this proposal.

(2) Refueling Benefit

Increasing standards affects the amount of time drivers spend refueling their vehicles in several ways. First, higher standards increase the fuel efficiency of ICE vehicles produced in the future, which may increase their driving range and decrease the number of refueling events. Conversely, to the extent that more stringent standards increase the purchase price of new vehicles, they may reduce sales of new vehicles and scrappage of existing ones, causing more VMT to be driven by older and less efficient vehicles that require more refueling events for the same amount of driving. Finally, as the number of EVs in the fleet increases, some of the time spent previously refueling ICE vehicles at the pump will be replaced with recharging EVs at public charging stations. While the analysis does not allow electrification to be chosen as a compliance pathway with the proposed standards for LDVs, it is still important to model recharging since excluding these costs would underestimate scenarios with additional BEVs, such as our sensitivity cases that examine lower battery costs.

NHTSA estimates these savings by calculating the amount of refueling time avoided—including the time it takes to locate a retail outlet, refuel one's vehicle, and pay—and multiplying it by DOT's estimated value of travel time. For a full description of the methodology, refer to Chapter 6.1.4 of the Draft TSD.

We seek comment on this methodology. In particular, we seek comment on whether increasing fuel economy for LDVs and fuel efficiency for HDPUVs should be expected to reduce the amount of refueling benefits. An alternative hypothesis NHTSA is considering is whether manufacturers maintain vehicle range by lowering tank size as vehicle efficiency improves without, therefore, reducing refueling time.

(3) Additional Mobility

Any increase in travel demand provides benefits that reflect the value to drivers and passengers of the added—or more desirable—social and economic opportunities that additional travel makes available. Under each of the alternatives considered in this analysis, the fuel CPM of driving would decrease as a consequence of higher fuel economy and efficiency levels, thus increasing the number of miles that buyers of new cars, light trucks, and HDPUVs would drive as a consequence of the well-documented fuel economy rebound effect.

In theory, the decision by drivers and their passengers to make more frequent or longer trips when the cost of driving declines demonstrates that the benefits that they gain by doing so must exceed the costs they incur. At a minimum, one would expect the benefits of additional travel to equal the cost of the fuel consumed to travel additional miles (or they would not have occurred). Because the cost of that additional fuel is reflected in the simulated fuel expenditures, it is also necessary to account for the benefits associated with those extra miles traveled. But those benefits arguably should also offset the economic value of their (and their passengers') travel time, other vehicle operating costs, and the economic cost of safety risks due to the increase in exposure to crash risks that occurs with additional travel. The amount by which the benefit of this additional travel exceeds its economic costs measures the net benefits drivers and their passengers experience, usually referred to as increased consumer surplus.

Chapter 6.1.5 of the Draft TSD explains NHTSA's methodology for calculating benefits from additional mobility. The benefit of additional mobility over and above its costs is measured by the change in consumers' surplus, which NHTSA approximates as one-half of the change in fuel CPM times the increase in VMT due to the rebound effect. NHTSA seeks comment on both the assumption and methodology employed to capture the value of additional mobility.

When the size of the vehicle stock decreases in the LD alternative cases, VMT and fuel cost per-vehicle increase. Because maintaining constant non-rebound VMT assumes consumers are willing to pay the full cost of the reallocated vehicle miles, we offset the increase in fuel cost per-vehicle in the LD analysis by adding the product of the reallocated VMT and fuel CPM to the mobility value in the per-vehicle consumer analysis. Because we do not estimate other changes in cost per-vehicle that could result from the reallocated miles (*e.g.,* maintenance, depreciation, etc.) we do not estimate the portion of the transferred mobility benefits that would correspond to consumers' willingness to pay for those costs. We do not estimate the consumers' surplus associated with the reallocated miles because there is no change in total non-rebound VMT and thus no change in consumers' surplus per consumer. Chapter 6.1.5 of the Draft TSD explains NHTSA's methodology for calculating the benefits of reallocated miles. We seek comment on this assumption and methodology.

2. External Costs and Benefits

a. Costs

(1) Congestion and Noise

Increased vehicle use associated with the rebound effect also contributes to increased traffic congestion and highway noise. Although drivers obviously experience these impacts, they do not fully value their effects on other travelers or bystanders, just as they do not fully value the emissions impacts of their own driving. Congestion and noise costs are thus "external" to the vehicle owners whose decisions about how much, where, and when to drive more in response to changes in fuel economy result in these costs. Thus, unlike changes in the costs incurred by drivers for fuel consumption or safety risks they willingly assume, changes in congestion and noise costs are not offset by corresponding changes in the travel benefits drivers experience.

Congestion costs are limited to road users; however, since road users include a significant fraction of the U.S. population, changes in congestion costs are treated as part of the proposal's external economic impact on society as a whole instead of as a cost to private parties. Costs resulting from road and highway noise are even more widely dispersed because they are borne partly by surrounding residents, pedestrians, and other non-road users, and for this reason are also considered as costs that drivers impose on society as a whole.

To estimate the economic costs associated with changes in congestion and noise caused by increases in driving, NHTSA updated the estimates of per-mile congestion and noise costs from increased automobile and light truck use reported in FHWA's 1997 Highway Cost Allocation Study to account for changes in travel activity and economic conditions since they were originally developed, as well as to express them in 2021 dollars for consistency with other economic inputs. NHTSA employed a similar approach for the 2022 final rule. Because HDPUVs and light-trucks share similar operating characteristics, we also apply the noise and congestion cost estimates for light-trucks to HDPUVs.

See Chapter 6.2 of the Draft TSD for details on how NHTSA calculated estimates of the economic costs associated with changes in congestion and noise caused by differences in miles driven. NHTSA specifically seeks comment on the congestion costs employed in this analysis, and whether and how to change them for the analysis for the final rule.

(2) Fuel Tax Revenue

As mentioned in Section II.G.1.b(1), a portion of the fuel savings experienced by consumers includes avoided fuel taxes. While fuel taxes are a transfer and do not affect net benefits, NHTSA reports an estimate of changes in fuel tax revenues together with external costs to show the potential impact on state and local government finances.

b. Benefits

(1) Climate Benefits

The combustion of petroleum-based fuels to power cars, light trucks, and HDPUVs generates emissions of various GHGs, which contribute to changes in the global climate and resulting economic damages. Extracting and transporting crude petroleum, refining it to produce transportation fuels, and distributing fuel all generate additional emissions of GHGs and criteria air pollutants beyond those from vehicle usage. By reducing the volume of petroleum-based fuel produced and consumed, adopting standards will thus mitigate global climate-related economic damages caused by accumulation of GHGs in the atmosphere, as well as the more immediate and localized health damages caused by exposure to criteria pollutants. Because they fall broadly on the U.S. population, and on the global population as a whole in the case of climate damages, population, reducing GHG emissions and criteria pollutants represents an external benefit from requiring higher fuel economy.

(a) Valuation of the Social Cost of Greenhouse Gases

NHTSA estimates the climate benefits of CO_2, CH_4, and N_2O emission reductions expected from this proposed rule using the SC–GHG estimates presented in the Technical Support Document: SC of Carbon (SCC), Methane, and Nitrous Oxide Interim Estimates under E.O. 13990 (''February 2021 TSD''). These estimates are interim values developed under E.O. 13990 for use in benefit-cost analyses until updated estimates of the impacts of climate change can be developed. NHTSA uses the SC–GHG interim values to estimate the climate benefits of decreased fuel consumption stemming from this proposal.

The SC–GHG estimates used in our analysis were developed over many years, using a transparent process, peer-reviewed methodologies, the best science available at the time, and with input from the public. Specifically, in 2009, an IWG that included the DOT and other executive branch agencies and offices was established to ensure that agencies were using the best available science and to promote consistency in the SC–CO_2 values used across agencies. The IWG published its initial SC–CO_2 estimates in 2010. These estimates were updated in 2013 using new versions of the various models initially used to derive them. In August 2016, the IWG published estimates of the SC of methane (SC–CH_4) and nitrous oxide (SC–N_2O) using methodologies that are consistent with the methodology underlying the SC–CO_2 estimates.

E.O. 13990 (issued on January 20, 2021) re-established the IWG and directed it to publish interim SC–GHG values for CO_2, CH_4, and N_2O within thirty days. Furthermore, the E.O. tasked the IWG with devising long-term recommendations to update the methodologies used in calculating these SC–GHG values, based on ''the best available economics and science,'' and incorporating principles of ''climate risk, environmental justice (EJ), and intergenerational equity''. The E.O. also instructed the IWG to take into account recommendations from the NAS committee convened on this topic, which were published in 2017. The February 2021 TSD provides a complete discussion of the IWG's initial review conducted under E.O. 13990.

NHTSA is using the IWG's interim values, published in the February 2021 TSD, for the analysis accompanying this NPRM. This approach is the same as that taken in DOT regulatory analyses extending from 2009 through 2022. If updated estimates of the social cost of greenhouse gas emissions are available before the final rule, NHTSA will consider revising the estimates within the CAFE Model, time permitting. We request comment on this approach to estimating social benefits of reducing GHG emissions in this rulemaking in light of the ongoing interagency process. For additional details, see Chapter 6.2.1.1 of the Draft TSD.

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 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. As such, NHTSA agrees with the global focus of the IWG's interim guidance.

Furthermore, the IWG found that domestic SC–GHG estimates fail to reflect the full impact of GHG emissions to the United States in multiple ways. The IWG concluded that those estimates fail to capture many climate impacts that can affect the welfare of U.S. citizens and residents. Examples of affected interests include direct effects on U.S. citizens and assets located abroad, international trade, and tourism, and spillover pathways such as economic and political destabilization and global migration that can lead to adverse impacts on U.S. national security, public health, and humanitarian concerns. Those impacts are better captured within global measures of the social cost of greenhouse gases.

NHTSA is mindful that our understanding of the SC–GHG is still evolving. In addition to participating in the IWG process, DOT continues to track developments in the economic and environmental sciences literature regarding the SC of GHG emissions, including research from Federal sources like the EPA.[440] NHTSA seeks comment on whether an alternative approach should be considered for the final rule.

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[440] For more information on EPA's proposed estimates and process, including the final external peer review report on EPA's draft methodology, see EPA. 2022. EPA External Review Draft of Report on the Social Cost of Greenhouse Gases: Estimates Incorporating Recent Scientific Advances. Avaliable at *https://www.epa.gov/environmental-economics/scghg.* (Accessed: May 31, 2023).

(b) Discount Rates for Climate Related Benefits

As mentioned earlier, NHTSA discounts costs and benefits at both the 3% consumption rate of interest and the 7% opportunity cost of capital, in accordance with OMB Circular A–4. The IWG rejected the use of the opportunity cost of capital approach to discounting reductions in climate-related damages (currently set at 7%), concluding that the ''consumption rate of interest is the correct discounting concept to use when future damages from elevated temperatures are estimated in consumption-equivalent units as is done in the Integrated Assessment Models used to estimate the SC–GHG (NAS 2017).'' In fact, 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. DOT concurs that in light of Circular A–4's guidance on discount rates spanning displacement of investments and/or consumption, and considering that climate damages are modeled in consumption equivalent units and heightened concerns over intergenerational equity, the use of consumption-based discount rates is superior for estimating SC–GHG.

As the IWG states, ''GHG emissions are stock pollutants, where damages are associated with what has accumulated in the atmosphere over time, and they are long lived such that subsequent damages resulting from emissions today occur over many decades or centuries depending on the specific [GHG] under consideration.'' OMB Circular A–4 states that impacts occurring over such intergenerational time horizons require special treatment:

> Special ethical considerations arise when comparing benefits and costs across generations. Although most people demonstrate time preference in their own consumption behavior, it may not be appropriate for society to demonstrate a similar preference when deciding between the well-being of current and future generations. Future citizens who are affected by such choices cannot take part in making them, and today's society must act with some consideration of their interest.

Furthermore, NHTSA notes that in 2015, OMB—along with the rest of the IWG—articulated that ''Circular A–4 is a living document, which may be updated as appropriate to reflect new developments and unforeseen issues,'' and that ''the use of 7 percent is not considered appropriate for intergenerational discounting. There is wide support for this view in the academic literature, and it is recognized in Circular A–4 itself.'' Following this statement from OMB, and recognizing the need to balance welfare improvements to current and future generations, it would be inappropriate to apply an opportunity cost of capital rate to estimate SC–GHG.

In addition to the ethical considerations, Circular A–4 also identifies uncertainty in long-run interest rates as another reason why it is appropriate to use lower rates to discount intergenerational impacts, since recognizing such uncertainty causes the appropriate discount rate to decline gradually over progressively longer time horizons. Circular A–4 also acknowledges the difficulty in estimating appropriate discount rates for ''intergenerational'' time horizons, noting that ''[p]rivate market rates provide a reliable reference for determining how society values time within a generation, but for extremely long time periods no comparable private rates exist.'' The social costs of distant future climate damages—and by implication, the value of reducing them by lowering emissions of GHGs—are highly sensitive to the discount rate, and the present value of reducing future climate damages grows at an increasing rate as the discount rate used in the analysis declines.

This ''non-linearity'' means that even if uncertainty about the exact value of the long-run interest rate is equally distributed between values above and below the 3 percent consumption rate of interest, the probability-weighted (or ''expected'') present value of a unit reduction in climate damages will be higher than the value calculated using a 3 percent discount rate. The effect of such uncertainty about the correct discount rate can be accounted for by using a lower ''certainty-equivalent'' rate to discount distant future damages, defined as the rate that produces the same expected present value of a reduction in future damages implied by the distribution of possible discount rates around what is believed to be the most likely single value.

The IWG identifies ''a plausible range of certainty-equivalent constant consumption discount rates: 2.5, 3, and 5 percent per year,'' each intended to reflect the effect of uncertainty surrounding alternative estimates of the correct discount rate. The IWG TSD does not address the question of how agencies should combine its estimates of benefits from reducing GHG emissions that reflect these alternative discount rates with the discount rates for nearer-term benefits and costs prescribed in OMB Circular A–4.

NHTSA has not selected a primary discount rate for the SC of GHGs. This approach was selected because the IWG does not specify which of the discount rates it recommends should be considered the agency's primary estimate. The agency's analysis showing our primary non-GHG impacts at 3 and 7 percent alongside climate-related benefits discounted at each rate recommended by the IWG may be found in Chapter 8 of the PRIA for both LDVs and HDPUVs. For the sake of simplicity, most tables throughout this analysis pair both the 3 percent and the 7 percent discount rates for other costs and benefits with the SCs of GHGs discounted at a 3 percent rate. We believe that this approach provides policymakers with a range of costs and benefits associated with the rule using a reasonable range of discounting approaches and associated climate benefits, while also reporting that the 95th percentile value illustrates the potential for climate change to cause damages that are much higher than the ''best guess'' damage estimates.

For additional details, see Chapter 6.2.1.2 of the Draft TSD. We seek comment on our choice to consider a broad range of discount rates for SC–GHGs, and we will consider modifying our approach to discounting SC–GHGs based on such comments and any updated guidance.

(2) Reduced Health Damages

The CAFE Model estimates monetized health effects associated with emissions from three criteria pollutants: NO_X, SO_X, and $PM_{2.5}$. As discussed in Section II.F above, although other criteria pollutants are currently regulated, only impacts from these three pollutants are calculated since they are known to be emitted regularly from mobile sources, have the most adverse effects on human health, and have been the subject of extensive research by EPA to estimate the benefits of reducing these pollutants. Other pollutants, especially those that are precursors to ozone, are more difficult to model due to the complexity of their formation in the atmosphere, and EPA does not calculate BPT estimates for these. The CAFE Model computes the monetized health damages from each of the three pollutants by multiplying the monetized health impact per ton by the total tons of each pollutant emitted, including from both upstream and downstream sources. Reductions in these costs from their level under the baseline alternative that are projected to result from adopting alternative standards are treated as external benefits of those alternatives. Chapter 5 of the Draft TSD accompanying this proposal includes a detailed description of the EFs that inform the CAFE Model's calculation of the total tons of each pollutant associated with upstream and downstream emissions.

These monetized health impacts per ton values are closely related to the health incidence per ton values described above in Section II.F and in detail in Chapter 5.4 of the Draft TSD. We use the same EPA sources that provided health incidence values to determine which monetized health impacts per ton values to use as inputs in the CAFE Model. Like the estimates associated with health incidences per ton of criteria pollutant emissions, we used multiple EPA papers and conversations with EPA staff to appropriately account for monetized damages for each pollutant associated with the source sectors included in the CAFE Model and based our final estimates on the most up-to-date data. The various emission source sectors included in the EPA papers do not always correspond exactly to the emission source categories used in the CAFE Model. In those cases, we mapped multiple EPA sectors to a single source category and computed a weighted average of the health impact per ton values.

The EPA uses the value of a statistical life (VSL) to estimate premature mortality impacts, and a combination of willingness to pay estimates and costs of treating the health impact for estimating the morbidity impacts. EPA's 2018 technical support document, ''Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors,'' (referred to here as the 2018 EPA source apportionment TSD) contains a more detailed account of how health incidences are monetized. It is important to note that the EPA sources cited frequently refer to these monetized health impacts per ton as ''benefits per ton,'' since they describe these estimates in terms of emissions avoided. In the CAFE Model input structure, these are generally referred to as monetized health impacts or damage costs associated with pollutants emitted (rather than avoided), unless the context states otherwise.

The CAFE Model health impacts inputs are based partially on the structure of the 2018 EPA source apportionment TSD, which reported benefits per ton values for the years 2020, 2025, and 2030. For the years in between the source years used in the input structure, the CAFE Model applies values from the closest source year. For example, the model applies 2020 monetized health impact per ton values for calendar years 2020–2022 and applies 2025 values for calendar years 2023–2027. In order for some of the monetized health damage values to match the structure of other impacts costs, DOT staff developed proxies for 7% discounted values for specific source sectors by using the ratio between a comparable sector's 3% and 7% discounted values. In addition, we used implicit price deflators from the Bureau of Economic Analysis (BEA) to convert different monetized estimates to 2021 dollars, in order to be consistent with the rest of the CAFE Model inputs.

This process is described in more detail in Chapter 6.2.2 of the Draft TSD accompanying this proposal. In addition, the CAFE Model documentation contains more details of the model's computation of monetized health impacts. We seek comment on this approach. All resulting emissions damage costs for criteria pollutants are located in the Criteria Emissions Cost worksheet of the Parameters file.

(3) Reduction in Petroleum Market Externalities

The proposed standards would decrease domestic consumption of gasoline, producing a corresponding decrease in the Nation's demand for crude petroleum, a commodity that is traded actively in a worldwide market. Because the U.S. accounts for a significant (albeit diminishing) share of global oil consumption, the resulting decrease in global petroleum demand will exert some downward pressure on worldwide prices.

U.S. consumption and imports of petroleum products have three potential effects on the domestic economy that are often referred to collectively as ''energy security externalities,'' and increases in their magnitude are sometimes cited as possible SCs of increased U.S. demand for petroleum. Symmetrically, reducing U.S. petroleum consumption and imports can reduce these costs, and by doing so provide additional external benefits from establishing higher CAFE and fuel efficiency standards.

First, any increase in global petroleum prices that results from higher U.S. gasoline demand will cause a transfer of revenue to oil producers worldwide from consumers of petroleum, because consumers throughout the world are ultimately subject to the higher global price that results. Under competitive market assumptions, this transfer is simply a shift of resources that produces no change in global economic output or welfare. Since the financial drain it produces on the U.S. economy may not be considered by individual consumers of petroleum products, it is sometimes cited as an external cost of increased U.S. petroleum consumption.

As the U.S. has transitioned towards self-sufficiency in petroleum production (the nation became a net exporter of petroleum in 2020), this transfer is increasingly from U.S. consumers of refined petroleum products to U.S. petroleum producers, so it not only leaves welfare unaffected but even ceases to be a financial burden on the U.S. economy. In fact, to the extent that the U.S. becomes a larger net petroleum exporter, any transfer from global consumers to petroleum producers becomes a financial benefit to the U.S. economy. Nevertheless, uncertainty in the nation's long-term import-export balance makes it difficult to project precisely how these effects might change in response to increased consumption.

The loss of potential GDP from this externality will depend on the degree that global petroleum suppliers like the Organization of Petroleum Exporting Countries (OPEC) and Russia exercise market power which raise oil market prices above competitive market levels. In that situation, increases in U.S. gasoline demand will drive petroleum prices further above competitive levels, thus exacerbating this deadweight loss. More stringent standards lower gasoline demand and hence reduce these losses.

Over most of the period spanned by NHTSA's analysis, any decrease in domestic spending for petroleum caused by the effect of lower U.S. fuel consumption and petroleum demand on world oil prices is expected to remain entirely a transfer within the U.S. economy. In the case in which large producers are able to exercise market power to keep global prices for petroleum above competitive levels, this reduction in price should also increase potential GDP in the U.S. However, the degree to which OPEC and other producers like Russia are able to act as a cartel depends on a variety of economic and political factors and has varied widely over recent history, so there is significant uncertainty over how this will evolve over the horizon that NHTSA models. For these reasons, lower U.S. spending on petroleum products that results from raising standards, reducing U.S. gasoline demand, and the downward pressure it places on global petroleum prices is not included among the economic benefits accounted for in the agency's evaluation of this proposed rule. We seek comment on this assumption.

Second, higher U.S. petroleum consumption can also increase domestic consumers' exposure to oil price shocks and thus increase potential costs to all

U.S. petroleum users (including those outside the LDV and HDPUV sectors, whose consumption would be unaffected by this proposed rule) from possible interruptions in the global supply of petroleum or rapid increases in global oil prices. Because users of petroleum products are unlikely to consider the effect of their increased purchases on these risks, their economic value is often cited as an external cost of increased U.S. consumption. Decreased consumption, which we expect as a result of the proposed standards, decreases this cost. We include an estimate of this impact of the standards, and an explanation of our methodology can be found in Chapter 6.2.4.4 of the Draft TSD.

Finally, some analysts argue that domestic demand for imported petroleum may also influence U.S. military spending; because the increased cost of military activities would not be reflected in the price paid at the gas pump, this is often suggested as a third category of external costs from increased U.S. petroleum consumption. For example, NHTSA has received extensive comments about exactly this effect on its past actions from the group Securing America's Energy Future. Most recent studies of military-related costs to protect U.S. oil imports conclude that significant savings in military spending are unlikely to result from incremental reductions in U.S. consumption of petroleum products on the scale that would result from adopting higher standards. While the cumulative effects of increasing fuel economy over the long-term likely have reduced the amount the U.S. has to spend to protect its interest in energy sources globally—avoid being beholden to geo-political forces that could disrupt oil supplies—it is extremely difficult to quantify the impacts and even further to identify how much a single fuel economy rule contributes. As such NHTSA does not estimate the impact of the proposed standards on military spending. See Chapter 6.2.4.5 of the Draft TSD for additional details.

Each of these three factors would be expected to decrease incrementally as a consequence of a decrease in U.S. petroleum consumption resulting from the proposed standards. Chapter 6.2.4 of the Draft TSD provides a comprehensive explanation of NHTSA's analysis of these three impacts. NHTSA seeks comment on its accounting of energy security.

NHTSA is also monitoring the availability of critical minerals used in electrified powertrains and whether any shortage of such materials could emerge as an additional energy security concern. While nearly all electricity in the United States is generated through the conversion of domestic energy sources and thus its supply does not raise security concerns, EVs also require sophisticated batteries to store and deliver that electricity. Currently, the most commonly used vehicle battery chemistries include materials that are either scarce or expensive, are sourced from potentially insecure or unstable overseas sites, and can pose environmental challenges during extraction and conversion to usable material. Known supplies of some of these critical minerals are also highly concentrated in a few countries and therefore face the same market power concerns as petroleum products.

NHTSA is restricted from considering the fuel economy of alternative fuel sources in determining CAFE standards, and as such, the CAFE Model restricts the application of BEV pathways and PHEV electric efficiency in simulating compliance with the regulatory alternatives. However, the cost of critical minerals may affect the cost to supply both plug-in and non-plug-in hybrids that require larger batteries. Further, as manufacturers choose to produce more electrified vehicles, they will also become more susceptible to disruptions to critical mineral markets, which may make it harder for them to comply with CAFE standards if their voluntary compliance strategy relies on electrification rather than other technologies. NHTSA does not include costs or benefits related to these emerging energy security considerations in its analysis for this proposed rule but seeks comment on whether it is appropriate to include an estimate in the analysis and, if so, which data sources and methodologies it should employ.

(4) Changes in Labor Use and Employment

As vehicle prices rise, we expect consumers to purchase fewer vehicles than they would have at lower prices. If manufacturers produce fewer vehicles as a consequence of lower demand, they may need less labor to produce and assemble vehicles, while dealers may need less labor to sell the vehicles. Conversely, as manufacturers add equipment to each new vehicle, the industry will require labor resources to develop, sell, and produce additional fuel-saving technologies. We also account for the possibility that new standards could shift the relative shares of passenger cars and light trucks in the overall fleet. Since the production of different vehicles involves different amounts of labor, this shift affects the required quantity of labor.

The analysis considers the direct labor effects that the standards have across the automotive sector. The effects include (1) dealership labor related to new LDV and HDPUV unit sales; (2) assembly labor for vehicles, engines, and transmissions related to new vehicle unit sales; and (3) labor related to mandated additional fuel savings technologies, accounting for new vehicle unit sales. NHTSA has now used this methodology across several rulemakings but has generally not emphasized its results, largely because NHTSA found that attempting to quantify the overall labor or economic effects was too uncertain and difficult. We have also excluded any analysis of how changes in direct labor requirements could change employment in adjacent industries.

NHTSA still believes that such an expanded analysis may be outside the effects that are reasonably traceable to the proposal; however, NHTSA has identified an exogenous model that can capture both the labor impacts contained in the CAFE Model and the secondary macroeconomic impacts due to changes in sales, vehicle prices, and fuel savings. Accompanying this proposal is a docket memo explaining how the CAFE Model's outputs may be used within Regional Economic Models, Inc. (REMI)'s PI + employment model to quantify the impacts of this proposal. We seek comment on the practicability of expanding the scope of the proposal's labor analysis for the final rule and whether the REMI model is appropriate.

All labor effects are estimated and reported at a national aggregate level, in person-years, assuming 2,000 hours of labor per person-year. These labor hours are not converted to monetized values because we assume that the labor costs are included into a new vehicle's purchasing price. The analysis estimates labor effects from the forecasted CAFE Model technology costs and from review of automotive labor for the MY 2022 fleet. NHTSA uses information about the locations of vehicle assembly, engine assembly, and transmission assembly, and the percent of U.S. content of vehicles collected from American Automotive Labeling Act (AALA) submissions for each vehicle in the reference fleet. The analysis assumes that the fractions of parts that are currently made in the U.S. will remain constant for each vehicle as manufacturers add fuel-savings technologies. This should not be construed as a prediction that the percentage of U.S.-made parts—and by extension U.S. labor—will remain constant, but rather as an acknowledgement that NHTSA does not have a clear basis to project where future production may shift. The analysis also uses data from the NADA annual report to derive dealership labor estimates.

We seek comment on these assumptions, and whether there are any data sources or methodologies the agency could employ to dynamically model parts content across different regulatory alternatives. While the IRA tax credit eligibility is *not* dependent on our labor assumptions here, if NHTSA were able to dynamically model changes in parts content with enough confidence in its precision, NHTSA could potentially employ those results to dynamically model a portion of tax credit eligibility.

In sum, the analysis shows that the increased labor from producing additional technology necessary to meet the preferred alternative will outweigh any decreases attributable to the change in new vehicle sales. For a full description of the process NHTSA uses to estimate labor impacts, see Chapter 6.2.5 of the Draft TSD.

3. Costs and Benefits Not Quantified

In addition to the costs and benefits described above, Table II–19 includes two-line items without values. The first is maintenance and repair costs. Many of the technologies manufacturers apply to vehicles to meet the standards are sophisticated and costly. The technology costs capture only the initial or ''upfront'' costs to incorporate this equipment into new vehicles; however, if the equipment is costlier to maintain or repair—as seems likely because the materials used to produce the equipment are more expensive and the equipment itself is significantly more complex and requires more time and labor to maintain or repair—then consumers will also experience increased costs throughout the lifetime of the vehicle to keep it operational. Conversely, electrification technologies offer the potential to lower repair and maintenance costs. For example, BEVs do not have engines that are costly to maintain, and all electric pathways with regenerative braking may reduce the strain on braking equipment and consequential extend the useful life of braking equipment. However, NHTSA notes that due to 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 comparing alternatives. NHTSA seeks comment on methods for estimating these costs.

The second empty line item in the table is the value of potential sacrifices in other vehicle attributes. Some technologies that could be used to improve fuel economy can also be used to increase other vehicle attributes, especially performance, carrying capacity, comfort, and energy-using accessories, though some technologies can also increase both fuel economy and performance simultaneously. While this is most obvious for technologies that improve the efficiency of engines and transmissions, it may also be true of technologies that reduce mass, aerodynamic drag, rolling resistance or any road or accessory load. The exact nature of the potential to trade-off attributes for fuel economy varies with specific technologies, but at a minimum, increasing vehicle efficiency or reducing loads allows a more powerful engine to be used while achieving the same level of fuel economy. It is also possible if consumers are unable to access financing to cover the purchase price of the attributes they value as well as additional fuel economy that will more than pay for itself that the additional cost of the new technology leads consumers to purchase vehicles that are smaller or lack features such as heated seats, advanced entertainment systems, or panoramic sunroofs, which are amenities consumers value but are unrelated to the performance of the drivetrain.[441] How consumers value increased fuel economy and how fuel economy regulations affect manufacturers' decisions about using efficiency improving technologies can have important effects on the estimated costs, benefits, and indirect impacts of fuel economy standards. Nevertheless, any sacrifice in potential improvements to vehicles' other attributes could represent a net opportunity cost to their buyers (though performance-efficiency tradeoffs could also lower compliance costs, and some additional attributes, like acceleration, could come with their own countervailing social costs).

NHTSA has previously attempted to model the potential sacrifice in other vehicle attributes in sensitivity analyses by assuming the opportunity cost must be greater than some percentage of the fuel savings they voluntarily forego. In those previous rulemakings, NHTSA acknowledged that it is extremely difficult to quantify the potential loss of other vehicle attributes, and therefore included the value of other vehicle attributes only in sensitivity analyses. This approach is used in a sensitivity analysis for this proposed rule. NHTSA seeks comment on alternative methods for estimating the potential sacrifice in other vehicle attributes.

The results of NHTSA's analysis of the proposed HDPUV standards suggest that buyer's perceived reluctance to purchasing higher-mpg models is due to undervaluation of the expected fuel savings due to market failures, 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. This result is the same for vehicles purchased by individual consumers and those bought for commercial purposes. NHTSA tested the sensitivity of the analysis to the potential that the market failures listed do not apply to the commercial side of the HDPUV market. In this sensitivity analysis, commercial operators are modeled as profit maximizers who would not be made more or less profitable by more stringent standards by offsetting the estimated net private benefit to commercial operators.[442] NHTSA decided against including this alternative in the primary analysis to align with its approach to market failures in the light-duty analysis. Furthermore, there is insufficient data on the size and composition of the commercial share of the HDPUV market to develop a precise estimate of a commercial operator opportunity cost. For additional details, see Chapter 9.2.3.10 of the Draft RIA. We seek comment on this sensitivity analysis, and in particular, comments on market failures that are relevant to commercial operators and sources to help identify the market share of commercial operators.

H. Simulating Safety Effects of Regulatory Alternatives

The primary objective of the standards is to achieve maximum feasible fuel economy and fuel efficiency, thereby reducing fuel consumption. In setting standards to achieve this intended effect, the

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[441] NHTSA notes that if consumers simply take out a larger loan, then some future consumption is replaced by higher principle and interest payments in the future.

[442] Relevant sensitivity cases are labeled ''Commercial Operator Sales Share'' and denote the percent of the fleet assumed owned by commercial operators. 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.

potential of the standards to affect vehicle safety is also considered. As a safety agency, NHTSA has long considered the potential for adverse or positive safety consequences when establishing CAFE and fuel efficiency standards.

This safety analysis includes the comprehensive measure of safety impacts of the proposed LD and HDPUV standards from three sources:

- Changes in Vehicle Mass

Similar to previous analyses, NHTSA calculates the safety impact of changes in vehicle mass made to reduce fuel consumption to comply with the standards. Statistical analysis of historical crash data indicates reducing mass in heavier vehicles generally improves safety for occupants in lighter vehicles and other road users like pedestrians and cyclists, while reducing mass in lighter vehicles generally reduces safety. NHTSA's crash simulation modeling of vehicle design concepts for reducing mass revealed similar effects. These observations align with the role of mass disparity in crashes; when vehicles of different masses collide, the smaller vehicle will experience a larger change in velocity (and, by extension, force), which increases the risk to its occupants. NHTSA believes the most recent analysis represents the best estimate of the impacts of MR that results in changes in mass disparities on crash fatalities, although it is important to note that these best estimates are not significantly different from zero and are not significant at the 5th confidence level. NHTSA seeks comments on its approach to estimating the effects of the standards on mass-safety.

- Impacts of Vehicle Prices on Fleet Turnover

Vehicles have become safer over time through a combination of new safety regulations and voluntary safety improvements. NHTSA expects this trend to continue as emerging technologies, such as advanced driver assistance systems, are incorporated into new vehicles. Safety improvements will likely continue regardless of changes in the standards.

As discussed in Section III.E.2, technologies added to comply with fuel economy and efficiency standards have an impact on vehicle prices, therefore slowing the acquisition of newer vehicles and retirement of older ones. The delay in fleet turnover caused by the effect of new vehicle prices affect safety by slowing the penetration of new safety technologies into the fleet.

The standards also influence the composition of the LD fleet. As the safety provided by light trucks, SUVs and passenger cars responds differently to technology that manufacturers employ to meet the standards—particularly MR—fleets with different compositions of body styles will have varying numbers of fatalities, so changing the share of each type of LDV in the projected future fleet impacts safety outcomes.

However, any fatalities associated with changes in sales and fleet share represent a small fraction of the total number of expected fatalities in the No-Action Alternative.

- Increased Driving Because of Better Fuel Economy

The ''rebound effect'' predicts consumers will drive more when the cost of driving declines. More stringent standards reduce vehicle operating costs, and in response, some consumers may choose to drive more. Additional driving increases exposure to risks associated with motor vehicle travel, and this added exposure translates into higher fatalities and injuries. However, any fatalities associated with rebound driving represent a small fraction of the total number of fatalities that are expected in the No-Action Alternative.

The contributions of the three factors described above generate the differences in safety outcomes among regulatory alternatives. NHTSA'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 of travel) 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 a societal cost by multiplying fatalities with the DOT-recommended VSL supplemented by economic impacts that are external to VSL measurements. Traffic injuries and property damage are also modeled directly using the same process and valued using costs that are specific to each injury severity level.

All three factors influence predicted fatalities, but only two of them—changes in vehicle mass and in the composition of the LD fleet in response to changes in vehicle prices—impose increased risks on drivers and passengers that are not compensated for by accompanying benefits. In contrast, increased driving associated with the rebound effect is a consumer choice that reveals the benefits of additional travel. Consumers who choose to drive more have apparently concluded that the utility of additional driving exceeds the additional costs for doing so, including the crash risk that they perceive additional driving involves. As discussed in Chapter 7 of the Draft TSD, the benefits of rebound driving are accounted for by offsetting a portion of the added safety costs.

For the safety component of the analysis for this proposal, NHTSA assumed that HDPUVs have the same risk exposure as light trucks. Given that the HDPUV fleet is significantly smaller than the LD fleet, the sample size to derive safety coefficients separately for HDPUVs is challenging. We believe that HDPUVs share many physical commonalities with light trucks and the incidence and crash severity are likely to be similar. As such, we concluded it was appropriate to use the light truck safety coefficients for HDPUVs. We seek comment on this assumption.

NHTSA is also expanding its safety analysis to include non-occupants to the analysis. The agency categorizes safety outcome through three measures of LD and HDPUV vehicle safety: fatalities occurring in crashes, serious injuries, and the amount of property damage incurred in crashes with no injuries. Counts of fatalities to occupants of automobiles and non-occupants are obtained from NHTSA's Fatal Accident Reporting System. Estimates of the number of serious injuries to drivers and passengers of LD and HDPUV vehicles are tabulated from NHTSA's General Estimates System (GES) for 1990–2015, and from its Crash Report Sampling System (CRSS) for 2016–2019. Both GES and CRSS include annual samples of motor vehicle crashes occurring throughout the United States. Weights for different types of crashes were used to expand the samples of each type to estimates of the total number of crashes occurring during each year. Finally, estimates of the number of automobiles involved in property damage-only crashes each year were also developed using GES.

NHTSA seeks comment on its safety assumptions and methodology, which is described in detail in Chapter 7 of the Draft TSD.

1. Mass Reduction Impacts

Vehicle mass reduction can be one of the more cost-effective means of improving efficiency, particularly for makes and models not already built with much high-strength steel or aluminum closures or low-mass components. Manufacturers have stated that they will continue to reduce mass of some of their models to meet more stringent standards, and therefore, this expectation is incorporated into the modeling analysis supporting the standards. Safety trade-offs associated with mass-reduction have occurred in the past, particularly before standards were attribute-based because manufacturers chose, in response to standards, to build smaller and lighter vehicles; these smaller, lighter vehicles did not fare as well in crashes as larger, heavier vehicles, on average. Although NHTSA now uses attribute-based standards, in part to reduce or eliminate the incentive to downsize vehicles to comply with the standards, NHTSA must be mindful of the possibility of related safety trade-offs. For this reason, NHTSA accounts for how MR applied to meet the standards would affect the safety of a specific vehicle given its starting and ending GVWR.

For this proposed rule, the agency employed the modeling technique developed in the 2016 Puckett and Kindelberger report to analyze the updated crash and exposure data by examining the cross sections of the societal fatality rate per billion vehicle miles of travel (VMT) by mass and footprint, while controlling for driver age, gender, and other factors, in separate logistic regressions for five vehicle groups and nine crash types. NHTSA utilized the relationships between weight and safety from this analysis, expressed as percentage increases in fatalities per 100-pound weight reduction (which is how MR is applied in the technology analysis; see Section III.D.4), to examine the weight impacts applied in this analysis. The effects of MR on safety were estimated relative to (incremental to) the regulatory baseline in the analysis, across all vehicles for MY 2021 and beyond. NHTSA agency is faced with competing challenges. Research has consistently shown that MR affects ‘‘lighter’’ and ‘‘heavier’’ vehicles differently across crash types. The 2016 Puckett and Kindelberger report found MR concentrated among the heaviest vehicles is likely to have a beneficial effect on overall societal fatalities, while MR concentrated among the lightest vehicles is likely to have a detrimental effect on occupant fatalities but a slight benefit to pedestrians and cyclists. This represents a relationship between the dispersion of mass across vehicles in the fleet and societal fatalities: decreasing dispersion is associated with a decrease in fatalities. MR in heavier vehicles is more beneficial to the occupants of lighter vehicles than it is harmful to the occupants of the heavier vehicles. MR in lighter vehicles is more harmful to the occupants of lighter vehicles than it is beneficial to the occupants of the heavier vehicles.

To accurately capture the differing effect on lighter and heavier vehicles, NHTSA splits vehicles into lighter and heavier vehicle classifications in the analysis. However, this poses a challenge of creating statistically meaningful results. There is limited relevant crash data to use for the analysis. Each partition of the data reduces the number of observations per vehicle classification and crash type, and thus reduces the statistical robustness of the results. The methodology employed by NHTSA was designed to balance these competing forces as an optimal trade-off to accurately capture the impact of mass-reduction across vehicle curb weights and crash types while preserving the potential to identify robust estimates.

A more detailed description of the mass-safety analysis can be found in Chapter 7.2 of the Draft TSD.

2. Sales/Scrappage Impacts

The sales and scrappage responses to higher vehicle prices discussed in Section III.E.2 have important safety consequences and influence safety through the same basic mechanism, fleet turnover. In the case of the scrappage response, delaying fleet turnover keeps drivers in older vehicles which tend to be less safe than newer vehicles. Similarly, the sales response slows the rate at which newer vehicles, and their associated safety improvements, enter the on-road population. The sales response also influences the mix of vehicles on the road–with more stringent CAFE standards leading to a higher share of light trucks sold in the new vehicle market, assuming all else is equal. Light trucks have higher rates of fatal crashes when interacting with passenger cars and, as earlier discussed, different directional responses to MR technology based on the existing mass and body style of the vehicle.

Any effect on fleet turnover (either from delayed vehicle retirement or deferred sales of new vehicles) will affect the distribution of both ages and MYs present in the on-road LD and HDPUV fleets. Because each of these vintages carries with it inherent rates of fatal crashes, and newer vintages are generally safer than older ones, changing that distribution will change the total number of on-road fatalities under each regulatory alternative. Similarly, the DFS model captures the changes in the LD fleet’s composition of cars and trucks. As cars and trucks have different fatality rates, differences in fleet composition across the alternatives will affect fatalities.

At the highest level, NHTSA calculates the impact of the sales and scrappage effects by multiplying the VMT of a vehicle by the fatality risk of that vehicle. For this analysis, calculating VMT is rather simple: NHTSA uses the distribution of miles calculated in Chapter 4.3 of the Draft TSD. The trickier aspect of the analysis is creating fatality rate coefficients. The fatality risk measures the likelihood that a vehicle will be involved in a fatal accident per mile driven. NHTSA calculates the fatality risk of a vehicle based on the vehicle’s MY, age, and style, while controlling for factors that are independent of the intrinsic nature of the vehicle, such as behavioral characteristics. Using this same approach, NHTSA designed separate models for fatalities, non-fatal injuries, and property damaged vehicles. We seek comment on the fatality models in Chapter 7.1 of the Draft TSD.

The vehicle fatality risk described above captures the historical evolution of safety. Given that modern technologies are proliferating faster than ever and offer greater safety benefits than traditional safety improvements, NHTSA augmented the fatality risk projections with knowledge about forthcoming safety improvements. NHTSA applied estimates of the market uptake and improving effectiveness of crash avoidance technologies to estimate their effect on the fleet-wide fatality rate, including explicitly incorporating both the direct effect of those technologies on the crash involvement rates of new vehicles equipped with them, as well as the ‘‘spillover’’ effect of those technologies on improving the safety of occupants of vehicles that are not equipped with these technologies.

NHTSA’s approach to measuring these impacts is to derive effectiveness rates for these advanced crash-avoidance technologies from safety technology literature. NHTSA then applies these effectiveness rates to specific crash target populations for which the crash avoidance technology is designed to mitigate and adjusted to reflect the current pace of adoption of the technology, including the public commitment by manufactures to install these technologies. The products of these factors, combined across all 7 advanced technologies, produce a fatality rate reduction percentage that is applied to the fatality rate trend model discussed above, which projects both vehicle and non-vehicle safety trends. The combined model produces a projection of impacts of changes in vehicle safety technology as well as behavioral and infrastructural trends. A much more detailed discussion of the methods and inputs used to make these projections of safety impacts from advanced technologies is included in Chapter 7.1 of the Draft TSD. We seek comment on our general approach to modeling the impact of advance crash avoidance systems on safety and invite commenters to provide any additional empirical data and research that we can use to augment the analysis.

3. Rebound Effect Impacts

The additional VMT demanded due to the rebound effect is accompanied by more exposure to risk, however, rebound miles are not imposed on consumers by regulation. They are a freely chosen activity resulting from reduced vehicle operational costs. As such, NHTSA believes a large portion of the safety risks associated with additional driving are offset by the benefits drivers gain from added driving. The level of risk internalized by drivers is uncertain. This analysis assumes that drivers of both HDPUV and LDVs internalize 90 percent of this risk, which mostly offsets the societal impact of any added fatalities from this voluntary consumer choice. Additional discussion of internalized risk is contained in Chapter 7.4 of the Draft TSD. NHTSA seeks comment on this assumption and asks commenters to provide any academic literature that may attempt to further illuminate this topic.

4. Value of Safety Impacts

Fatalities, nonfatal injuries, and property damage crashes are valued as a societal cost within the CAFE Model's cost and benefit accounting. Their value is based on the comprehensive value of a fatality, which includes lost quality of life and is quantified in the VSL as well as economic consequences such as medical and emergency care, insurance administrative costs, legal costs, and other economic impacts not captured in the VSL alone. These values were derived from data in Blincoe et al. (2015), adjusted to 2021 dollars, and updated to reflect the official DOT guidance on the VSL.

Nonfatal injury costs, which differ by severity, were weighted according to the relative incidence of injuries across the Abbreviated Injury Scale (AIS). To determine this incidence, NHTSA applied a KABCO/MAIS translator to CRSS KABCO based injury counts from 2017 through 2019. This produced the MAIS-based injury profile. This profile was used to weight nonfatal injury unit costs derived from Blincoe et al., adjusted to 2021 economics and updated to reflect the official DOT guidance on the VSL. Property-damaged vehicle costs were also taken from Blincoe et al. and adjusted to 2021 economics.

For the analysis, NHTSA assigns a societal value of $12.2 million for each fatality, $153,000 for each nonfatal injury, and $7,700 for each property damaged vehicle.

As discussed in the previous section, NHTSA discounts 90% of the safety costs associated with the rebound effect. The remaining 10% of those safety costs are not considered to be internalized by drivers and appear as a cost of the standards that influence net benefits. Similarly, the effects on safety attributable to changes in mass and fleet turnover are not considered costs internalized by drivers since manufacturers are responsible for deciding how to design and price vehicles. The costs not internalized by drivers is therefore the summation of the mass-safety effects, fleet turnover effects, and the remaining 10% of rebound-related safety effects.

III. Regulatory Alternatives Considered in This NPRM

A. General Basis for Alternatives Considered

Agencies typically consider regulatory alternatives in order to evaluate the comparative effects of different potential ways of implementing their statutory authority to achieve their intended policy goals. NEPA requires agencies to compare the potential environmental impacts of their actions to a reasonable range of alternatives. E.O. 12866 and 13563, as well as OMB Circular A–4, also request that agencies evaluate regulatory alternatives in their rulemaking analyses.

Alternatives analysis begins with a ''No-Action'' Alternative, typically described as what would occur in the absence of any further 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.'' [443]

This proposal includes a No-Action Alternative for passenger cars and light trucks and a No-Action alternative for HDPUVs, both described below; four ''action alternatives'' for passenger cars and light trucks; and three action alternatives for HDPUVs. The proposed standards may, in places, be referred to as the ''Preferred Alternative,'' which is NEPA parlance, but NHTSA intends ''proposed standards'' and ''Preferred Alternative'' to be used interchangeably for purposes of this proposal. NHTSA believes this appropriately comports with the Council on Environmental Quality's (CEQ) directive that ''agencies shall . . . limit their consideration to a reasonable number of alternatives.'' [444]

The different regulatory alternatives for passenger cars and light trucks are defined in terms of percent-increases in CAFE stringency from year to year. 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 for the *actual* CAFE standards (as in, on a gallon per mile basis, the CAFE standards change by a given percentage from one MY to the next). One action alternative is less stringent than the Preferred Alternative for passenger cars and light trucks and two action alternatives are more stringent. The alternatives considered in this proposal for passenger cars and light trucks represent a reasonable range of possible agency actions.[445]

In a departure from recent CAFE rulemaking trends, we have applied different rates of increase to the passenger car and the light truck fleets. Rather than have both fleets increase their respective standards at the same rate, light truck standards will increase at a faster rate than passenger car standards. Each action alternative evaluated for this proposal has a passenger car fleet rate-of-increase of fuel economy lower than the rate-of-increase of fuel economy for the light truck 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.[446] We have selected

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[443] OMB Circular A–4. General Issues, 2. Developing a Baseline. Available at: *https://obamawhitehouse.archives.gov/omb/circulars_a004_a-4/.* (Accessed: May 31, 2023).

[444] 40 CFR 1502.14(f).

[445] See Draft TSD Chapter 1.2.1 for a complete discussion about the footprint curve functions and how they are calculated.

[446] 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 light

this approach for the current proposal for several reasons.

First, NHTSA believes that manufacturers will deploy considerable amounts of technology to reach the existing passenger car fuel economy standards adopted 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 fuel economy in response to those standards, in the absence of further technological innovation, less technology will remain on the table to be used for additional stringent increases in subsequent years, particularly for passenger cars. Because the CAFE statute prohibits us from considering BEVs and full PHEVs' combined fuel economy, we believe manufacturers will find it difficult to improve fuel economy with ICE engine technologies beyond what we are proposing for passenger cars and maintain a reasonable cost. This is supported by feedback we have received from industry stakeholders, suggesting that consumers are less willing and able to absorb significant additional regulatory costs for passenger cars than they are for light trucks. This phenomenon is more pronounced for smaller cars, where manufacturers have already significantly increased fuel economy in response to existing standards, leaving only the most expensive fuel saving technology options and where additional regulatory costs may represent a larger percentage of the overall vehicle cost. Our (statutorily constrained) analysis also suggests that costs for improvements in fuel economy for passenger cars 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.[447] 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, NHTSA carefully considered the existing curve shapes in light of ongoing trends in the fleet, 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[448] to also be driven by new types of vehicles classified as light trucks simply on the basis of having AWD that would otherwise be subject to the generally-more-stringent passenger car curve. Consumers appear receptive to these offerings, but they may end up with less fuel savings than if the vehicles had been classified as passenger cars instead, which appears to run counter to EPCA's overarching purpose of energy conservation. Attribute-based standards and separate standards for cars and trucks are statutorily required and are designed to accommodate these market trends but have resulted in less fuel savings which would otherwise accrue to American consumers. Additionally, we believe light trucks have significantly more opportunity for fuel economy improvements due to lower baseline technology levels, and greater average VMT values. Our analysis shows that for light truck stringency increases, the value of fuel savings alone outweighs the increased regulatory cost. In short, there appears to be more room to improve the light truck fleet, and thus NHTSA has considered larger ongoing increases in stringency for this fleet compared to passenger cars, though still generally smaller increases than those finalized for MYs 2024–2026.

For HDPUVs, the different regulatory 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 passenger car and light truck standards, because HDPUV standards are in fuel consumption space, year-over-year percent changes actually do represent gallon/mile differences across the work-factor range. Under each action alternative, the stringency changes at the same percentage rate in each MY in the rulemaking time frame. One action alternative is less stringent than the Preferred Alternative for HDPUVs, and one action alternative is more stringent. The alternatives considered in this proposal for HDPUVs represent a reasonable range of possible agency actions.

B. Regulatory Alternatives Under Consideration in This Proposal

The regulatory alternatives considered by the agency in this proposal are presented here as the percent-increases-per-year that they represent. The sections that follow will present the alternatives as the literal coefficients that define standards curves increasing at the given percentage rates. NHTSA requests comment on the full range of standards encompassed between the No-Action Alternative and Alternative PC6LT8 for MYs 2027–2032 passenger cars and light trucks, including the possibility of setting standards in between the considered alternatives. NHTSA also requests comment on the full range of standards encompassed between the No-Action Alternative and Alternative HDPUV14 for MYs 2030–2035 HDPUVs, including the possibility of setting standards in between the considered alternatives.

TABLE III–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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trucks were different. 77 FR 62623, 62638–39 (Oct. 15, 2012).

[447] This is true specifically because of the statutory restrictions on considering the fuel economy of BEVs and the full fuel economy of PHEVs for new CAFE standards, and especially for passenger cars given their technology levels.

[448] See trends discussion in TSD Chapter 1.2.3.1.

TABLE III–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, fuel price 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 a more accurate picture of the effects of different potential CAFE and HDPUV standards to decision-makers and to the public.

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

1. No-Action Alternative

As with the 2022 final rule, 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 has adopted, and other states have agreed to follow through 2035.
- Manufacturers will make production decisions in response to estimated market demand for fuel economy or fuel efficiency, considering estimated fuel prices, 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.[449] Consequently, the CAFE Model evaluates each requirement in each MY, 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 another 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 passenger car and light truck 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 passenger cars and light trucks, or to potential new HDPUV standards?

Additionally, within the context of 4 and 5, the CAFE Model may consider, as appropriate and allowed by statutory restrictions on technology application for a given MY, 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. This approach allows the analysis to isolate the effects of the decision being made on the appropriate CAFE standards, 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 passenger cars and light trucks, 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 MYs:

TABLE III–3—PASSENGER CAR CAFE TARGET FUNCTION COEFFICIENTS FOR NO-ACTION ALTERNATIVE[450]

	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

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[449] To be clear, this is for purposes of properly estimating the *No-Action* Alternative, which represents what NHTSA believes is likely to happen in the world in the *absence* of future NHTSA regulatory action. NHTSA does not attempt to simulate further application of BEVs, for example, in determining amongst the *action* alternatives for passenger cars and light trucks which one would be maximum feasible, because the statute prohibits NHTSA from considering the fuel economy of BEVs in determining maximum feasible CAFE standards.

TABLE III–4—LIGHT TRUCK CAFE TARGET FUNCTION COEFFICIENTS FOR NO-ACTION ALTERNATIVE [451]

	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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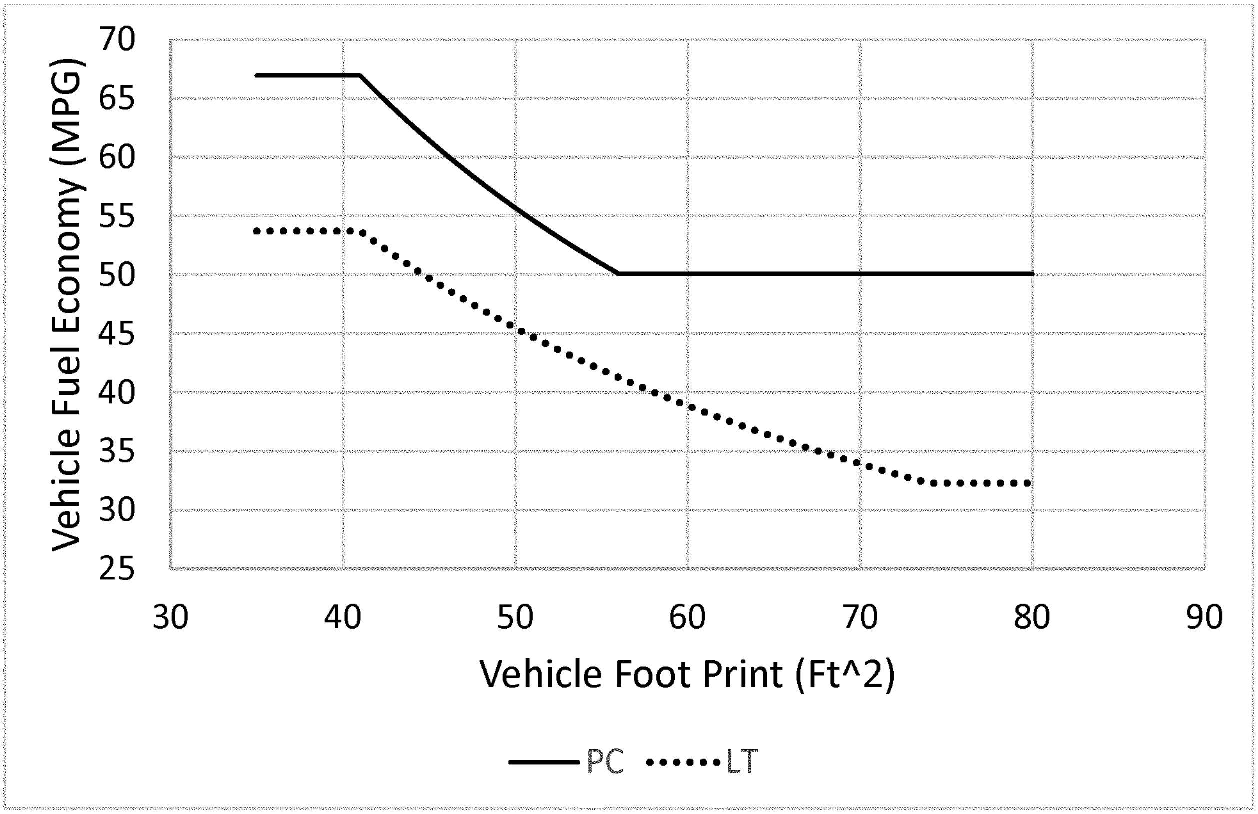

Figure III-1: No-Action Alternative, Passenger Car and Light Truck Fuel Economy, Target Curves

Additionally, EPCA, as amended by EISA, requires that any manufacturer's domestically-manufactured passenger car 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 MY. 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 passenger car fleet fuel economy, and used in rulemakings since.[452] [453] The projection shall be published in the **Federal Register** when the standard for that MY is promulgated in accordance with 49 U.S.C. 32902(b).[454] [455] 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 III–5 below:

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[450] The Passenger Car Function Coefficients 'a', 'b', 'c', and 'd' are defined in Draft TSD Chapter 1.2.1, Equation 1–1.

[451] The Light Truck Function Coefficients 'a', 'b', 'c', and 'd' are defined in Draft TSD Chapter 1.2.1, Equation 1–1.

[452] 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 NPRM discusses the basis for the offset.

[453] 87 FR 25710 (May 2, 2022).

[454] 49 U.S.C. 32902(b)(4).

[455] 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.

TABLE III–5—NO-ACTION ALTERNATIVE—MINIMUM DOMESTIC PASSENGER CAR STANDARD (MDPCS)

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 MYs:

TABLE III–6—HDPUV CI VEHICLE TARGET FUNCTION COEFFICIENTS FOR NO-ACTION ALTERNATIVE[456]

	2030	2031	2032	2033	2034	2035
e (gal/100 miles per WF)	0.0003418	0.0003418	0.0003418	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 III–7—HDPUV SI VEHICLE TARGET FUNCTION COEFFICIENTS FOR NO-ACTION ALTERNATIVE[457]

	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:

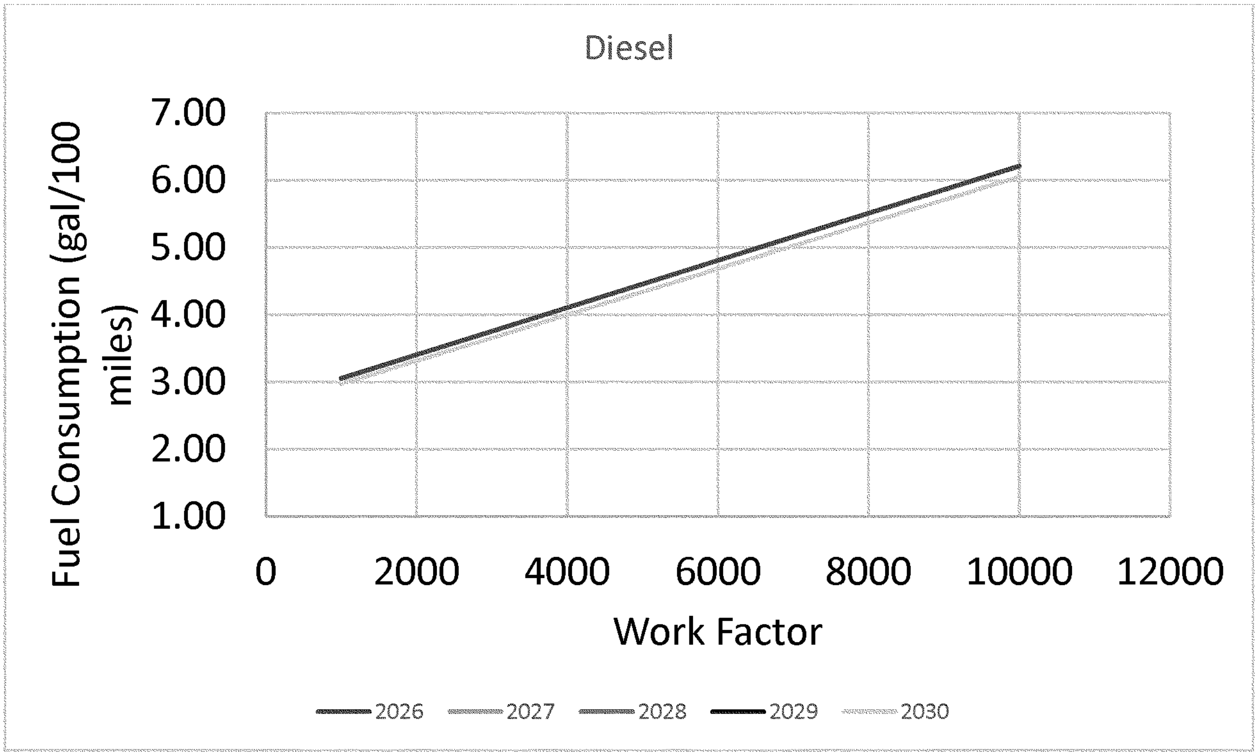

Figure III-2: No-Action Alternative, HDPUV – CI Vehicles, Target Curves

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

[457] 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 TSD Chapter 1.2.1.

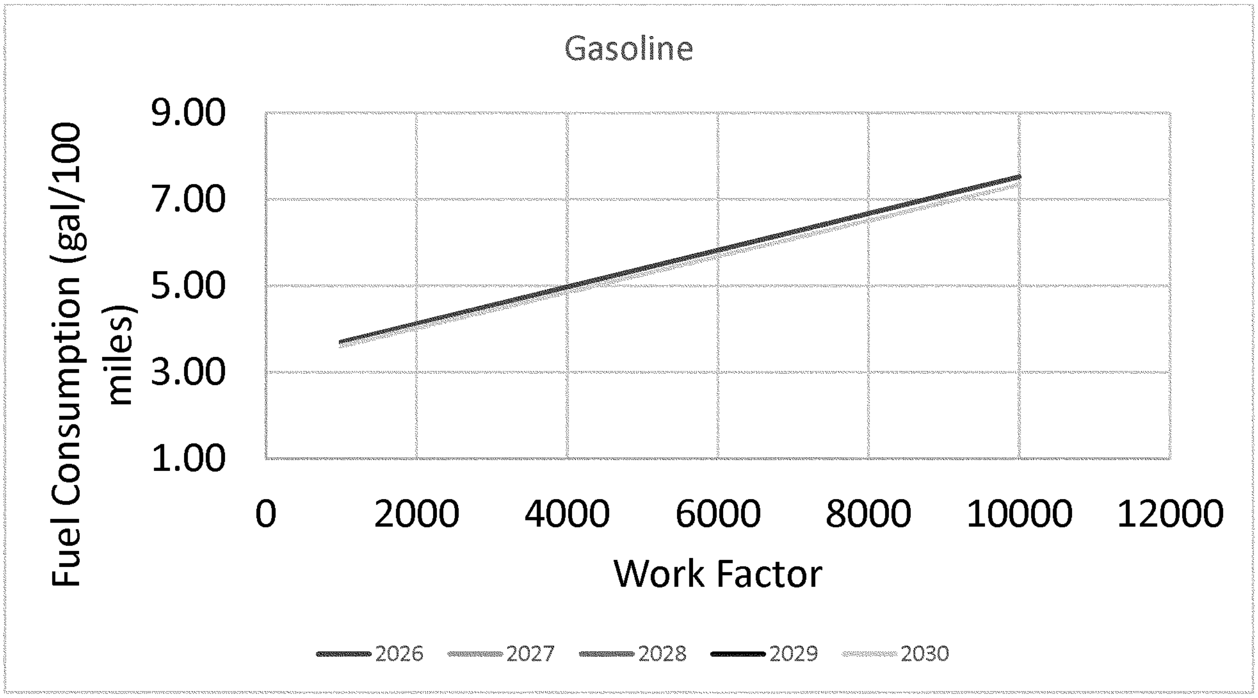

Figure III-3: No-Action Alternative, HDPUV – SI Vehicles, Target Curves

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As the baseline scenario, the No-Action Alternative also includes the following additional 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 passenger cars and light trucks 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 MYs:

TABLE III–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 III–9—LIGHT TRUCK CO_2 TARGET FUNCTION COEFFICIENTS FOR NO-ACTION ALTERNATIVE

	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 passenger cars and light trucks, respectively, in Table III–8 and Table III–9 above. Analogous to coefficients defining CAFE standards, coefficients *a* and *b* specify minimum and maximum CO_2 targets in each MY. 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 includes the following coefficients defining the WF based standards set by EPA for MY 2027 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 III–10—HDPUV CI VEHICLE TARGET FUNCTION COEFFICIENTS FOR NO-ACTION ALTERNATIVE

	2027 and later
e	0.0348
f	268

TABLE III–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 III–10 and Table III–11 above. The coefficients are linear work-factor based function with c and d representing gasoline, CNG vehicles, SHEVs and PHEVS and *e* and *f* representing diesels, BEVS and FCEVs. For this rulemaking, 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 battery-electric vehicles (BEVs) so that a manufacturer's fleet meets the calculated ZEV credit requirements.[458] The two programs have different requirements per MY, so they are modeled separately in the CAFE analysis. Chapter 2.3 of the Draft TSD discusses, in detail, how NHTSA developed these estimates.

The No-Action Alternative also includes NHTSA 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 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).[459] These credits, with the exception of the critical minerals credit, phase out from 2030 to 2032. The second provision explicitly modeled is the CVC,[460] which provides up to $7,500 toward the purchase of clean vehicles with critical minerals and battery components manufactured in North America.[461] The AMPC and CVC provide tax credits for PHEVs, BEVs, and FCVs. Chapter 2.2 in the Draft TSD discusses, in detail, how NHTSA has modeled these tax credits. These credits likely make the use of BEVs and PHEVs more attractive in complying with the California ZEV mandate and EPA's GHG standards.

The No-Action Alternative for the passenger car, light truck 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.[462] 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 MYs.[463] Others have similarly observed the auto industry's secular march toward higher fuel economy over time, even in the absence of standards.[464]

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 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.'' [465] Furthermore, the 2020 NAS HD report states: ''The

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[458] 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.

[459] 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.

[460] 26 U.S.C. 30D.

[461] There are vehicle price and consumer income limitations on the CVC as well, see Congressional Research Service. Tax Provisions in the Inflation Reduction Act of 2002 (H.R. 5376). Aug. 10, 2022.

[462] 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.

[463] See 2022 TSD, at 68.

[464] 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).

[465] National Research Council. 2015. Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles. The National Academies Press: Washington, DC. Page 31. Available at: *https://doi.org/10.17226/21744.* (Accessed: May 31, 2023) and available for review in hard copy at DOT headquarters). (hereinafter ''2015 NAS report'').

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.''[466] 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 and hence lower fuel economy. 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 fuel price projections assume sustained increases in real fuel prices over the course of the rule (and beyond). As readers are certainly aware, fuel prices have changed over time—sometimes quickly, sometimes slowly, generally upward:

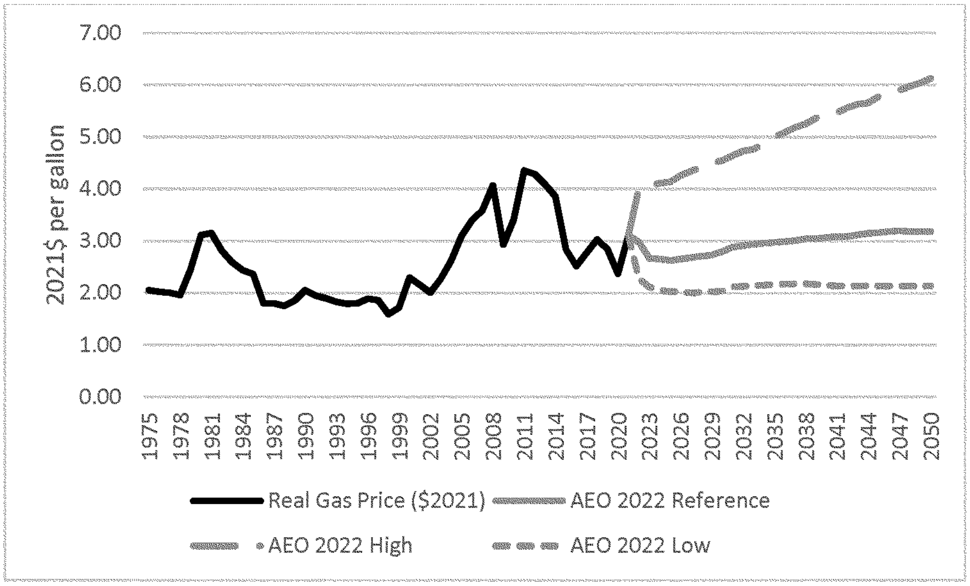

Figure III-4: Real Fuel Prices Over Time

In the 1990s, when fuel prices were historically low (as shown above), manufacturers did not tend to improve their fuel economy, likely in part because there simply was very little consumer demand for improved fuel economy and CAFE standards remained flat. In subsequent decades, when fuel prices were higher, many of them have exceeded their standards in multiple fleets, and for multiple years. Our current fuel price 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 fuel prices have generally declined on average and CAFE standards have continued to increase, fewer manufacturers have exceeded their standards. However, our compliance data show that at least some manufacturers do improve their fuel economy if fuel prices are high enough, even if they are not able to respond perfectly to fluctuations precisely when they happen. This highlights the importance of fuel price assumptions both in the analysis and in the real world on the future of fuel economy improvements.

2. Action Alternatives for MYs 2027–2032 Passenger Cars and Light Trucks

In addition to the No-Action Alternative, NHTSA has considered four ''action'' alternatives for passenger cars and light trucks, 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 passenger cars, light trucks, and HDPUVs. Section V discusses in more detail how the different alternatives reflect different possible balancing approaches.

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[466] 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. The National Academies Press: Washington, DC. p. 296. Available at: *https://doi.org/10.17226/25542.* (Accessed: May 31, 2023).

a. Alternative PC1LT3

Alternative PC1LT3 would increase CAFE stringency by 1 percent per year, year over year, for MYs 2027–2032 passenger cars, and by 3 percent per year, year over year, for MYs 2027–2032 light trucks.

TABLE III–12—PASSENGER CAR CAFE TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE PC1LT3 [467]

	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

TABLE III–13—LIGHT TRUCK CAFE TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE PC1LT3 [468]

	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 equations are represented graphically below:

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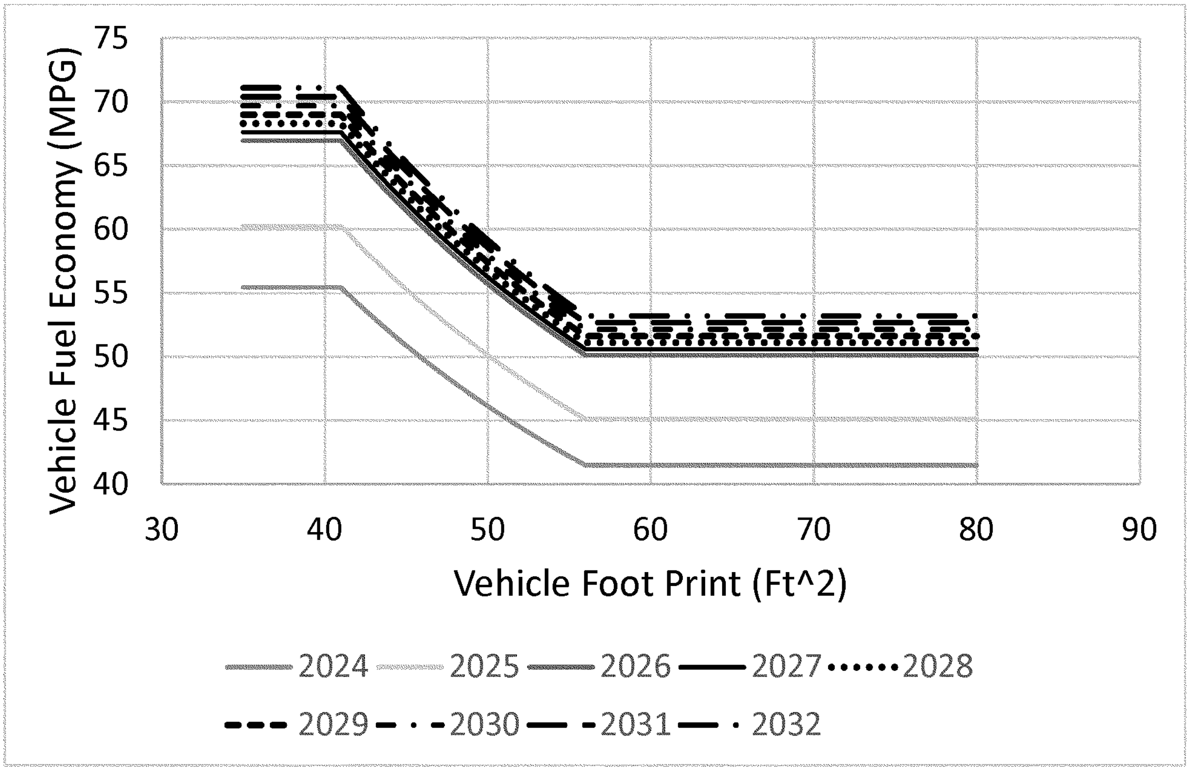

Figure III-5: Alternative PC1LT3, Passenger Car Fuel Economy, Target Curves

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

[468] The Light Truck Function Coefficients 'a', 'b', 'c', and 'd' are defined in Draft TSD Chapter 1.2.1.

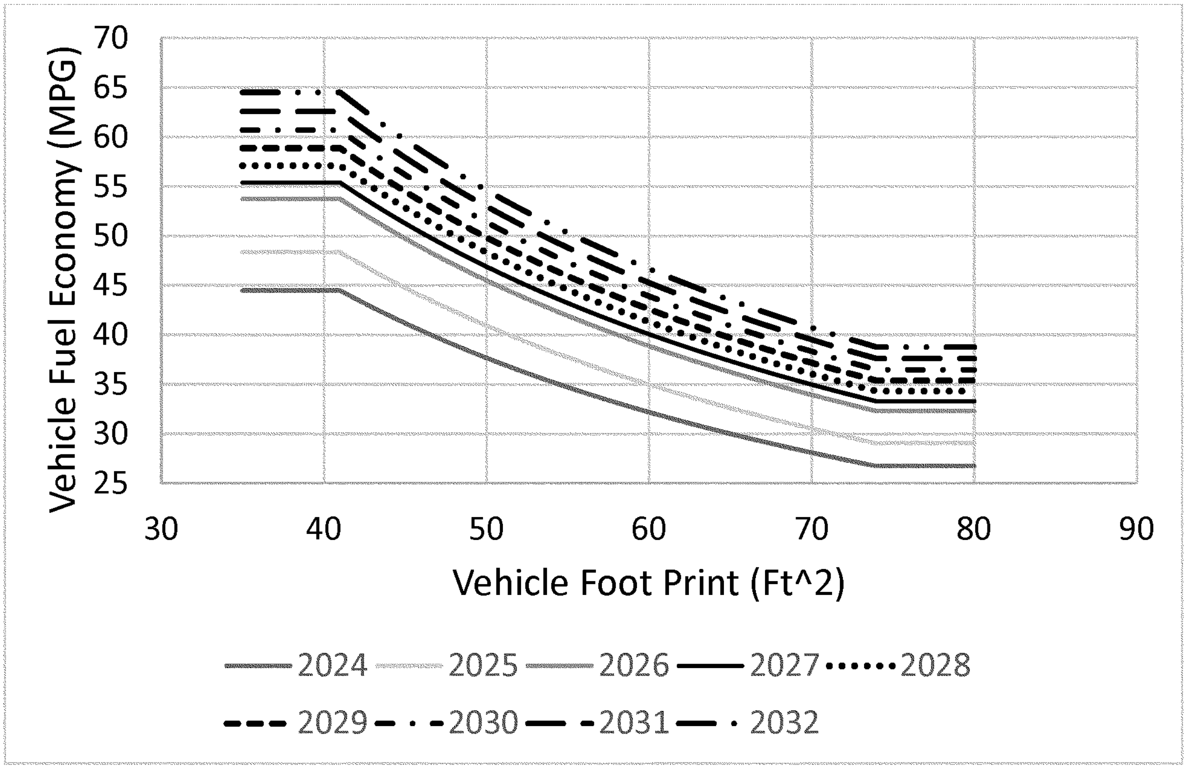

Figure III-6: Alternative PC1LT3, Light Truck Fuel Economy, Target Curves

Under this alternative, the MDPCS is as follows:

Table III–14—Alternative PC1LT3—Minimum Domestic Passenger Car Standard (MDPCS)

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

b. Alternative PC2LT4—Preferred Alternative

Alternative PC2LT4 would increase CAFE stringency by 2 percent per year, year over year, for MYs 2027–2032 passenger cars, and by 4 percent per year, year over year, for MYs 2027–2032 light trucks.

Table III–15—Passenger Car CAFE Target Function Coefficients for Alternative PC2LT4 [469]

	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 III–16—Light Truck CAFE Target Function Coefficients for Alternative PC2LT4 [470]

	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

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

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

These equations are represented graphically below:

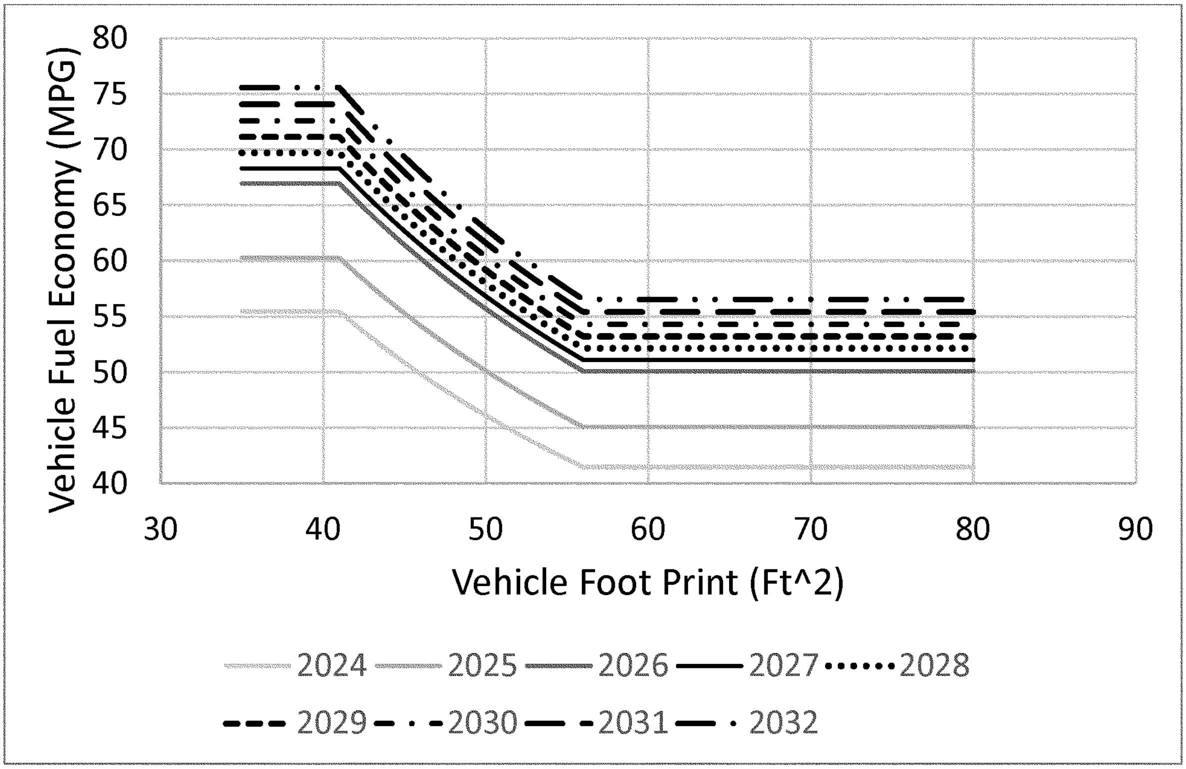

Figure III-7: Alternative PC2LT4, Passenger Car Fuel Economy, Target Curves

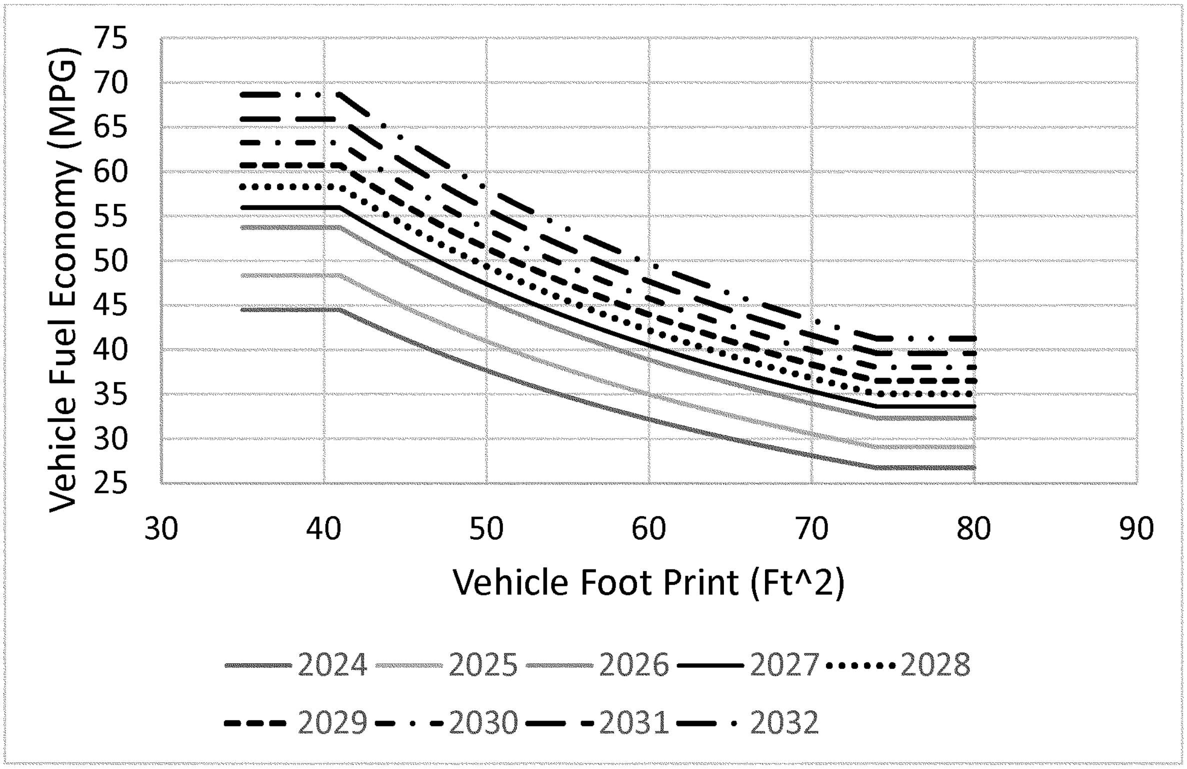

Figure III-8: Alternative PC2LT4, Light Truck Fuel Economy, Target Curves

Under this alternative, the MDPCS is as follows:

TABLE III–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

c. Alternative PC3LT5

Alternative PC3LT5 would increase CAFE stringency by 3 percent per year, year over year, for MYs 2027–2032 passenger cars, and by 5 percent per year, year over year, for MYs 2027–2032 light trucks.

TABLE III–18—PASSENGER CAR CAFE TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE PC3LT5[471]

	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 III–19—LIGHT TRUCK CAFE TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE PC3LT5[472]

	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 equations are represented graphically below:

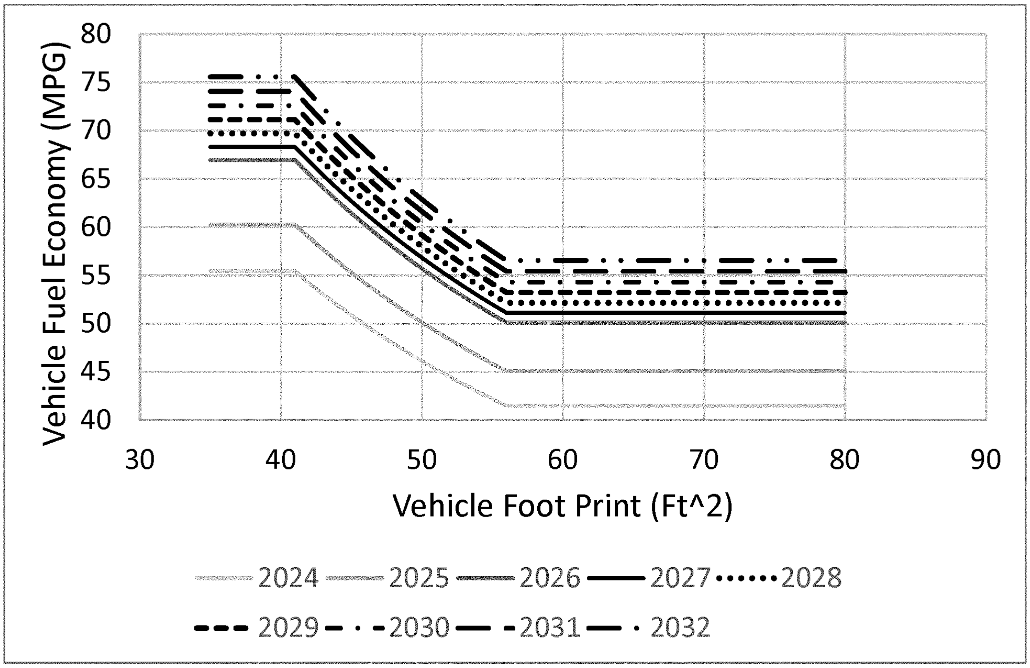

Figure III-9: Alternative PC3LT5, Passenger Car Fuel Economy, Target Curves

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

[472] The Light Truck Function Coefficients "a","b","c",and "d" are defined in Draft TSD Chapter 1.2.1.

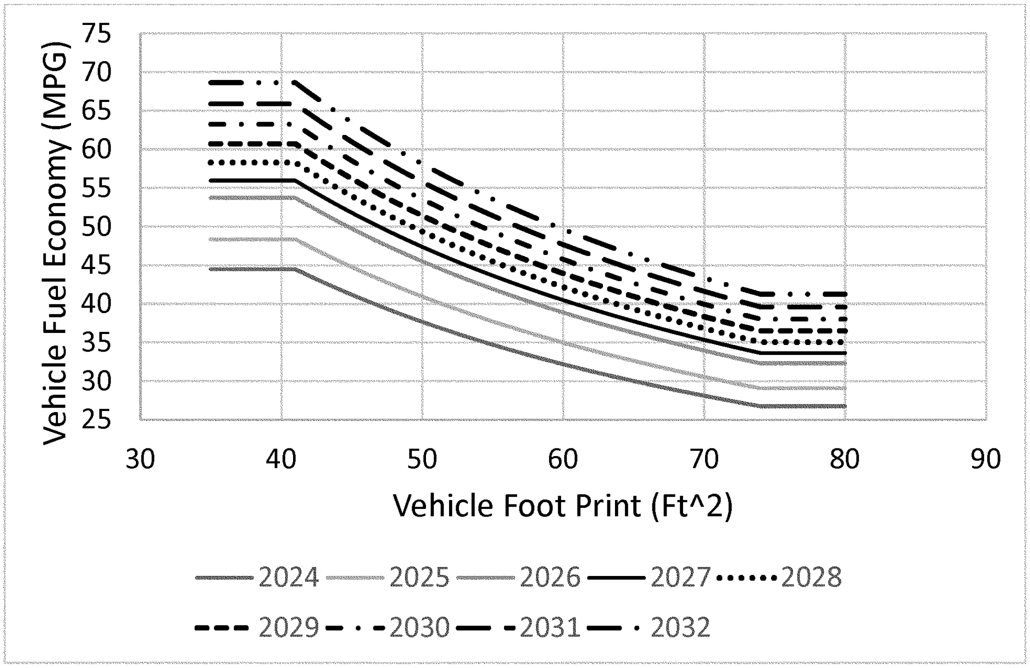

Figure III-10: Alternative PC3LT5, Light Truck Fuel Economy, Target Curves

Under this alternative, the MDPCS is as follows:

TABLE III–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

d. Alternative PC6LT8

Alternative PC6LT8 would increase CAFE stringency by 6 percent per year, year over year, for MYs 2027–2032 passenger cars, and by 8 percent per year, year over year, for MYs 2027–2032 light trucks.

TABLE III–21—PASSENGER CAR CAFE TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE PC6LT8[473]

	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 III–22—LIGHT TRUCK CAFE TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE PC6LT8[474]

	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
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 equations are represented graphically below:

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

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

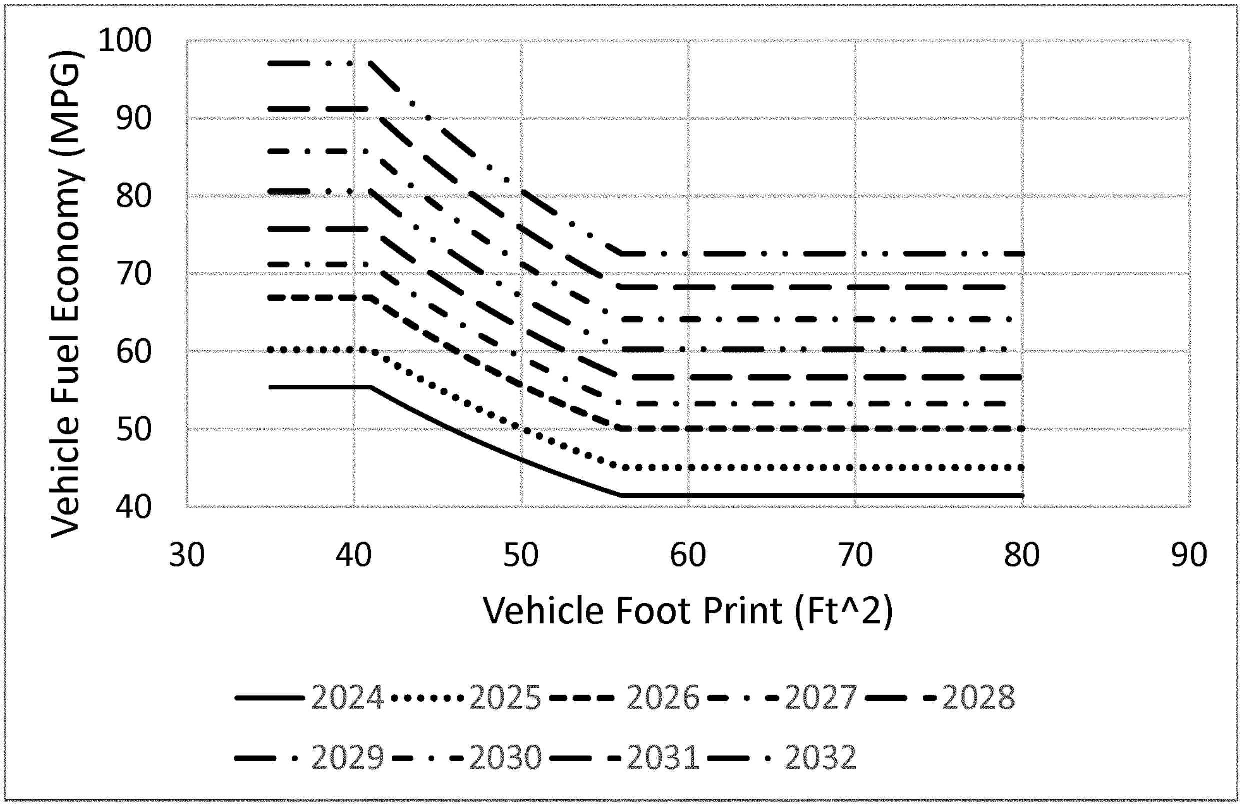

Figure III-11: Alternative PC6LT8, Passenger Car Fuel Economy, Target Curves

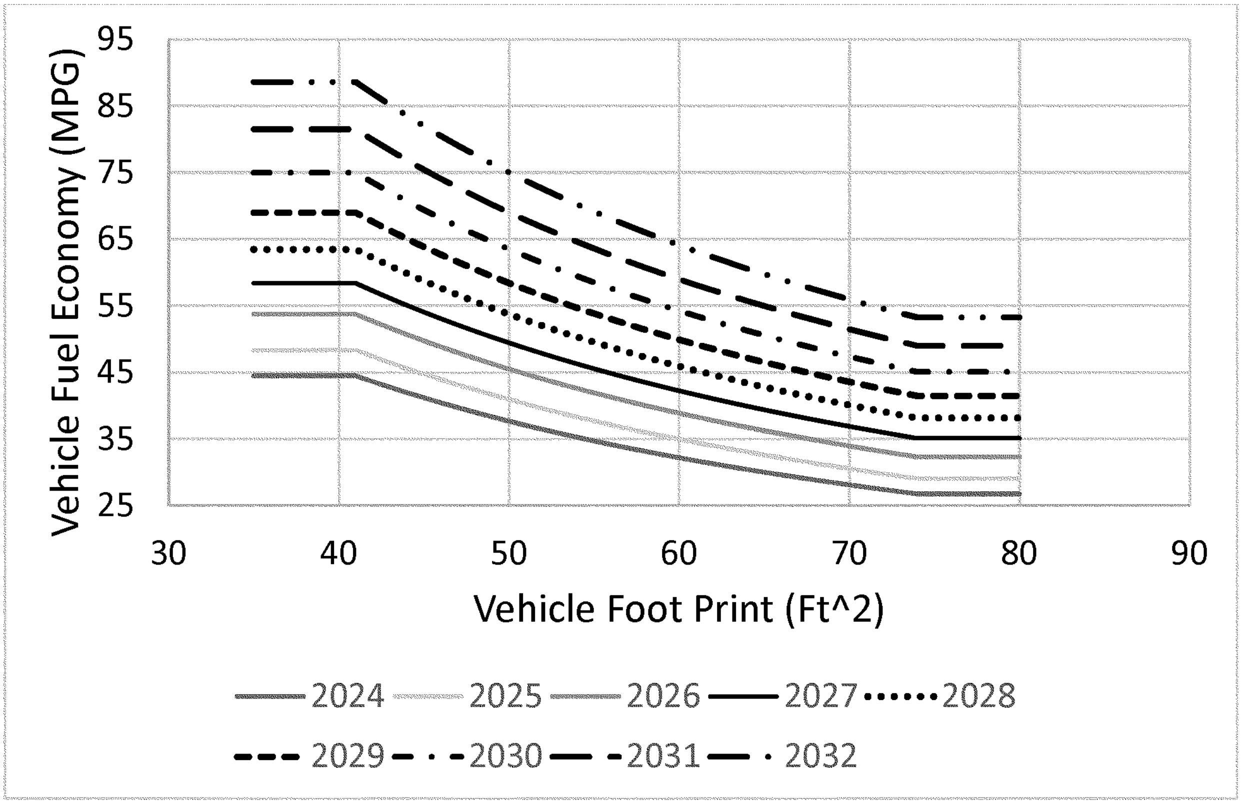

Figure III-12: Alternative PC6LT8, Light Truck Fuel Economy, Target Curves

Under this alternative, the MDPCS is as follows:

TABLE III–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. Action Alternatives for MYs 2030–2035 Heavy-Duty Pickups and Vans

In addition to the No-Action Alternative, NHTSA has considered three action alternatives for HDPUVs, each of which is more stringent than the No-Action Alternative during the rulemaking time frame. While each of the Action Alternatives described below would establish increases in stringency from MY 2030 through MY 2035, NHTSA also requests comment on a scenario where these Action Alternatives would extend only through MY 2032, which coincides with the timeframe of the EPA proposed GHG standards for this vehicle segment.[475] These action alternatives are specified below.

a. Alternative HDPUV4

Alternative HDPUV4 would increase HDPUV standard stringency by 4 percent per year for MYs 2030–2035 HDPUVs. NHTSA included this alternative in order to evaluate a possible balancing of statutory factors in which cost-effectiveness outweighed all other factors. The four-wheel drive coefficient is maintained at 500 (coefficient ‘a’) and the weighting multiplier coefficient is maintained at 0.75 (coefficient ‘b’).

TABLE III–24—HDPUV (CI VEHICLE) TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE HDPUV4[476]

	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 III–25—HDPUV (SI VEHICLE) TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE HDPUV4[477]

	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 equations are represented graphically below:

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[475] *See* 87 FR 29242–29243 (May 5, 2023). NHTSA recognizes that the Draft EIS accompanying this proposal examines only regulatory alternatives for HDPUVs in which standards cover MYs 2030–2035.

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

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

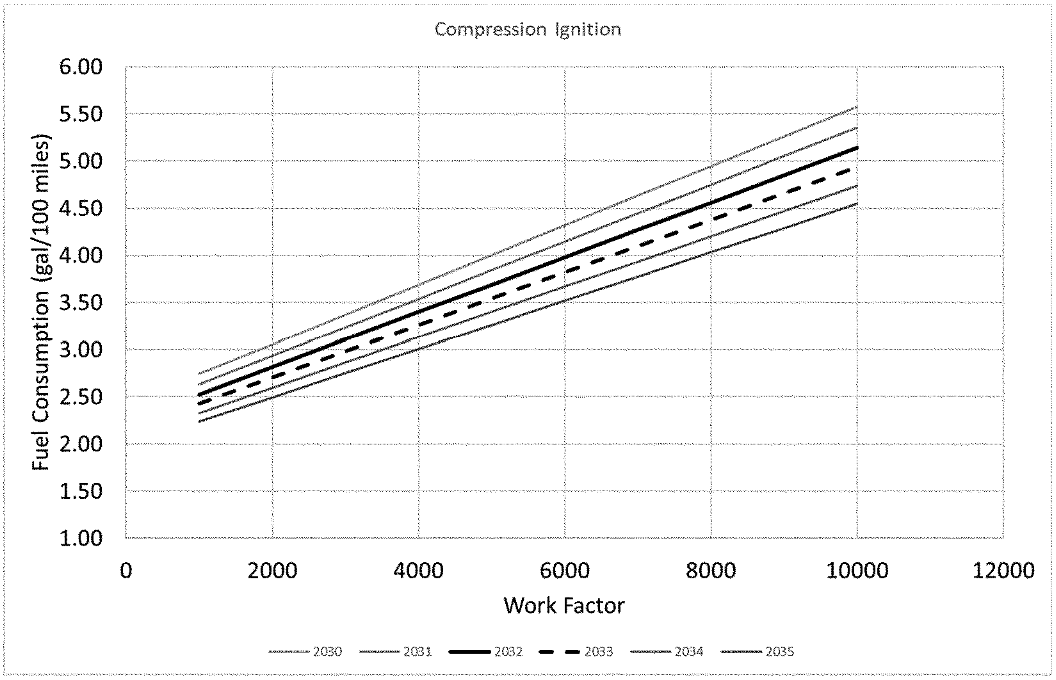

Figure III-13: Alternative HDPUV4, HDPUV Fuel Efficiency – CI Vehicles, Target Curves

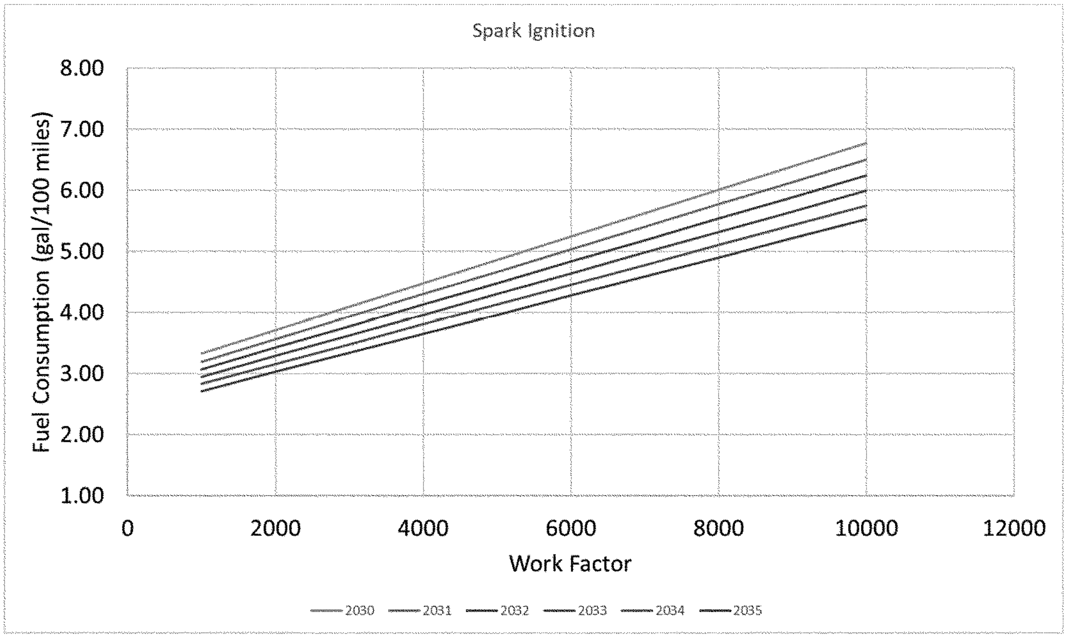

Figure III-14: Alternative HDPUV4, HDPUV Fuel Efficiency – SI Vehicles, Target Curves

b. 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 III–26—HDPUV (CI VEHICLE) TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE HDPUV10[478]

	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 III–27—HDPUV (SI VEHICLE) TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE HDPUV10[479]

	2030	2031	2032	2033	2034	2035
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 equations are represented graphically below:

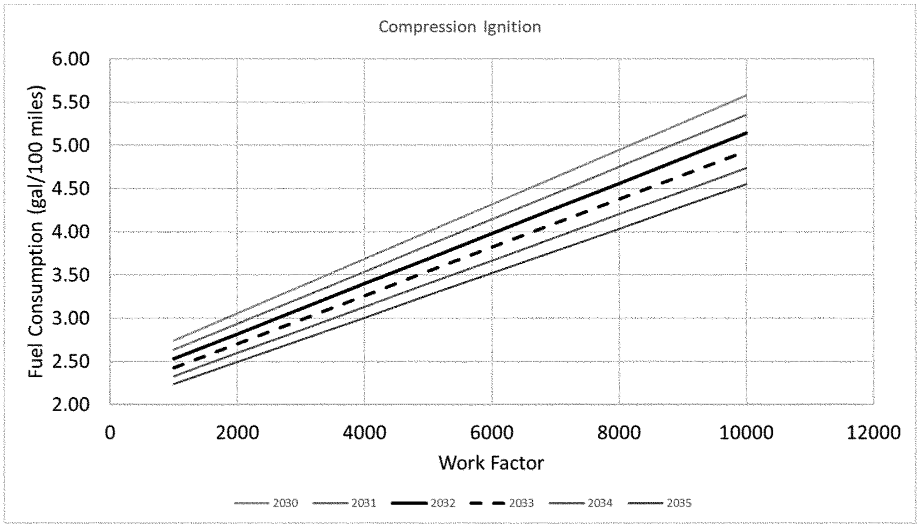

Figure III-15: Alternative HDPUV10, HDPUV Fuel Efficiency – CI Vehicles, Target Curves

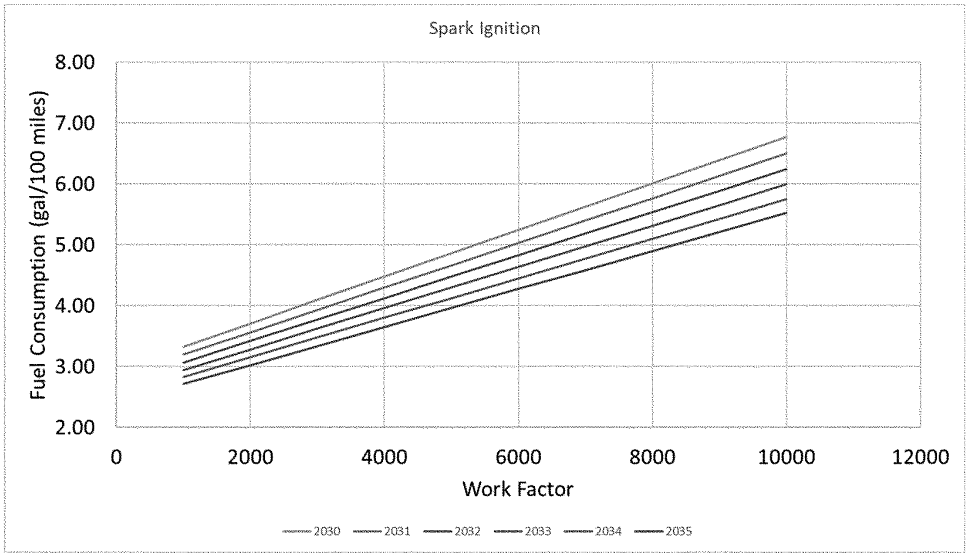

Figure III-16: Alternative HDPUV10, HDPUV Fuel Efficiency – SI Vehicles, Target Curves

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

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

c. 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 III–28—HDPUV (CI VEHICLE) TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE HDPUV14[480]

	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 III–29—HDPUV (SI VEHICLE) TARGET FUNCTION COEFFICIENTS FOR ALTERNATIVE HDPUV14[481]

	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 equations are represented graphically below:

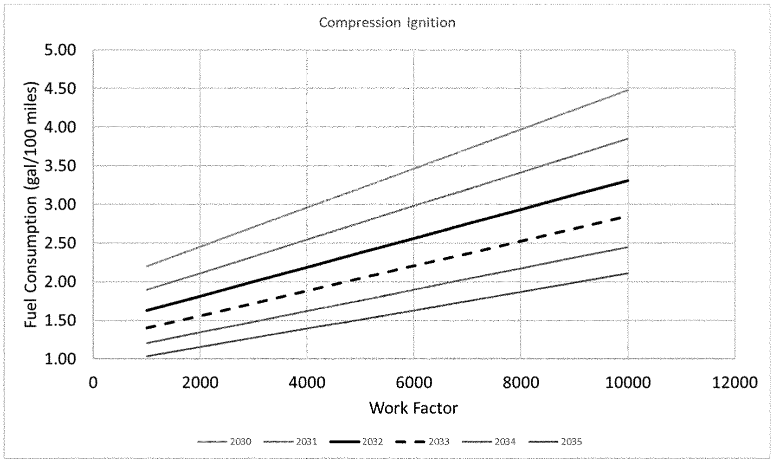

Figure III-17: Alternative HDPUV14, HDPUV Fuel Efficiency – CI Vehicles, Target Curves

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

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

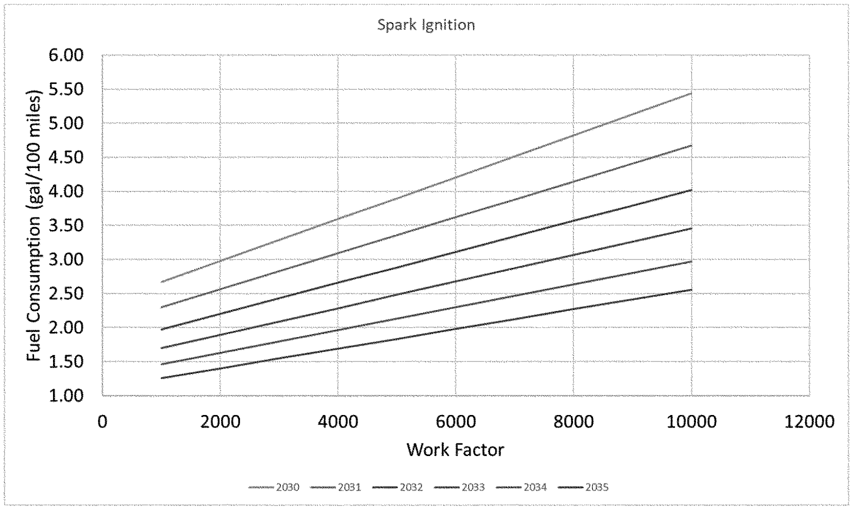

Figure III-18: Alternative HDPUV14, HDPUV Fuel Efficiency – SI Vehicles, Target Curves

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IV. Effects of the Regulatory Alternatives

A. Effects on Vehicle Manufacturers

1. Passenger Cars and Light Trucks

Each regulatory alternative considered in this proposal, aside from the No-Action Alternative, would increase the stringency of both passenger car and light truck CAFE standards during MYs 2027–2032 (with MY 2032 being an augural standard). To estimate the potential effects of each of these alternatives, NHTSA has, as with all recent rulemakings, assumed that standards would continue unchanged after the last model year to be covered by proposed CAFE targets (in this case an augural MY, 2032). NHTSA recognizes that it is possible that the size and composition of the fleet (*i.e.,* in terms of distribution across the range of vehicle footprints) could change over time, affecting the average fuel economy requirements under both the passenger car and light truck standards, and for the overall fleet. If fleet changes ultimately differ from NHTSA's projections, average requirements would differ from NHTSA's projections.

Following are the estimated required average fuel economy values for the passenger car, light truck, and total fleets for each action alternative that NHTSA considered alongside values for the No-Action alternative.

TABLE IV–1—ESTIMATED REQUIRED AVERAGE FUEL ECONOMY (MPG), BY REGULATORY FLEET

Model year	2022	2027	2028	2029	2030	2031	2032
Passenger Car							
No Action	44.1	58.8	58.8	58.8	58.8	58.8	58.8
PC1LT3	44.1	59.4	60.0	60.6	61.2	61.8	62.4
PC2LT4	44.1	60.0	61.2	62.5	63.7	65.1	66.4
PC3LT5	44.1	60.6	62.5	64.4	66.4	68.5	70.6
PC6LT8	44.1	62.5	66.5	70.8	75.3	80.1	85.2
Light Truck							
No Action	32.1	42.6	42.6	42.6	42.6	42.6	42.6
PC1LT3	32.1	43.9	45.3	46.7	48.1	49.6	51.2
PC2LT4	32.1	44.4	46.2	48.2	50.2	52.2	54.4
PC3LT5	32.1	44.9	47.2	49.7	52.3	55.1	58.0
PC6LT8	32.1	46.3	50.3	54.7	59.5	64.6	70.3

TABLE IV–2—ESTIMATED REQUIRED AVERAGE FUEL ECONOMY (MPG), TOTAL LIGHT-DUTY FLEET

Model year	2022	2027	2028	2029	2030	2031	2032
No Action	35.8	46.7	46.7	46.7	46.7	46.7	46.7
PC1LT3	35.8	47.9	49.1	50.3	51.6	53.0	54.3
PC2LT4	35.8	48.4	50.1	51.9	53.8	55.7	57.8
PC3LT5	35.8	48.9	51.2	53.5	56.1	58.7	61.5
PC6LT8	35.8	50.5	54.5	58.9	63.7	68.9	74.5

Manufacturers do not always comply exactly with each CAFE standard in each MY. To date, some manufacturers have tended to regularly exceed one or both requirements.[482] Many manufacturers make use of EPCA's provisions allowing CAFE compliance credits to be applied when a fleet's CAFE level falls short of the corresponding requirement in a given MY.[483] Some manufacturers have paid civil penalties (*i.e.,* fines) required under EPCA when a fleet falls short of a standard in a given MY and the manufacturer lacks compliance credits sufficient to address the compliance shortfall. As discussed in the accompanying PRIA and Draft TSD, NHTSA simulates manufacturers' responses to each alternative given a wide range of input estimates (*e.g.,* technology cost and efficacy, fuel prices), and, per EPCA requirements, setting aside the potential that any manufacturer would respond to CAFE standards in MYs 2027–2032 by applying CAFE compliance credits or considering the fuel economy attributable to alternative fuel sources.[484] Many of these inputs are subject to uncertainty, and, in any event, as in all CAFE rulemakings, NHTSA's analysis simply illustrates one set of ways manufacturers could potentially respond to each regulatory alternative. For this proposal, NHTSA estimates that manufacturers' responses to standards defining each alternative could lead average fuel economy levels to increase through MY 2032, as shown in the following tables.

TABLE IV–3—ESTIMATED ACHIEVED AVERAGE FUEL ECONOMY (MPG), BY REGULATORY FLEET

Model year	2022	2027	2028	2029	2030	2031	2032
Passenger Car							
No Action	47.1	63.0	64.4	65.8	67.5	69.1	70.3
PC1LT3	47.1	63.2	64.8	66.7	68.4	70.3	71.5
PC2LT4	47.1	63.5	65.3	67.5	69.3	71.3	72.8
PC3LT5	47.1	63.5	65.8	68.1	70.5	73.0	74.8
PC6LT8	47.1	63.6	67.5	71.1	74.8	78.9	83.6
Light Truck							
No Action	31.9	43.4	44.1	45.2	46.2	47.3	48.1
PC1LT3	31.9	44.2	45.5	47.2	48.4	50.2	51.5
PC2LT4	31.9	44.2	45.7	47.5	49.0	50.9	52.4
PC3LT5	31.9	44.3	46.0	47.9	49.6	51.7	53.5
PC6LT8	31.9	44.3	46.1	48.3	50.3	52.6	55.2

TABLE IV–4—ESTIMATED ACHIEVED AVERAGE FUEL ECONOMY (MPG), TOTAL LIGHT-DUTY FLEET

Model year	2022	2027	2028	2029	2030	2031	2032
No Action	36.4	48.2	49.0	50.2	51.3	52.6	53.6
PC1LT3	36.4	48.9	50.2	51.9	53.3	55.2	56.5
PC2LT4	36.4	49.0	50.5	52.4	54.0	56.0	57.6
PC3LT5	36.4	49.0	50.8	52.8	54.7	57.0	58.9
PC6LT8	36.4	49.0	51.2	53.7	56.1	58.9	62.0

While these increases in average fuel economy reflect currently estimated changes in the composition of the fleet (*i.e.,* the relative shares of passenger cars and light trucks), they result almost wholly from the projected application of fuel-saving technology. As mentioned above, NHTSA's analysis merely illustrates one set of ways manufacturers could potentially respond to each regulatory alternative. Manufacturers' actual responses will almost assuredly differ from NHTSA's current simulations.

The SHEV share of the LD fleet initially (*i.e.,* in MY 2022) is relatively low, but increases to approximately 25 percent by the beginning of the proposed regulatory period. Across action alternatives, SHEV penetration rates increase as alternatives become more stringent, in both the passenger car and light truck fleets. SHEVs are estimated to make up a larger portion of light truck fleet than passenger car fleet across MYs 2027–2032. While their market shares do not increase to the

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[482] Overcompliance can be the result of multiple factors including projected ''inheritance'' of technologies (*e.g.,* changes to engines shared across multiple vehicle model/configurations) applied in earlier MYs, future technology cost reductions (*e.g.,* decreased techology costs due to learning), and changes in fuel prices that affect technology cost effectiveness. As in all past rulemakings over the last decade, NHTSA assumes that beyond fuel economy improvements necessitated by CAFE standards, EPA–GHG standards, and ZEV mandates, manufacturers may also improve fuel economy via technologies that would pay for themselves within the first 30 months of vehicle operation.

[483] For additional detail on the creation and use of compliance credits, see Chapters 1.1 and 2.2.2.3 of the accompanying Draft TSD.

[484] In the case of battery-electric vehicles, this means BEVs will not be built in response to the proposed standards. For plug-in hybrid vehicles, this means only the gasoline-powered operation (*i.e.,* non-electric fuel economy, or charge sustaining mode operation only) is considered when selecting technology to meet the proposed standards.

levels of SHEVs, PHEVs make up approximately 10 percent of the estimated light truck fleet in the three most stringent action alternatives.

Table IV–5—Estimated Strong Hybrid Electric Vehicle (SHEV) Penetration Rate, by Regulatory Fleet

Model year	2022	2027	2028	2029	2030	2031	2032
Passenger Car							
No Action	5.4	13.0	13.5	13.5	13.0	12.7	12.8
PC1LT3	5.4	14.3	15.7	16.0	15.4	16.1	16.1
PC2LT4	5.4	15.5	17.5	20.7	20.6	20.6	20.6
PC3LT5	5.4	15.5	18.6	22.1	23.2	24.8	25.1
PC6LT8	5.4	15.5	27.0	33.2	37.8	44.1	49.8
Light Truck							
No Action	7.8	30.1	30.8	31.6	30.8	26.9	26.2
PC1LT3	7.8	33.3	39.3	41.4	41.4	40.0	40.7
PC2LT4	7.8	33.1	39.5	42.2	43.4	42.6	44.6
PC3LT5	7.8	33.1	41.3	44.1	46.6	45.9	48.2
PC6LT8	7.8	33.4	41.4	46.0	47.1	46.8	51.6

Table IV–6—Estimated Strong Hybrid Electric Vehicle (SHEV) Penetration Rate, Total Light-Duty Fleet

Model year	2022	2027	2028	2029	2030	2031	2032
No Action	6.9	24.6	25.3	25.9	25.1	22.3	21.9
PC1LT3	6.9	27.3	31.9	33.5	33.2	32.3	32.8
PC2LT4	6.9	27.5	32.6	35.5	36.2	35.6	36.9
PC3LT5	6.9	27.5	34.1	37.2	39.2	39.2	40.7
PC6LT8	6.9	27.7	36.9	42.0	44.2	45.9	51.0

Table IV–7—Estimated Plug-in Hybrid-Electric Vehicle (PHEV) Penetration Rate, by Regulatory Fleet

Model year	2022	2027	2028	2029	2030	2031	2032
Passenger Car							
No Action	1.2	0.0	0.0	0.0	0.0	0.0	0.0
PC1LT3	1.2	0.0	0.0	0.0	0.0	0.0	0.0
PC2LT4	1.2	0.0	0.0	0.0	0.0	0.0	0.0
PC3LT5	1.2	0.0	0.0	0.0	0.1	0.1	0.1
PC6LT8	1.2	0.0	0.0	0.2	0.9	1.1	1.4
Light Truck							
No Action	2.0	0.6	0.6	1.1	1.1	4.3	4.3
PC1LT3	2.0	2.6	2.9	4.3	4.6	7.7	9.1
PC2LT4	2.0	2.9	3.6	5.7	6.1	9.4	11.0
PC3LT5	2.0	2.9	2.9	5.3	5.6	9.3	11.6
PC6LT8	2.0	2.9	3.0	6.4	9.4	13.6	16.8

Table IV–8—Estimated Plug-in Hybrid-Electric Vehicle (PHEV) Penetration Rate, Total Light-Duty Fleet

Model year	2022	2027	2028	2029	2030	2031	2032
No Action	1.7	0.4	0.4	0.8	0.8	2.9	2.9
PC1LT3	1.7	1.8	2.0	2.9	3.1	5.2	6.2
PC2LT4	1.7	2.0	2.5	3.9	4.1	6.4	7.5
PC3LT5	1.7	2.0	2.0	3.6	3.9	6.3	7.9
PC6LT8	1.7	2.0	2.1	4.5	6.8	9.6	11.8

Due to the statutory constraints imposed on the analysis by EPCA that exclude consideration of AFVs, BEVs are not a compliance option during the standard setting years. As seen in Table IV–9 and Table IV–10, BEV penetration increases across MYs in the No-Action Alternative. During the standard setting years, BEVs are only added to account for manufacturers' expected response to state ZEV mandates. In MYs *outside* of the standard setting years, BEVs may be added to the No-Action Alternative if they are profit-maximizing for manufacturers to produce for reasons other than the CAFE standards; however, the number of vehicles added in the non-standard-setting years on this basis are very minimal and expected compliance with state ZEV mandates remains responsible for the majority of

BEVs produced during those years. The action alternatives show nearly the same BEV penetration rates as the No-Action Alternative, although in some cases there is a slight deviation, despite no new BEVs entering the fleet, due to rounding in some MYs where fewer vehicles are being sold in response to the proposed standards and altering fleet shares.

TABLE IV–9—ESTIMATED BATTERY ELECTRIC VEHICLE (BEV) PENETRATION RATE, BY REGULATORY FLEET

Model year	2022	2027	2028	2029	2030	2031	2032
Passenger Car							
No Action	12.4	32.0	33.4	35.5	38.1	40.4	42.2
PC1LT3	12.4	32.0	33.4	35.6	38.1	40.5	42.2
PC2LT4	12.4	32.0	33.4	35.6	38.1	40.5	42.2
PC3LT5	12.4	32.0	33.4	35.6	38.1	40.5	42.2
PC6LT8	12.4	32.0	33.4	35.6	38.1	40.5	42.2
Light Truck							
No Action	0.7	17.1	18.5	20.4	22.9	25.5	27.5
PC1LT3	0.7	17.2	18.5	20.4	23.0	25.5	27.5
PC2LT4	0.7	17.2	18.5	20.4	23.0	25.5	27.5
PC3LT5	0.7	17.2	18.5	20.5	23.0	25.5	27.5
PC6LT8	0.7	17.2	18.5	20.5	23.0	25.5	27.5

TABLE IV–10—ESTIMATED BATTERY ELECTRIC VEHICLE (BEV) PENETRATION RATE, TOTAL LIGHT-DUTY FLEET

Model year	2022	2027	2028	2029	2030	2031	2032
No Action	5.2	21.9	23.2	25.2	27.7	30.3	32.3
PC1LT3	5.2	21.9	23.2	25.2	27.8	30.3	32.3
PC2LT4	5.2	21.9	23.2	25.2	27.8	30.3	32.3
PC3LT5	5.2	21.9	23.2	25.2	27.8	30.3	32.3
PC6LT8	5.2	21.9	23.2	25.2	27.7	30.3	32.3

The PRIA provides a longer summary of NHTSA's estimates of manufacturers' potential application of fuel-saving technologies (including other types of technologies, such as advanced transmissions, aerodynamic improvements, and reduced vehicle mass) in response to each regulatory alternative. Appendices I and II of the accompanying PRIA provide more detailed and comprehensive results, and the underlying CAFE Model output files provide all the information used to construct these estimates, including the specific combination of technologies estimated to be applied to every vehicle model/configuration in each of MYs 2022–2050.

NHTSA's analysis shows manufacturers' regulatory costs for compliance with the proposed CAFE standards, combined with existing EPA GHG standards[485] and state ZEV mandates,[486] not surprisingly increasing more under the more stringent alternatives as more fuel-saving technologies would be required. NHTSA estimates manufacturers' *cumulative* regulatory costs across MYs 2027–2032 could total $187b under the No-Action Alternative, and an additional $45b, $63b, $91b, and $177b under alternatives PC1LT3, PC2LT4, PC3LT5, and PC6LT8, respectively, when accounting for fuel-saving technologies added under the simulation for each regulatory alternative (including AC improvements and other off-cycle technologies), and also accounting for CAFE civil penalties that NHTSA estimates some manufacturers could elect to pay rather than achieving full compliance with the proposed CAFE targets in some MYs in some fleets. The table below shows how these costs are estimated to vary among manufacturers, accounting for differences in the quantities of vehicles produced for sale in the U.S. Appendices I and II of the accompanying PRIA present results separately for each manufacturer's passenger car and light truck fleets in each MY under each regulatory alternative, and the underlying CAFE Model output files also show results specific to manufacturers' domestic and imported car fleets.

TABLE IV–11—ESTIMATED CUMULATIVE COSTS ($b) DURING MYS 2027–2032

Manufacturer	No action	Relative to no action			
		PC1LT3	PC2LT4	PC3LT5	PC6LT8
BMW	4.2	0.2	0.5	0.9	2.9
Ford	28.3	8.2	11.1	13.0	24.3
General Motors	26.7	15.1	17.5	22.3	33.3
Honda	13.5	1.1	1.7	4.9	12.8
Hyundai	9.5	8.6	10.4	11.8	17.5

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[485] EPA's proposed MY 2027–2032 CO_2 standards were not modeled for this NPRM combined with CAFE and FE new standards.

[486] NHTSA does not model state GHG programs outside of ZEV. See Chapter 2.2.2.6 of the accompanying Draft TSD for details about how NHTSA models anticipated manufacturer compliance with California's ZEV program.

TABLE IV–11—ESTIMATED CUMULATIVE COSTS ($b) DURING MYS 2027–2032—Continued

Manufacturer	No action	Relative to no action			
		PC1LT3	PC2LT4	PC3LT5	PC6LT8
Kia	4.2	3.3	6.3	8.6	12.9
Jaguar—Land Rover	0.9	0.3	0.5	0.6	1.1
Karma	0.0	0.0	0.0	0.0	0.0
Lucid	0.0	0.0	0.0	0.0	0.0
Mazda	2.6	0.0	0.1	5.7	8.7
Mercedes-Benz	3.8	0.3	0.6	1.0	2.7
Mitsubishi	1.2	0.3	0.4	0.8	1.5
Nissan	14.8	1.2	2.7	3.9	9.2
Stellantis	31.5	4.8	8.5	11.3	25.0
Subaru	11.3	0.0	0.0	0.0	2.9
Tesla	0.0	0.0	0.0	0.0	0.0
Toyota	25.3	−0.1	0.1	2.6	14.6
Volvo	0.8	0.3	0.4	0.6	1.5
VWA	8.6	1.2	2.0	2.9	6.7
Industry Total	187.3	44.9	62.9	90.8	177.4

As discussed in the TSD, these estimates reflect technology cost inputs that, in turn, reflect a ''markup'' factor that includes manufacturers' profits. In other words, if costs to manufacturers are reflected in vehicle price increases, NHTSA estimates that the average costs to new vehicle purchasers could increase through MY 2032 as summarized in Table IV–12 and Table IV–13.

TABLE IV–12—ESTIMATED AVERAGE PER-VEHICLE REGULATORY COST ($), BY REGULATORY FLEET

Model year	2022	2027	2028	2029	2030	2031	2032
Passenger Car							
No Action	159	1,462	1,412	1,389	1,386	1,383	1,312
PC1LT3	159	1,782	1,861	1,867	1,847	1,817	1,731
PC2LT4	159	1,847	1,966	2,087	2,069	2,033	1,966
PC3LT5	159	1,964	2,136	2,373	2,391	2,441	2,517
PC6LT8	159	2,166	2,616	3,175	3,671	4,039	4,393
Light Truck							
No Action	125	2,248	2,239	2,270	2,302	2,484	2,438
PC1LT3	125	2,555	2,696	2,805	2,886	3,078	3,125
PC2LT4	125	2,609	2,826	2,992	3,122	3,369	3,502
PC3LT5	125	2,732	2,990	3,213	3,441	3,740	4,232
PC6LT8	125	2,896	3,360	3,922	4,628	5,281	6,118

TABLE IV–13—ESTIMATED AVERAGE PER-VEHICLE REGULATORY COST ($), TOTAL LIGHT-DUTY FLEET

Model year	2022	2027	2028	2029	2030	2031	2032
No Action	138	1,998	1,977	1,993	2,012	2,132	2,077
PC1LT3	138	2,309	2,432	2,510	2,558	2,676	2,678
PC2LT4	138	2,367	2,555	2,708	2,790	2,942	3,008
PC3LT5	138	2,488	2,720	2,950	3,110	3,326	3,679
PC6LT8	138	2,664	3,126	3,689	4,328	4,886	5,562

Table IV–14 shows how these costs could vary among manufacturers, suggesting that disparities could increase as the stringency of standards increases.

TABLE IV–14—AVERAGE MANUFACTURER PER-VEHICLE COSTS BY ALTERNATIVE, TOTAL LIGHT-DUTY FLEET, MY 2032

[$]

Manufacturer	No action	PC1LT3	PC2LT4	PC3LT5	PC6LT8
BMW	2,066	2,150	2,357	2,646	4,529
Ford	2,384	3,165	3,720	4,183	6,327
General Motors	2,422	4,095	4,469	5,528	7,398

TABLE IV–14—AVERAGE MANUFACTURER PER-VEHICLE COSTS BY ALTERNATIVE, TOTAL LIGHT-DUTY FLEET, MY 2032—Continued

[$]

Manufacturer	No action	PC1LT3	PC2LT4	PC3LT5	PC6LT8
Honda	1,467	1,565	1,701	2,069	3,967
Hyundai	1,786	3,312	3,703	5,390	7,632
Kia	1,151	2,165	3,387	5,888	7,856
Jaguar—Land Rover	1,819	2,657	3,189	3,741	5,697
Karma	−3,543	−3,543	−3,543	−3,543	−3,543
Lucid	−62	−62	−62	−62	−62
Mazda	2,303	2,330	2,366	7,266	11,798
Mercedes-Benz	2,470	2,653	2,836	3,247	5,262
Mitsubishi	1,421	1,969	2,057	3,201	5,088
Nissan	2,363	2,558	2,902	3,203	5,010
Stellantis	2,956	3,807	4,388	4,892	7,459
Subaru	2,384	2,384	2,384	2,389	3,292
Tesla	13	13	13	13	13
Toyota	1,794	1,794	1,867	2,166	3,679
Volvo	1,202	1,517	1,768	2,172	4,068
VWA	2,249	2,635	2,913	3,360	5,346
Industry Average	2,077	2,678	3,008	3,679	5,562

NHTSA estimates that although projected fuel savings under the more stringent regulatory alternatives could tend to increase new vehicle sales, this tendency could be outweighed by the opposing response to higher prices, such that new vehicle sales could decline slightly under the more stringent alternatives. The magnitude of these fuel savings and vehicle price increases depends on manufacturer compliance decisions, especially technology application. In the event that manufacturers select technologies with lower prices and/or higher fuel economy improvements, vehicle sales effects could differ. Draft TSD Chapter 4.2.1.2 discusses NHTSA's approach to estimating new vehicle sales, including NHTSA's estimate that new vehicle sales could recover from 2020's aberrantly low levels.

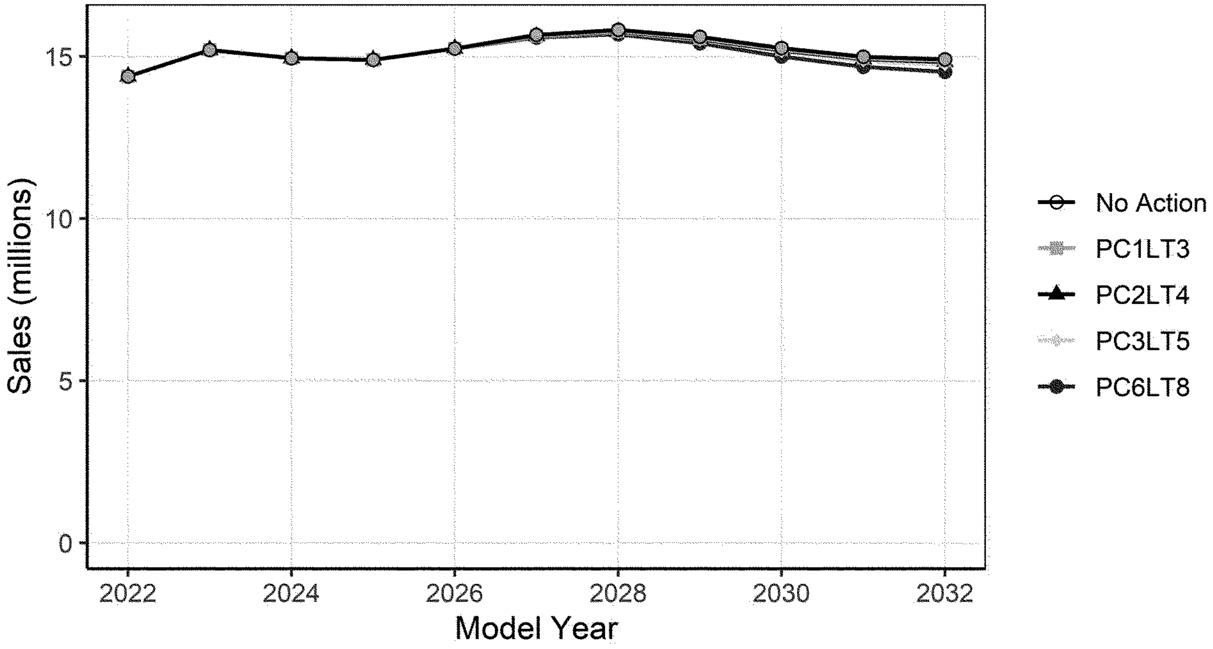

Figure IV-1: Estimated Annual New LDV Sales (Millions)

While these slight reductions in new vehicle sales tend to reduce projected automobile industry labor by small margins, NHTSA estimates that the cost increases could reflect an underlying increase in employment to produce additional fuel-saving technology, such that automobile industry labor could remain about the same under each of the four regulatory alternatives.

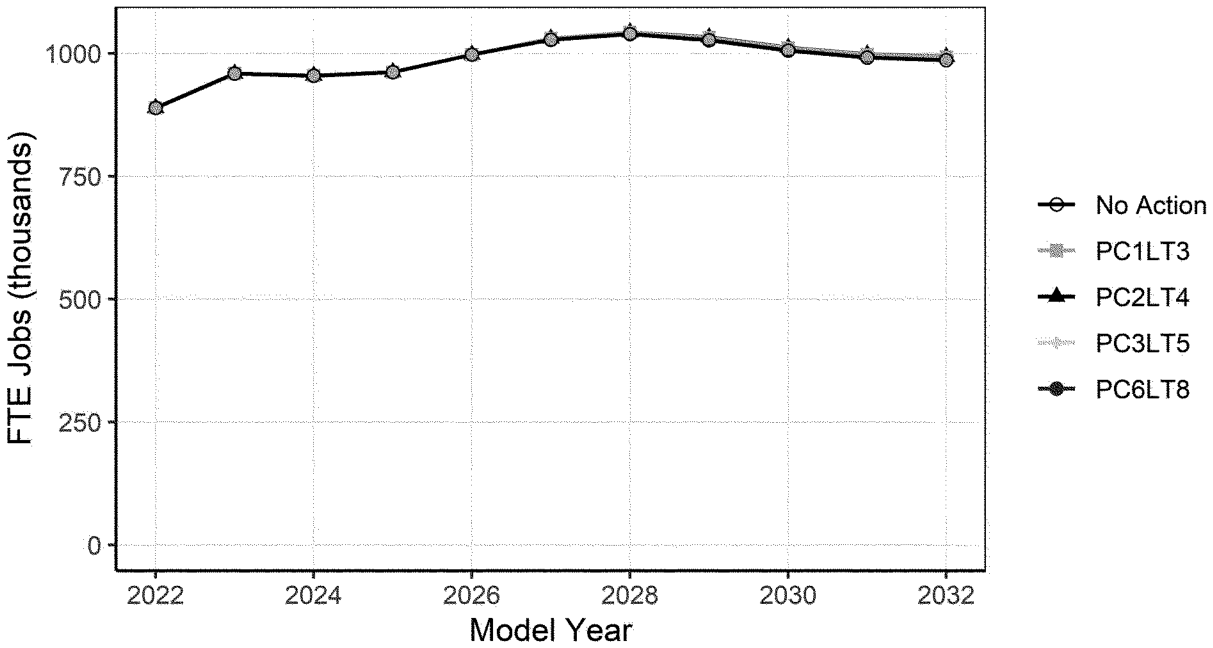

Figure IV-2: Estimated Light-Duty Automobile Industry Labor (as Thousands of Full-Time-Equivalent Jobs)

The accompanying TSD discusses NHTSA's approach to estimating automobile industry employment, and the accompanying PRIA Chapter 8.2 (and its Appendices I and II) and CAFE Model output files provide more detailed results of NHTSA's LD analysis.

2. Heavy-Duty Pickups and Vans

NHTSA is proposing an increase in HDPUV fuel efficiency standards for MYs 2030–2035 relative to the existing standards set in 2016. Unlike the LD CAFE program, NHTSA may consider AFVs when setting maximum feasible average standards for HDPUVs. Additionally, for purposes of calculating average fuel efficiency for HDPUVs, NHTSA considers EVs, fuel cell vehicles, and the proportion of electric operation of EVs and PHEVs that is derived from electricity that is generated from sources that are not onboard the vehicle to have a fuel efficiency value of 0 grams/mile. Each of the regulatory alternatives that NHTSA is considering in this proposal would increase the stringency of fuel efficiency standards for HDPUVs starting in MY 2030, with increases each year through MY 2035.

NHTSA recognizes that it is possible that the size and composition of the fleet (*i.e.,* in terms of vehicle attributes that impact calculation of standards for averaging sets) could change over time, affecting the currently-estimated average fuel efficiency requirements. If fleet changes ultimately differ from NHTSA's projections, average requirements could, therefore, also differ from NHTSA's projections. The table below includes the estimated required average fuel efficiency values for the HDPUV fleet in each of the regulatory alternatives considered in this proposal.

TABLE IV–15—ESTIMATED REQUIRED AVERAGE FUEL EFFICIENCY (gal/100mi), TOTAL HDPUV FLEET

Model year	2022	2030	2031	2032	2033	2034	2035
No Action	5.497	4.920	5.003	5.002	4.962	4.962	4.965
HDPUV4	5.497	4.723	4.610	4.425	4.214	4.046	3.886
HDPUV10	5.497	4.427	4.051	3.646	3.255	2.930	2.638
HDPUV14	5.497	4.231	3.684	3.167	2.702	2.324	1.999

As with the LD program, manufacturers do not always comply exactly with each fuel efficiency standard in each MY. Manufacturers may bank credits from overcompliance in one year that may be used to cover shortfalls in up to five future MYs. Manufacturers may also carry forward credit deficits for up to three MYs. If a manufacturer is still unable to address the shortfall, NHTSA may assess civil penalties. As discussed in the accompanying PRIA and Draft TSD, NHTSA simulates manufacturers' responses to each alternative given a wide range of input estimates (*e.g.,* technology cost and effectiveness, fuel prices, electrification technologies). For this proposed rule, NHTSA estimates that manufacturers' responses to standards defining each alternative could lead average fuel efficiency levels to improve through MY 2035, as shown in the following tables.

TABLE IV–16—ESTIMATED ACHIEVED AVERAGE FUEL EFFICIENCY (GAL/100mi), TOTAL HDPUV FLEET

Model year	2022	2030	2031	2032	2033	2034	2035
No Action	5.528	3.270	2.771	2.766	2.229	2.229	2.225
HDPUV4	5.528	3.269	2.769	2.764	2.227	2.227	2.223
HDPUV10	5.528	3.266	2.764	2.759	2.160	2.157	2.153
HDPUV14	5.528	3.265	2.632	2.627	1.972	1.972	1.878

Table IV–16 displays the projected achieved FE levels for the HDPUV fleet through MY 2035. Estimates of achieved levels are very similar between the No-Action Alternative and the least stringent Action Alternative. The narrow band of estimated average achieved levels in Table IV–16 is primarily due to several factors. Relative to the LD fleet, the HDPUV fleet (i) represents a smaller number of vehicles, (ii) includes fewer manufacturers, and (iii) is composed of a smaller number of manufacturer product lines. Technology choices for an individual manufacturer or individual product line can therefore have a large effect on fleet-wide average fuel efficiency. Second, Table IV–17 shows that in the No-Action Alternative a substantial portion of the fleet converts to an electrified powertrain (*e.g.,* SHEV, PHEV, BEV) between MY 2022 and MY 2030. This reduces the availability of, and need for,[487] additional fuel efficiency improvement to meet more stringent standards.

TABLE IV–17: APPLICATION LEVELS OF SELECTED TECHNOLOGIES BY MODEL YEAR FOR HDPUV FLEET

	2022 (%)	2030 (%)	2031 (%)	2032 (%)	2033 (%)	2034 (%)	2035 (%)	2036 (%)	2037 (%)	2038 (%)
Technology Application Levels in the No-Action Alternative										
Strong Hybrid (all types)	0	26	36	36	26	26	26	26	26	26
PHEV (all types)	0	0	4	4	13	13	13	13	9	9
BEV (all types)	6	31	35	35	41	41	41	41	45	45
Advanced Engines	40	21	7	6	3	3	3	3	3	3
Technology Application Levels Relative to the No-Action Alternative										
HDPUV4:										
Strong Hybrid (all types)	....	0	0	0	0	0	0	0	0	0
PHEV (all types)	....	0	0	0	0	0	0	0	0	0
BEV (all types)	....	0	0	0	0	0	0	0	0	0
Advanced Engines	....	0	0	0	0	0	0	0	0	0
HDPUV10:										
Strong Hybrid (all types)	....	0	0	0	0	0	0	0	0	0
PHEV (all types)	....	0	0	0	1	1	1	1	1	1
BEV (all types)	....	0	0	0	0	0	0	0	0	0
Advanced Engines	....	0	0	0	1	2	2	2	2	2
HDPUV14:										
Strong Hybrid (all types)	....	0	0	0	0	0	0	0	0	0
PHEV (all types)	....	0	0	0	2	2	4	4	4	4
BEV (all types)	....	0	3	3	3	3	3	3	3	3
Advanced Engines	....	0	−2	−2	4	4	10	10	10	10

Note: "advanced engines" represents the combined penetration of advanced cylinder deactivation, advanced turbo, variable compression ratio, high compression ratio, and diesel engines.[488]

In line with the technology application trends above, regulatory costs do not differ by large amounts between the No-Action Alternative and the proposed action alternatives. Most of the differences in regulatory costs occur in the HDPUV14 alternative and are concentrated in a few manufacturers (*e.g.,* Ford, GM), where the compliance modeling projects increases in PHEV, BEV, and advanced engine technologies.

TABLE IV–18—TOTAL REGULATORY COST BY MANUFACTURER, MY 2022–2038 (IN BILLIONS)

Manufacturer	No action	Relative to no action		
		HDPUV4	HDPUV10	HDPUV14
Ford	11.99	0.03	0.07	0.71
GM	0.66	0.00	0.86	4.02
Mercedes-Benz	0.67	0.00	0.00	0.00

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[487] The need for further improvements in response to more stringent HDPUV standards is further reduced by the fact that NHTSA regulations currently grant BEVs (and the electric-only operation of PHEVs) an HDPUV compliance value of 0 gallons/100 miles, a significant adjustment on which NHTSA seeks comment elsewhere in this document.

[488] Specifically, this includes technologies with the following codes in the CAFE Model: TURBO0, TURBOE, TURBOD, TURBO1, TURBO2, ADEACD, ADEACS, HCR, HRCE, HCRD, VCR, VTG, VTGE, TURBOAD, ADSL, DSLI.

TABLE IV–18—TOTAL REGULATORY COST BY MANUFACTURER, MY 2022–2038 (IN BILLIONS)—Continued

Manufacturer	No action	Relative to no action		
		HDPUV4	HDPUV10	HDPUV14
Nissan	1.17	0.00	0.00	0.00
Rivian	0.00	0.00	0.00	0.00
Stellantis	4.61	0.00	0.00	0.00
Total	19.11	0.03	0.93	4.72

On a per-vehicle basis, costs are minimal in HDPUV4 and increase with stringency and across MYs in HDPUV10 and HDPUV14.

TABLE IV–19—ESTIMATED AVERAGE PER-VEHICLE REGULATORY COST ($), TOTAL HDPUV FLEET

	2022	2030	2031	2032	2033	2034	2035
No Action	0	1,760	1,797	1,604	2,459	2,222	1,999
HDPUV4	0	3	3	3	4	4	4
HDPUV10	0	8	14	14	148	148	142
HDPUV14	0	33	352	334	563	540	697

The relatively similar responses across action alternatives carry over to the analysis of the sales and labor market as well. The increase in sales in the No Action Alternative carries over to each of the action alternatives as well. The vehicle-level price increases noted above produces very small declines in overall sales.

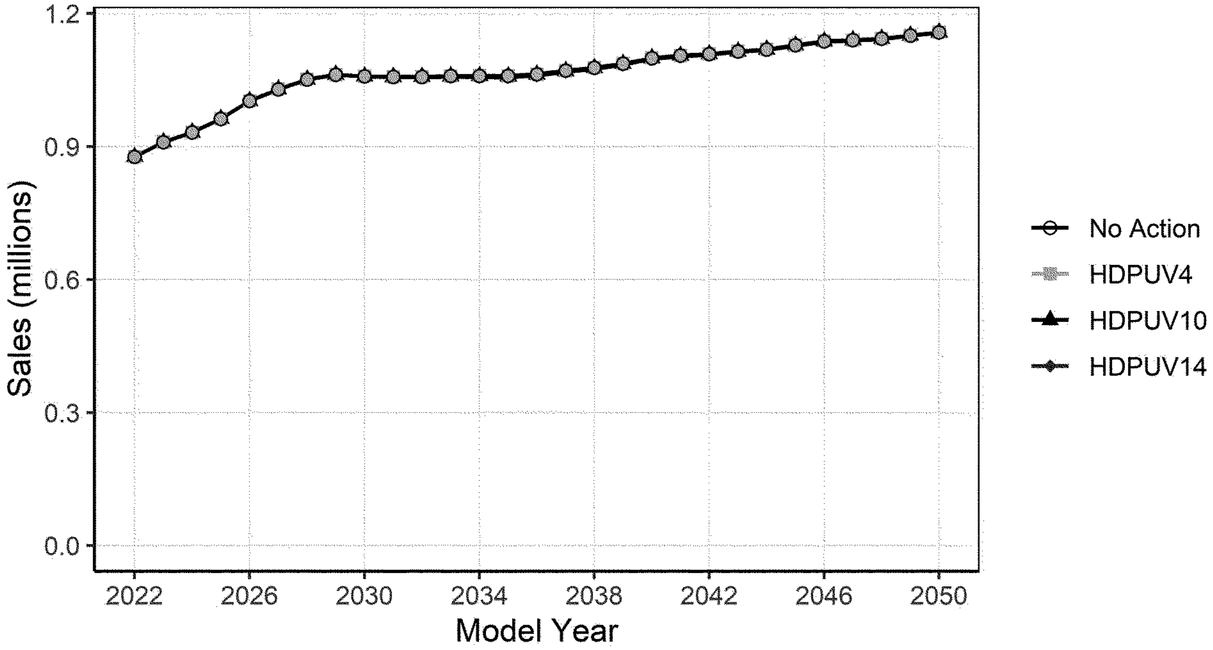

Figure IV-3: Estimated Annual New HDPUV Vehicle Sales (Millions)

These sales declines and limited additional technology application produce small decreases in labor utilization, as the sales effect ultimately outweighs job gains due to development and application of advanced technology. In aggregate, the alternatives represent less than half of a percentage point deviation from the No-Action Alternative.

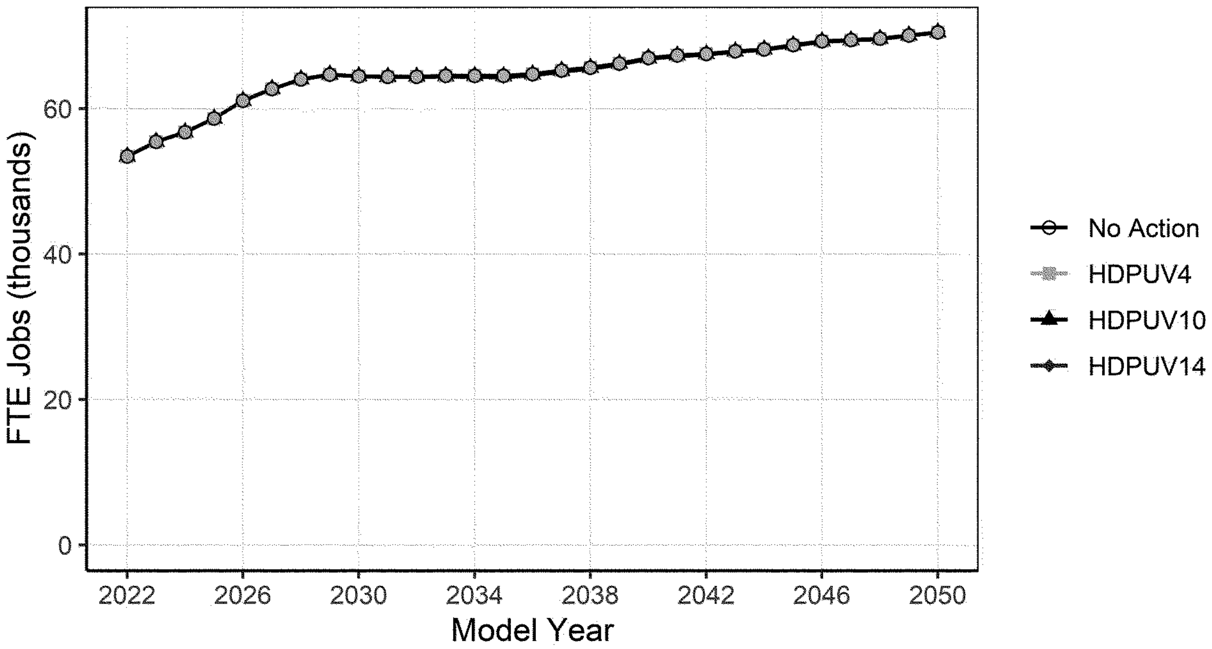

Figure IV-4: Estimated HDPUV Automobile Industry Labor (as Thousands of Full-Time-Equivalent Jobs)

The accompanying Draft TSD Chapter 6.2.5 discusses NHTSA's approach to estimating automobile industry employment, and the accompanying PRIA Chapter 8.3 (and its Appendix III) and CAFE Model output files provide more detailed results of NHTSA's HDPUV analysis.

B. Effects on Society

NHTSA accounts for the effects on society of the standards by using a benefit/cost categories framework. These categories include private costs borne by manufacturers and consumers, SCs to society, which include external and Government costs, pertaining to emissions, congestion, noise, energy security, and safety, and all the benefits resulting from related categories in the form of savings, however they may occur across the presented alternatives. In this accounting framework, the CAFE Model records costs and benefits for particular MYs in the LD fleet but also reports these measures over the lifetime of the vehicle and allows for the accounting of costs and benefits across calendar years. Examining program effects through this lens illustrates the temporal differences in major cost and benefit components. In the HDPUV FE analysis, where the proposed standard would continue until otherwise amended, we report only the costs and benefits across calendar years.

1. Passenger Cars and Light Trucks

We split effects on society into private costs, SCs, private benefits, and external benefits. Table IV–20 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 directly contribute to the calculation of net benefits (and are omitted from the tables below).

While incremental maintenance and repair costs and benefits would accrue to buyers of new cars and trucks affected by more stringent CAFE standards, we do not carry these impacts in the analysis. They are difficult to estimate but represent real costs (and potential benefits in the case of AFVs that require less frequent maintenance events). They may be included in future analyses as data become available to evaluate lifetime maintenance impacts. 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 fuel prices (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 light trucks—there are other benefits and costs from increasing CAFE standards that are borne more broadly throughout the economy or society, which NHTSA refers to as SCs.[489] 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. We also include transfers from one party to another other than those directly incurred by manufacturers or new vehicle buyers, the largest of which is the loss in fuel tax revenue that occurs as a result of falling fuel consumption.[490] Buyers of new cars and light trucks produced in MYs subject to increasing CAFE standards save on fuel purchases that include Federal, state, and sometimes local 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, but is offset by the benefits gained by drivers who spend less at the pump.[491]

Among the purely external benefits created when CAFE standards are increased, the largest is the reduction in damages resulting from GHG emissions. Table IV–20 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 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.

Table IV–20 shows that the social and SCC–GHG DRs have a significant impact on the estimated costs and benefits. With the exception of the highest SCC–GHG DR, net social benefits are positive for all alternatives at both the 3 percent and 7 percent social DRs. Net benefits are higher when assessed at a 3 percent social DR since the largest benefit—fuel savings—are accrued over a prolonged period, while the largest cost—technology costs—are accrued predominantly in earlier years. In the cases with the highest SCC–GHG DR (5%), net benefits are still positive in the lower stringent alternatives (PC1LT3 and PC2LT4) at a 3 percent social DR. Totals in the following table may not sum perfectly due to rounding.

TABLE IV–20—INCREMENTAL BENEFITS AND COSTS OVER THE LIFETIMES OF TOTAL FLEET PRODUCED THROUGH MY 2032 (2021$ BILLIONS), BY ALTERNATIVE

	3% Discount rate				7% Discount rate			
	PC1LT3	PC2LT4	PC3LT5	PC6LT8	PC1LT3	PC2LT4	PC3LT5	PC6LT8
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

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[489] 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.

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

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

TABLE IV–20—INCREMENTAL BENEFITS AND COSTS OVER THE LIFETIMES OF TOTAL FLEET PRODUCED THROUGH MY 2032 (2021$ BILLIONS), BY ALTERNATIVE—Continued

	3% Discount rate				7% Discount rate			
	PC1LT3	PC2LT4	PC3LT5	PC6LT8	PC1LT3	PC2LT4	PC3LT5	PC6LT8
Reduced Climate Damages								
SC–GHG @5% DR	2.7	3.5	4.0	5.5	2.7	3.5	4.0	5.5
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

2. Heavy-Duty Pickups and Vans

Our categorizations of benefits and costs in the HDPUV space mirrors the approach taken above for the LD passenger trucks and vans. Table IV–21 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 efficiency. We assume that those costs are fully passed through to new HDPUV buyers, in the form of higher prices.

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 IV–21—INCREMENTAL BENEFITS AND COSTS FROM CALENDAR YEARS 2022–2050

	3% Discount rate			7% Discount Rate		
Alternative	HDPUV4	HDPUV10	HDPUV14	HDPUV4	HDPUV10	HDPUV14
Private Costs						
Technology Costs to Increase Fuel Economy	0.05	1.28	5.81	0.02	0.64	3.02
Increased Maintenance and Repair Costs	0	0	0	0	0	0
Sacrifice in Other Vehicle Attributes	0	0	0	0	0	0
Consumer Surplus Loss from Reduced New Vehicle Sales	0	0	0	0	0	0
Safety Costs Internalized by Drivers	0	0.12	0.64	0	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	0.01	0.07	0	0.01	0.04
Safety Costs Not Internalized by Drivers	0	−0.10	−0.50	0	−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	0.3	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	1.3	6.15
Benefits from Additional Driving	0.01	0.26	1.36	0	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

TABLE IV–21—INCREMENTAL BENEFITS AND COSTS FROM CALENDAR YEARS 2022–2050—Continued

	3% Discount rate			7% Discount Rate		
Alternative	HDPUV4	HDPUV10	HDPUV14	HDPUV4	HDPUV10	HDPUV14
External Benefits						
Reduction in Petroleum Market Externality	0.01	0.15	0.67	0	0.07	0.30
Reduced Health Damages	0	0.05	0.22	0	0.02	0.08
Reduced Climate Damages.						
SC–GHG @5% DR	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
SC–GHG @95th pctile at 3% DR	0.11	4.24	17.10	0.11	3.43	14.55

C. Physical and Environmental Effects

1. Passenger Cars and Light Trucks

NHTSA estimates various physical and environmental effects associated with the proposed standards. These include quantities of fuel and electricity consumed, GHGs and criteria pollutants reduced, and health and safety impacts. Table IV–22 shows the cumulative impacts grouped by decade, including the on-road fleet sizes, VMT, fuel consumption, and CO_2 emissions, across alternatives. The size of the on-road fleet increases in later decades regardless of alternative, but the greatest on-road fleet size projection is seen in the baseline, with fleet sizes declining as the alternatives become increasingly more stringent.

VMT increases occur in the two later decades, with the highest miles occurring from 2041–2050. Fuel consumption (measured in gallons or gasoline gallon equivalents) declines across both decades and alternatives as the alternatives become more stringent, as do GHG emissions.

TABLE IV–22—CUMULATIVE EFFECTS FOR ALL ALTERNATIVES BY CALENDAR YEAR COHORT

	No action	PC1LT3	PC2LT4	PC3LT5	PC6LT8
On-Road Fleet (Million Units)[492]					
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)[493]					
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

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[492] These rows report total vehicle units observed during the period. For example, 2,393 million units are modeled in the on-road fleet for CYs 2022–2030. On average, this represents approximately 266 million vehicles in the on-road fleet for each calendar year in this CY cohort.

[493] These rows report total miles traveled during the period. For example, 28,057 billion miles traveled in CYs 2022–2030. On average, this represents approximately 3,117 billion annual miles traveled in this CY cohort.

TABLE IV–22—CUMULATIVE EFFECTS FOR ALL ALTERNATIVES BY CALENDAR YEAR COHORT—Continued

	No action	PC1LT3	PC2LT4	PC3LT5	PC6LT8
2041–2050	7,633	7,252	7,116	6,931	6,352

From a calendar year perspective, NHTSA's analysis estimates total annual consumption of fuel by the entire on-road fleet from calendar year 2022 through calendar year 2050. On this basis, gasoline and electricity consumption by the U.S. LDV fleet evolves as shown in Figure IV–5 and Figure IV–6, each of which shows projections for the No-Action Alternative (Alternative 0, *i.e.,* the baseline), Alternative PC1LT3, Alternative PC2LT4, Alternative PC3LT5, and Alternative PC6LT8. Gasoline consumption decreases over time, with the largest decreases occurring in more stringent alternatives. Electricity consumption increases over time, with the same pattern of Alternative PC6LT8 experiencing the highest magnitude of change.

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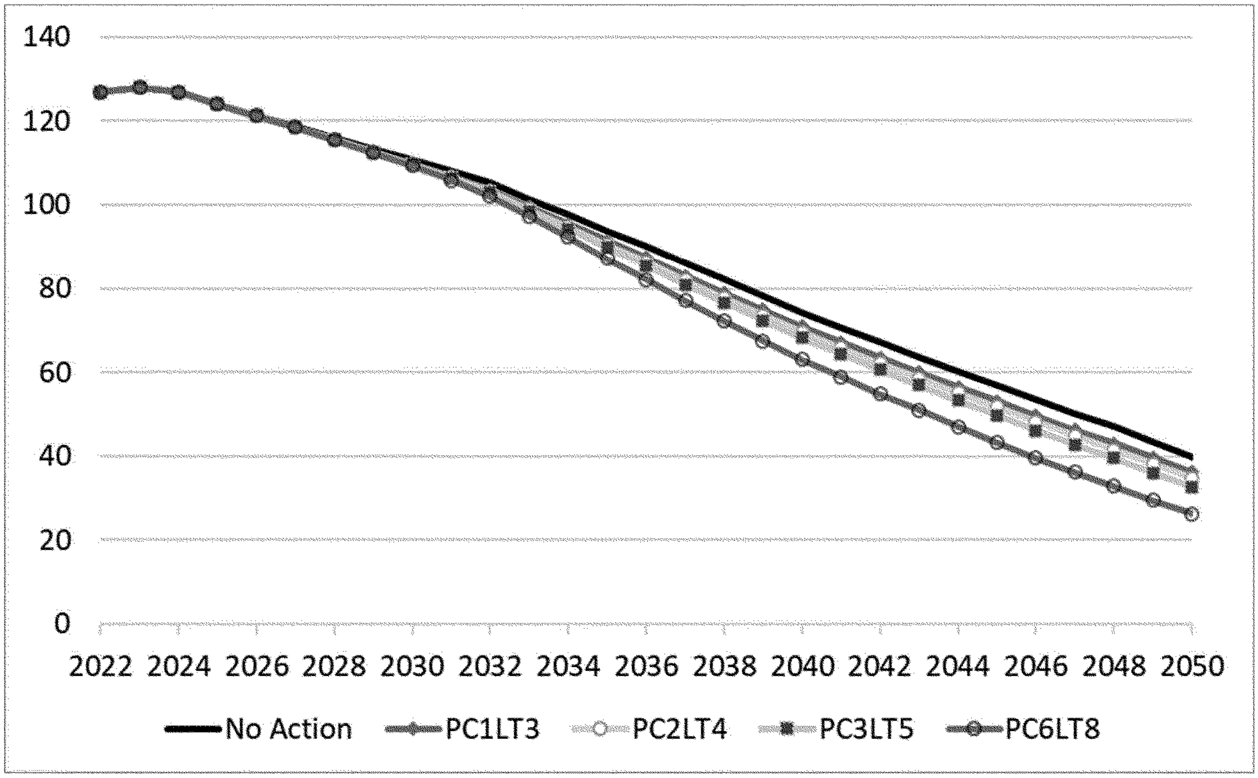

Figure IV-5: Gasoline Consumption by Calendar Year and Alternative (Billions of Gallons)

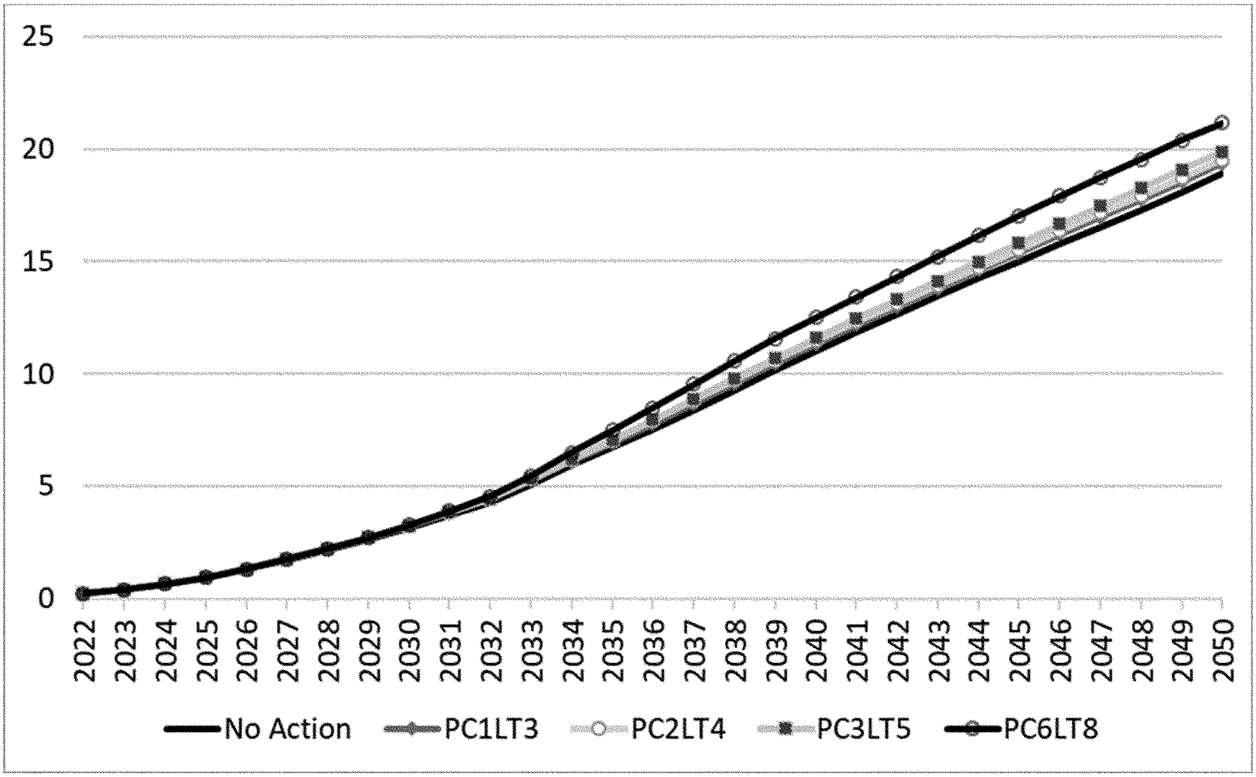

Figure IV-6: Electricity Consumption by Calendar Year and Alternative (Billions of Gasoline Gallon Equivalents)

NHTSA estimates the GHGs attributable to the LD on-road fleet, from both vehicles and upstream energy sector processes (*e.g.,* petroleum refining, fuel transportation and distribution, electricity generation). Figure IV–7, Figure IV–8, and Figure IV–9 present NHTSA's estimate of how emissions from these three GHGs across all fuel types could evolve over the years. Note that these graphs include emissions from both downstream (powertrain and BTW) and upstream processes. All three GHG emissions follow similar trends of decline in the years between 2022–2050. Note that CO_2 emissions are expressed in units of million metric tons (mmt) while emissions from other pollutants are expressed in metric tons.

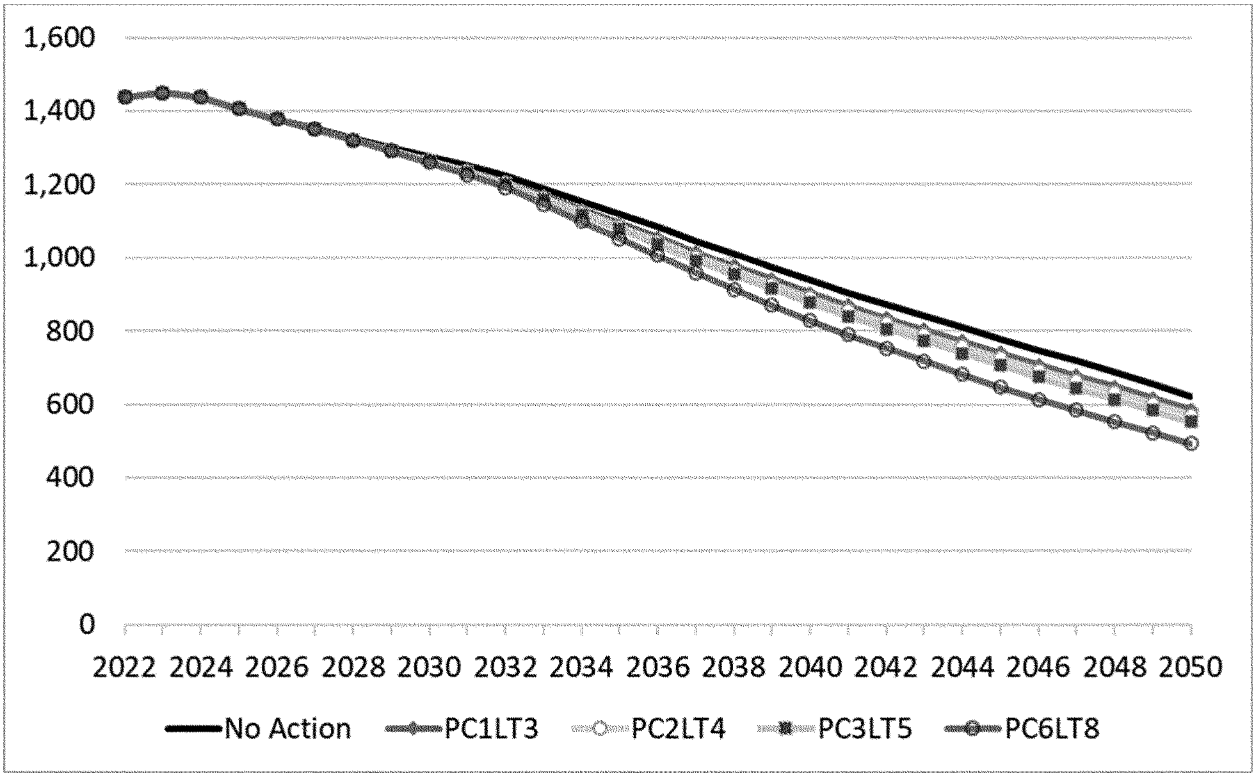

Figure IV-7: Total CO_2 Emissions by Calendar Year and Alternative (Million Metric Tons)

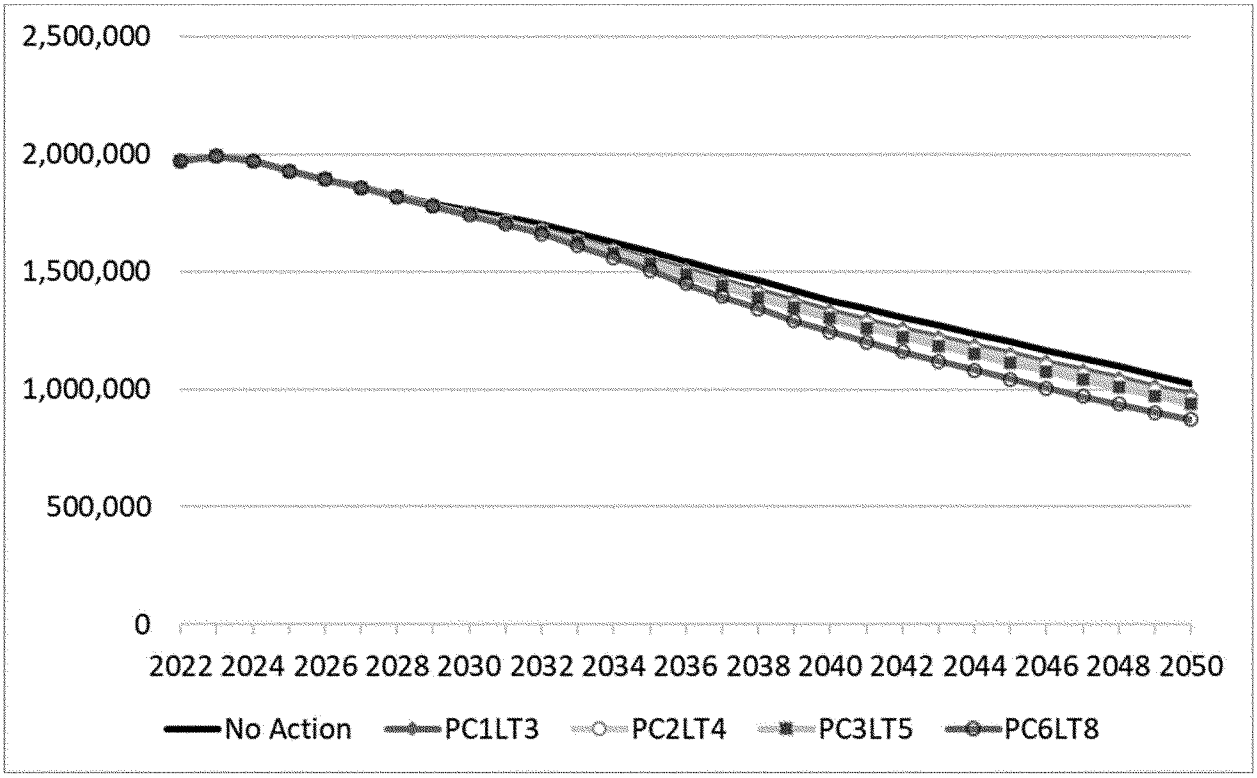

Figure IV-8: Total CH_4 Emissions by Calendar Year and Alternative (Tons)

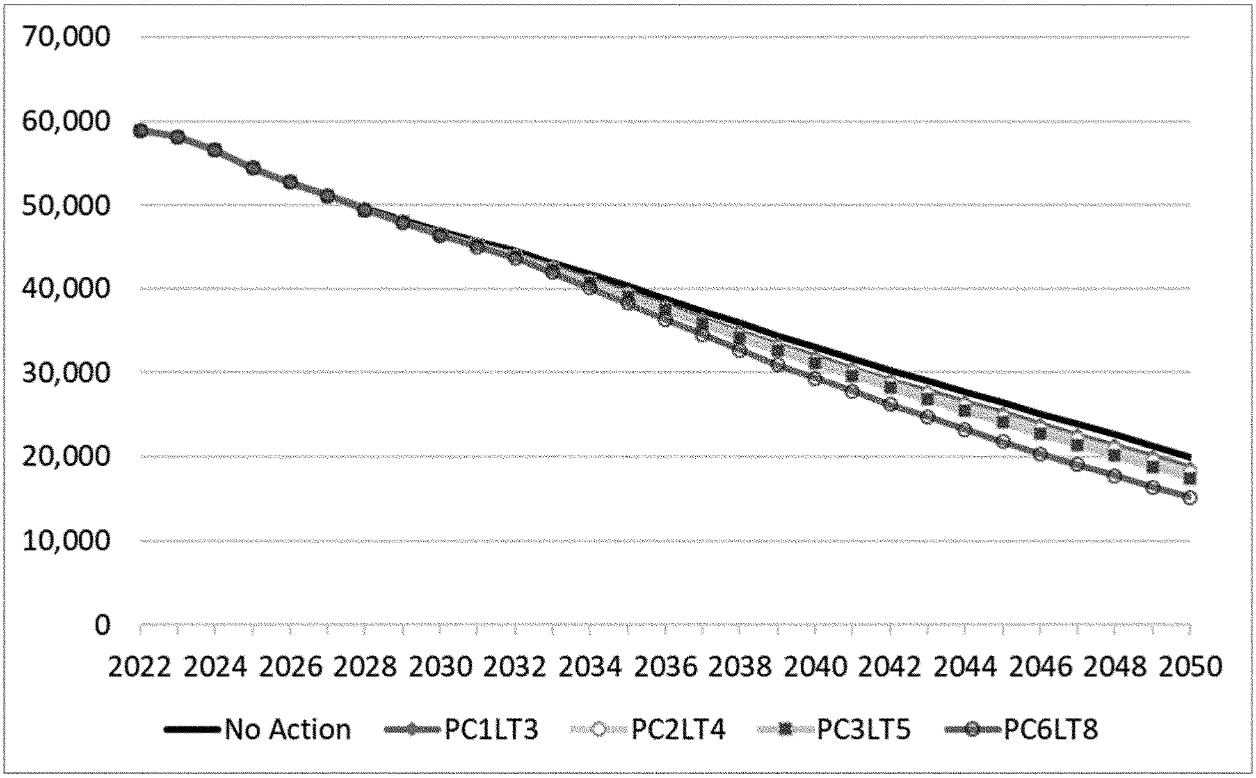

Figure IV-9: Total N_2O Emissions by Calendar Year and Alternative (Tons)

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The figures presented here are not the only estimates NHTSA calculates regarding projected GHG emissions in future years. The accompanying Draft EIS uses an ''unconstrained'' analysis as opposed to the ''standard setting'' analysis presented in this proposal. For more information regarding projected GHG emissions, as well as model-based estimates of corresponding impacts on several measures of global climate change, see the Draft EIS.

NHTSA also estimates criteria pollutant emissions resulting from downstream (powertrain and BTW) and upstream processes attributable to the LD on-road fleet. Under each regulatory alternative, NHTSA projects a dramatic decline in annual emissions of NO_X, and $PM_{2.5}$ attributable to the LD on-road fleet between 2022 and 2050. As exemplified in Figure IV–10, NO_X emissions in any given year could be very nearly the same under each regulatory alternative.

On the other hand, as discussed in the PRIA Chapter 8.2 and Chapter 4 of the Draft EIS accompanying this document, NHTSA projects that annual SO_2 emissions attributable to the LD on-road fleet could increase by 2050 in all of the alternatives, including the baseline, due to greater use of electricity for PHEVs and BEVs (See Figure IV–6). Differences between the action alternatives are modest. However, we also note that the adoption of actions that result in a cleaner electricity grid that reduces electricity generation emission rates below the projected levels underlying NHTSA's analysis (discussed in the Draft TSD) could dramatically reduce SO_2 emissions under all regulatory alternatives considered here.[494] We note that recent projections available since NHTSA finished modeling for this proposal show notable decreases in power sector emissions that would likely affect the CAFE Model emissions results. NHTSA intends to analyze these projections and update them for the final rule. Moreover, NHTSA notes that the projected increase in SO_2 emissions is not observed in analyses using more up-to-date data.

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[494] Other actions, such as President Biden's E.O.s regarding Federal clean electricity, vehicle procurement, and sustainability, may significantly alter the emissions pattern of the electrical grid. See, *e.g. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/.* See also, *https://www.whitehouse.gov/briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/.* AEO 2023 forecasts show that America's grid is likely to get cleaner in the forthcoming years, significantly reducing anticipated emissions as compared to today.

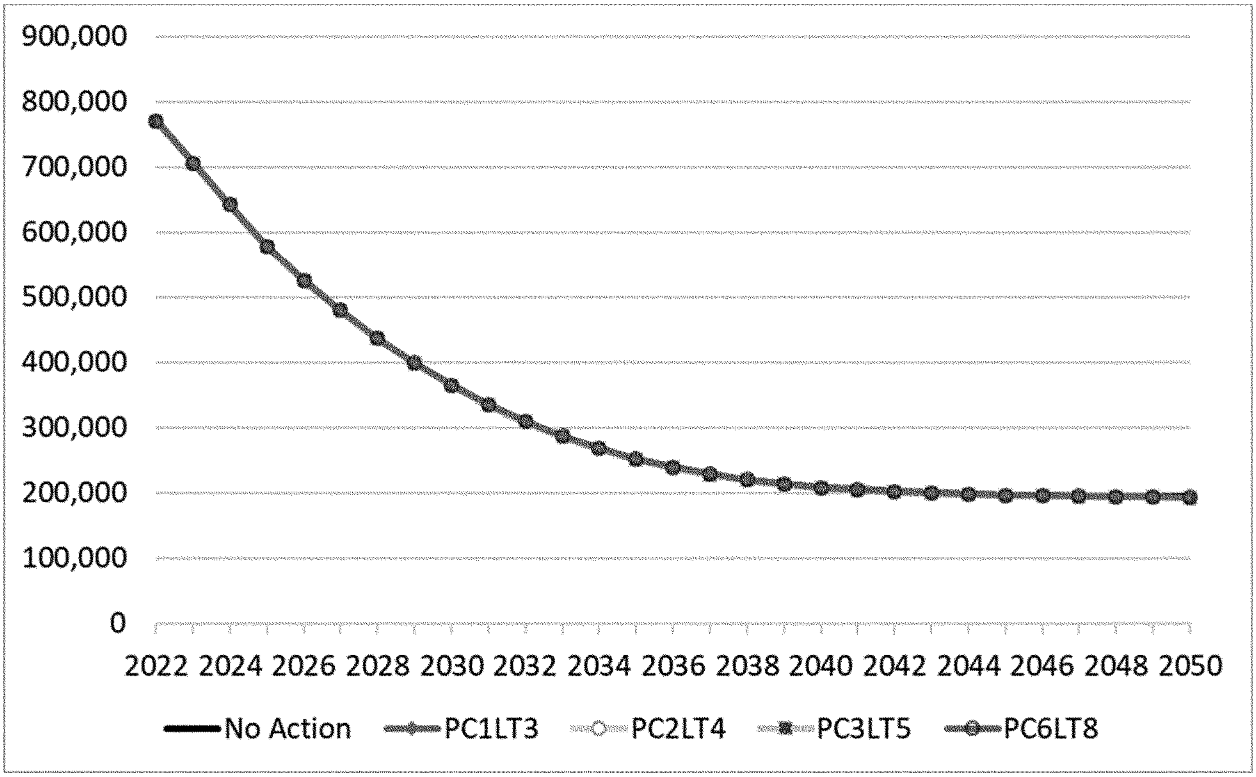

Figure IV-10: Total NOx Emissions by Calendar Year and Alternative (Tons)

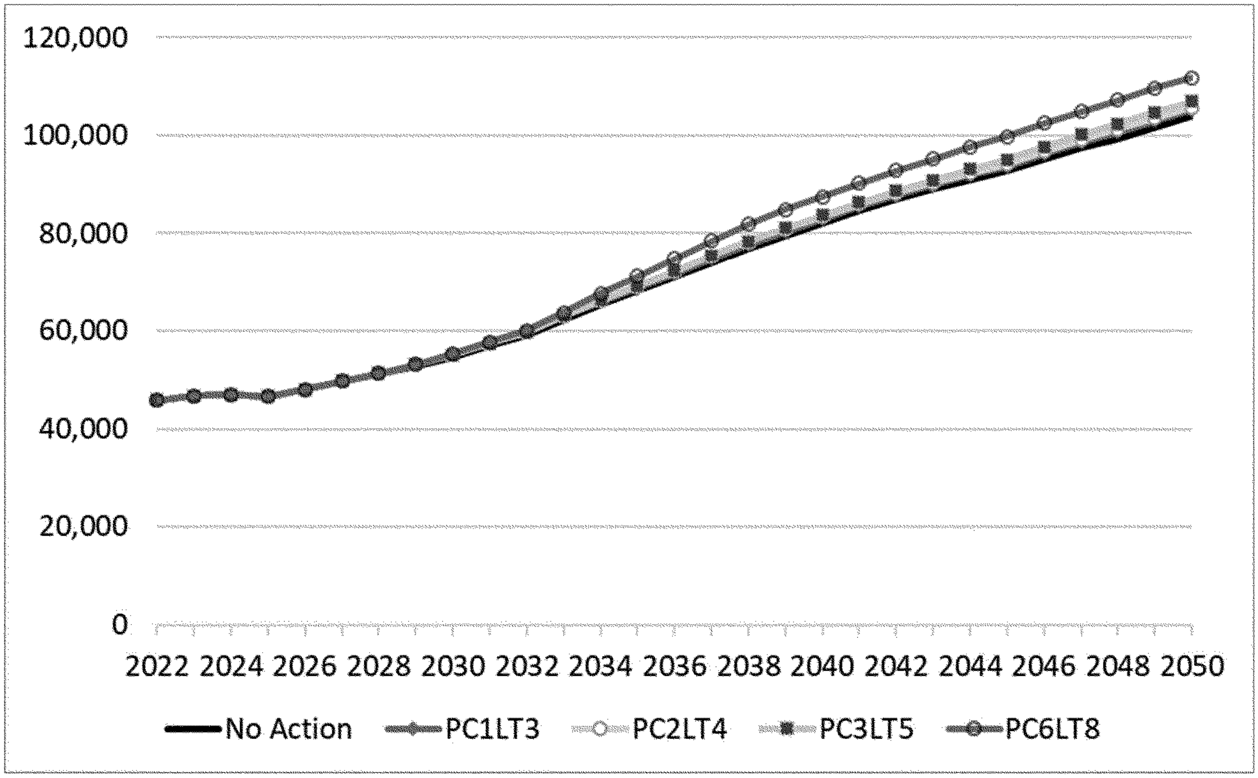

Figure IV-11: Total SO_2 Emissions by Calendar Year and Alternative (Tons)

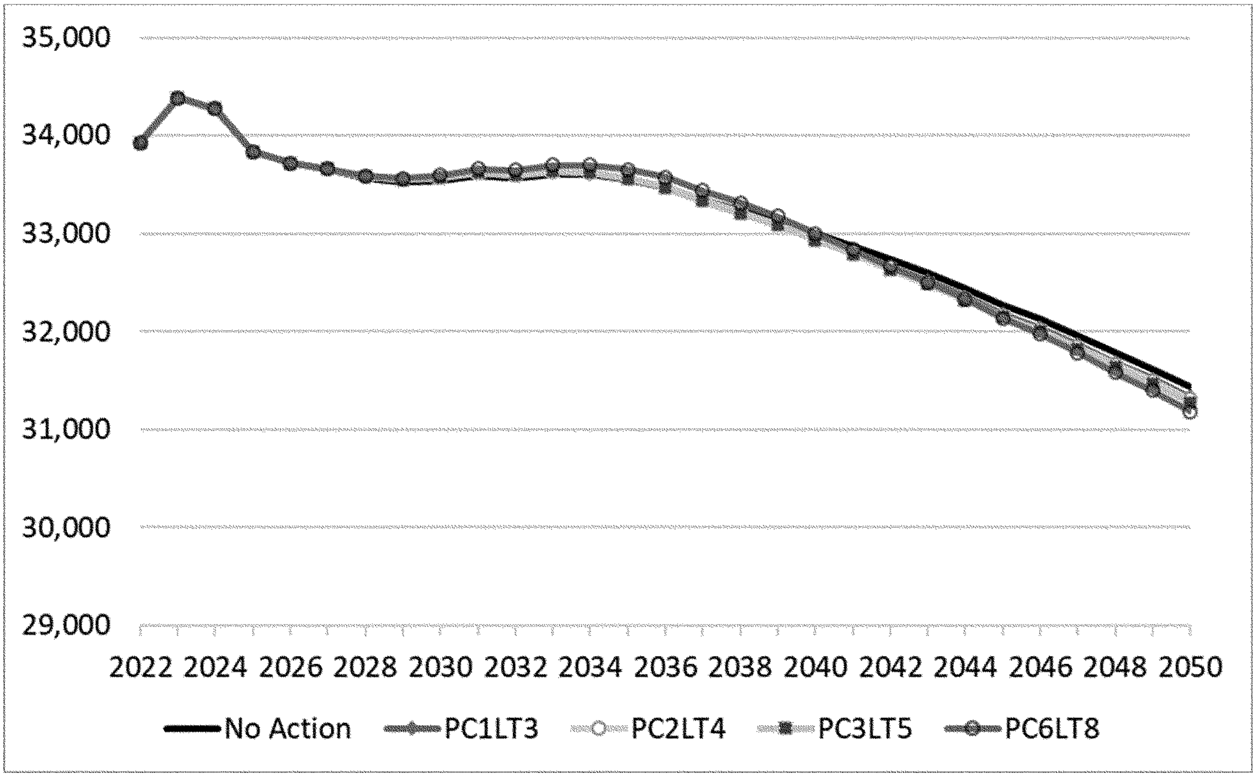

Figure IV-12: Total $PM_{2.5}$ Emissions by Calendar Year and Alternative (Tons)

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Health impacts quantified by the CAFE Model include various instances of hospital visits due to respiratory problems, minor restricted activity days, non-fatal heart attacks, acute bronchitis, premature mortality, and other effects of criteria pollutant emissions on health. Table IV–23 shows the split in select health impacts relative to the No-Action Alternative, across all action alternatives. The magnitude of the differences relates directly to the changes in tons of criteria pollutants emitted. The magnitudes differ across health impact types because of variation in the baseline totals; for example, the total Minor Restricted Activity Days are much higher than the Respiratory Hospital Admissions. See Chapter 5.4 of the Draft TSD for information regarding how the CAFE Model calculates these health impacts.

TABLE IV–23—EMISSION HEALTH IMPACTS ACROSS ALTERNATIVES RELATIVE TO THE NO-ACTION ALTERNATIVE

[CY 2022–2050]

Measure (Incidents)	PC1LT3	PC2LT4	PC3LT5	PC6LT8
Premature Deaths	−279	−367	−499	−1,037
Respiratory Emergency Room Visits	−184	−245	−330	−697
Acute Bronchitis	−458	−609	−823	−1,771
Lower Respiratory Symptoms	−5,806	−7,729	−10,444	−22,464
Upper Respiratory Symptoms	−8,307	−11,068	−14,949	−32,232
Minor Restricted Activity Days	−265,774	−355,489	−478,650	−1,038,111
Work Loss Days	−45,040	−60,215	−81,093	−175,702
Asthma Exacerbation	−9,804	−13,064	−17,644	−38,030
Cardiovascular Hospital Admissions	−73	−96	−130	−271
Respiratory Hospital Admissions	−69	−91	−124	−257
Non-Fatal Heart Attacks (Peters)	−291	−383	−520	−1,083
Non-Fatal Heart Attacks (All Others)	−31	−41	−55	−115

Lastly, NHTSA also quantifies safety impacts in its analysis. These include estimated counts of fatalities, non-fatal injuries, and property damage crashes occurring over the lifetimes of the LD on-road vehicles considered in the analysis. The following table shows the changes in these counts projected in action alternatives relative to the baseline.

TABLE IV–24—CHANGE IN SAFETY OUTCOMES ACROSS ALTERNATIVES RELATIVE TO THE NO-ACTION ALTERNATIVE
[CY 2022–2050]

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	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	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	230,079	315,523	420,494	648,413

Chapter 7.1.5 of the PRIA accompanying this document contains an in-depth discussion on the effects of the various alternatives on these safety measures, and Chapter 7 of the Draft TSD contains information regarding the construction of the safety estimates.

2. Heavy-Duty Pickups and Vans

NHTSA estimates the same physical and environmental effects for HDPUVs as it does for LDVs, including: quantities of fuel and electricity consumption; tons of GHG emissions and criteria pollutants reduced; and health and safety impacts. Table IV–22 shows the cumulative impacts grouped by decade, including the on-road fleet sizes, VMT, fuel consumption, and CO_2 emissions, across alternatives. The size of the on-road fleet increases in later decades regardless of the alternative, but the greatest on-road fleet size projection is seen in the baseline, with fleet sizes declining in the most stringent scenario, Alternative HDPUV14. The other differences between the alternatives are not visible in the Table IV–25 due to rounding.

VMT increases occur in the two later decades, with the highest numbers occurring from 2041–2050. Across alternatives, the VMT increases remain around approximately the same magnitude. Fuel consumption (measured in gallons or gasoline gallon equivalents) declines across decades, as do GHG emissions. Differences between the alternatives are minor but fuel consumption and GHG emissions also decrease as alternatives become more stringent.

TABLE IV–25—CUMULATIVE IMPACTS FOR ALL ALTERNATIVES BY CALENDAR YEAR COHORT

	No action	HDPUV4	HDPUV10	HDPUV14
On-Road Fleet (Million Units) [495]				
2022–2030	152	152	152	152
2031–2040	187	187	187	187
2041–2050	208	208	208	207
Vehicle Miles Traveled (Billion Miles) [496]				
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

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[495] These rows report total vehicle units observed during the period. For example, 152 million units are modeled in the on-road fleet for CYs 2022–2030. On average, this represents approximately 17 million vehicles in the on-road fleet for each calendar year in this CY cohort.

[496] These rows report total miles traveled during the period. For example, 2,040 billion miles traveled in CYs 2022–2030. On average, this represents approximately 227 billion annual miles traveled in this CY cohort.

TABLE IV–25—CUMULATIVE IMPACTS FOR ALL ALTERNATIVES BY CALENDAR YEAR COHORT—Continued

	No action	HDPUV4	HDPUV10	HDPUV14
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 IV–13 and Figure IV–14 show the estimates of gasoline and electricity consumption of the on-road HDPUV fleet for all fuel types over time on a calendar year basis, from 2022–2050. The three action alternatives, HDPUV4, HDPUV10, and HDPUV14, are compared to the baseline changes over time.

Gasoline consumption decreases over time, with the largest decreases occurring in more stringent alternatives. Electricity consumption increases over time, with the same pattern of Alternative HDPUV14 experiencing the highest magnitude of change. In both charts, the differences in magnitudes across alternatives do not vary drastically.

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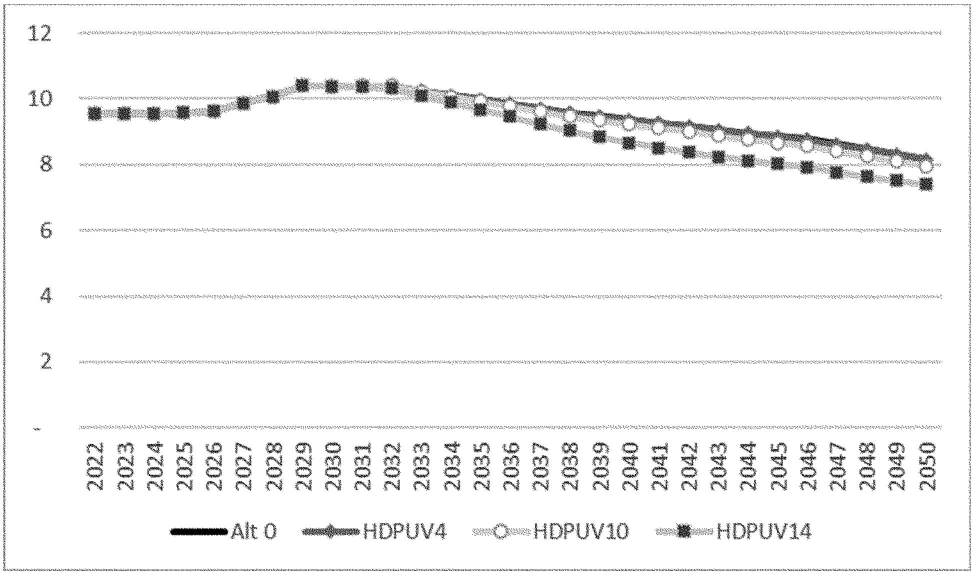

Figure IV-13: Total Gasoline Consumption by Calendar Year and Alternative (Billions of Gallons)

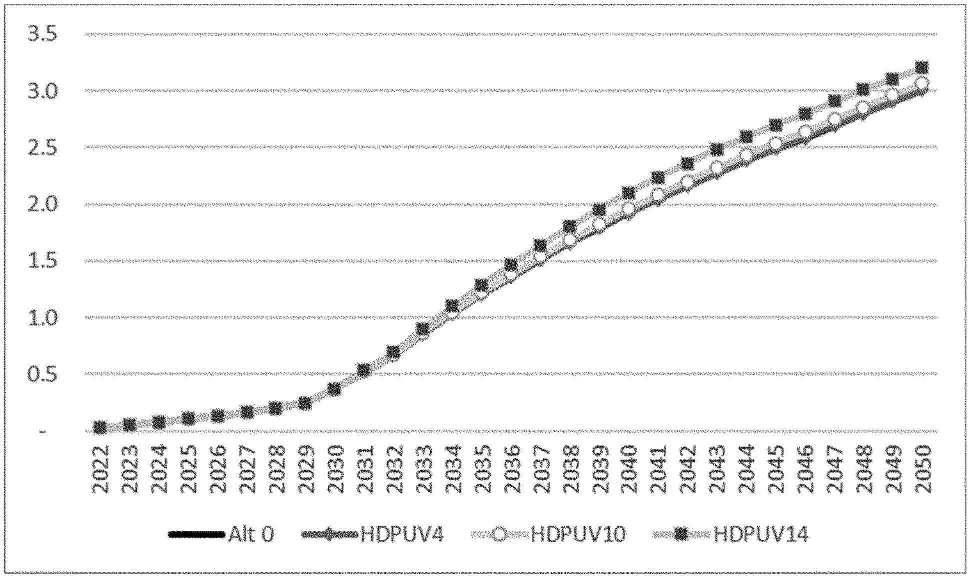

Figure IV-14: Total Electricity Consumption by Calendar Year and Alternative (Billions of Gasoline Gallon Equivalents)

NHTSA estimates the GHGs attributable to the HD on-road fleet, from both downstream and upstream energy sector processes (*e.g.*, petroleum refining, fuel transportation and distribution, electricity generation). These estimates mirror those discussed in the LD section above. Figure IV–15, Figure IV–16, and Figure IV–17 present NHTSA's estimate of how emissions from these three GHGs could evolve over the years (CY 2022–2050). Emissions from all three GHG types tracked follow similar trends of decline in the years between 2022–2050. Note that these graphs include emissions from both vehicle and upstream processes and scales vary by figure (CO_2 emissions are expressed in units of million metric tons (mmt) while emissions from other pollutants are expressed in metric tons).

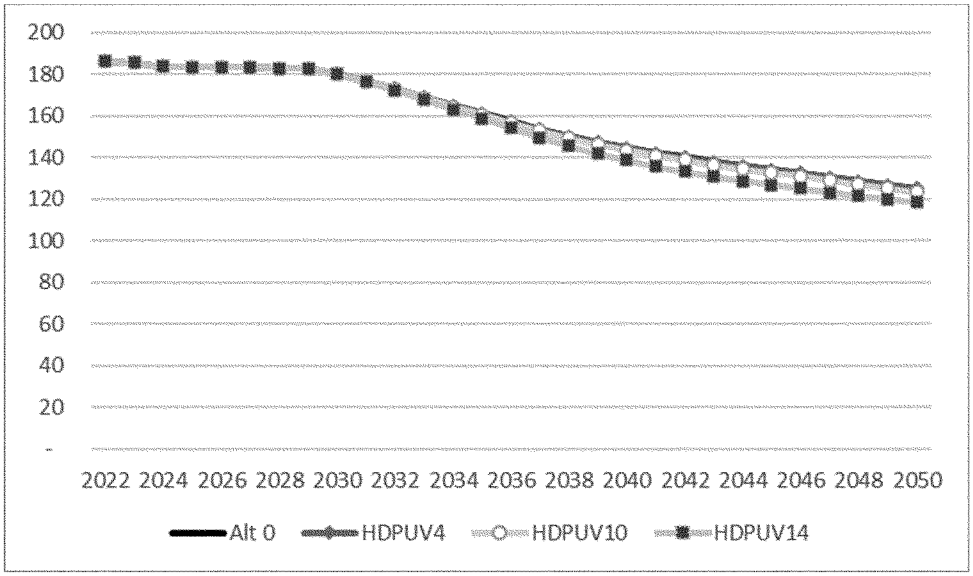

Figure IV-15: Total CO_2 Emissions by Calendar Year and Alternative (Millions of Metric Tons)

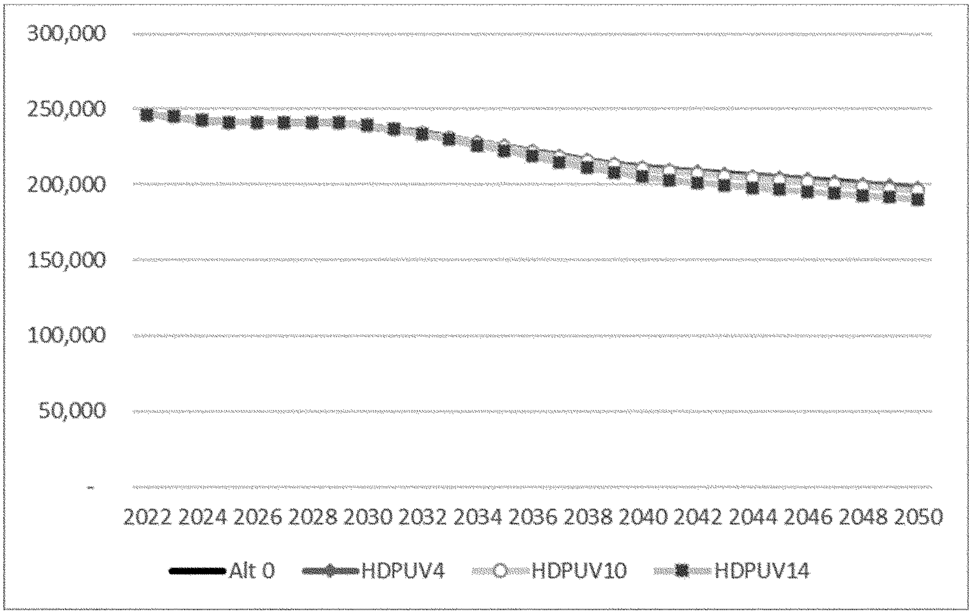

Figure IV-16: Total CH4 Emissions by Calendar Year and Alternative (Tons)

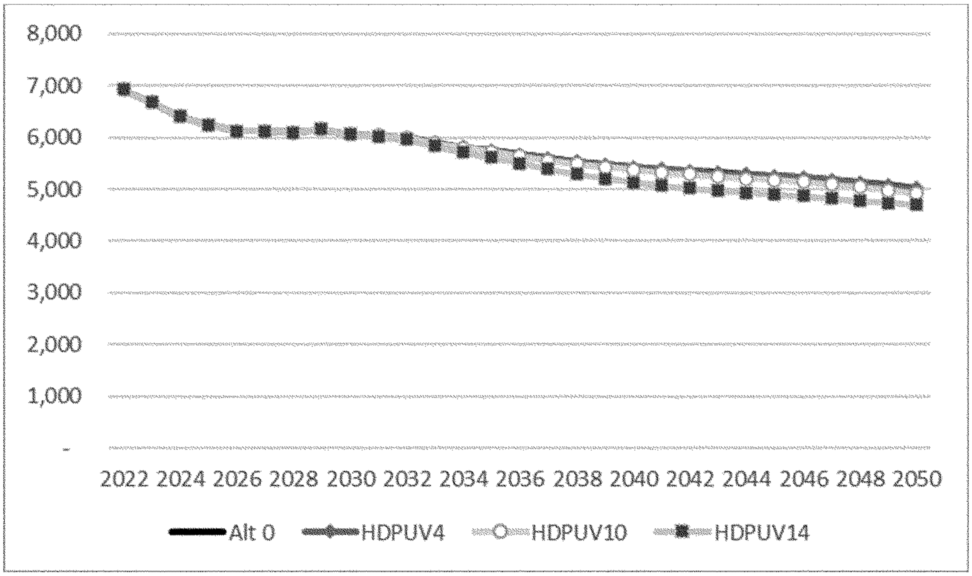

Figure IV-17: Total N2O Emissions by Calendar Year and Alternative (Tons)

For more information regarding projected GHG emissions, as well as model-based estimates of corresponding impacts on several measures of global climate change, see the Draft EIS.

NHTSA also estimates criteria pollutant emissions resulting from vehicle and upstream processes attributable to the HDPUV on-road fleet. Under each regulatory alternative, NHTSA projects a significant decline in annual emissions of NO_X, and $PM_{2.5}$ attributable to the HDPUV on-road fleet between 2022 and 2050. As exemplified in Figure IV–18, the magnitude of emissions in any given year could be very similar under each regulatory alternative.

On the other hand, as discussed in the PRIA Chapter 8.3 and the Draft EIS, NHTSA projects that annual SO_2 emissions attributable to the HDPUV on-road fleet could increase modestly under the action alternatives, because, as discussed above, NHTSA projects that each of the action alternatives could lead to greater use of electricity (for PHEVs and BEVs) in later calendar years. However, as for the LD analysis, we note that the adoption of actions that result in a cleaner electricity grid that reduces electricity generation emission rates below the projected levels underlying NHTSA's analysis (discussed in the TSD) could dramatically reduce SO_2 emissions under all regulatory alternatives considered here.[497]

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[497] Other actions, such as President Biden's E.O.s regarding Federal clean electricity, vehicle procurement, and sustainability, may significantly alter the emissions pattern of the electrical grid. See, *e.g. https://www.whitehouse.gov/briefing-room/presidential-actions/2021/01/27/executive-order-on-tackling-the-climate-crisis-at-home-and-abroad/*. See also *https://www.whitehouse.gov/*

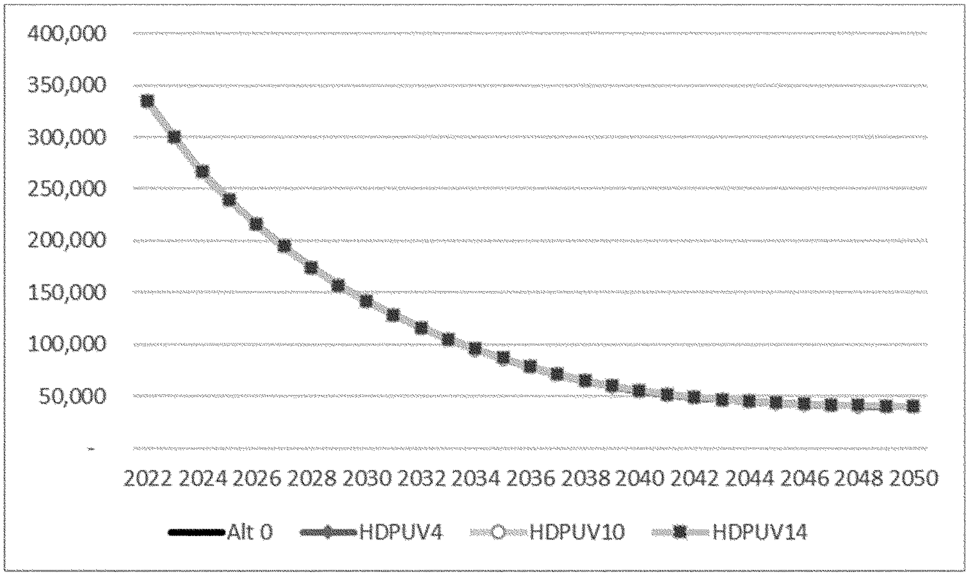

Figure IV-18: Total NO_x Emissions by Calendar Year and Alternative (Tons)

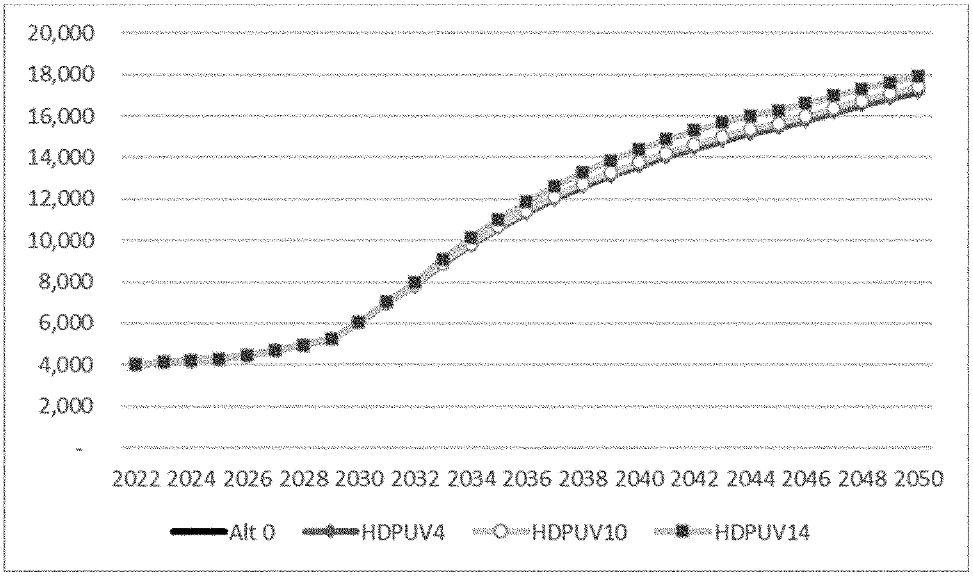

Figure IV-19: Total SO_2 Emissions by Calendar Year and Alternative (Tons)

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briefing-room/presidential-actions/2021/12/08/executive-order-on-catalyzing-clean-energy-industries-and-jobs-through-federal-sustainability/. AEO 2023 forecasts show that America's grid is likely to get cleaner in the forthcoming years significantly reducing anticipaited emissions as compared to today.

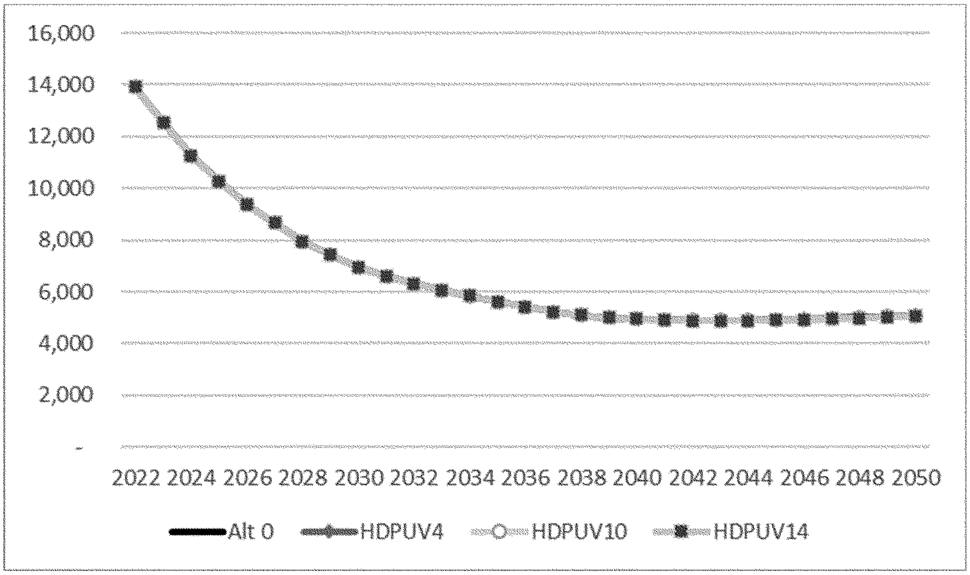

Figure IV-20: Total $PM_{2.5}$ Emissions by Calendar Year and Alternative (Tons)

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Health impacts quantified by the CAFE Model include various instances of hospital visits due to respiratory problems, minor restricted activity days, non-fatal heart attacks, acute bronchitis, premature mortality, and other effects of criteria pollutant emissions on health. Table IV–26 shows select health impacts relative to the baseline, across all action alternatives. The magnitude of the differences relates directly to the changes in tons of criteria pollutants emitted. The magnitudes differ across health impact types because of variation in the totals; for example, the total Minor Restricted Activity Days are much higher than the Respiratory Hospital Admissions. See Chapter 5.4 of the Draft TSD for information regarding how the CAFE Model calculates these health impacts.

TABLE IV–26—EMISSION HEALTH IMPACTS ACROSS ALTERNATIVES RELATIVE TO THE NO-ACTION ALTERNATIVE

[CY 2022–2050]

Measures (incidents)	HDPUV4	HDPUV10	HDPUV14
Premature Deaths	−0.4	−10.8	−40.2
Respiratory Emergency Room Visits	−0.4	−8.6	−31.1
Acute Bronchitis	−0.9	−21.9	−79.0
Lower Respiratory Symptoms	−11.9	−277.0	−998.9
Upper Respiratory Symptoms	−17.3	−401.8	−1,446.3
Minor Restricted Activity Days	−623.4	−14,190.9	−50,583.5
Work Loss Days	−99.9	−2,286.6	−8,182.8
Asthma Exacerbation	−20.5	−474.9	−1,709.1
Cardiovascular Hospital Admissions	−0.1	−2.7	−10.2
Respiratory Hospital Admissions	−0.1	−2.6	−9.6
Non-Fatal Heart Attacks (Peters)	−0.5	−11.2	−41.8
Non-Fatal Heart Attacks (All Others)	0.0	−1.2	−4.3

Lastly, NHTSA also quantifies safety impacts in its analysis. These include estimated counts of fatalities, non-fatal injuries, and property damage crashes occurring over the lifetimes of the HD on-road vehicles considered in the analysis. The following table shows projections of these counts in action alternatives relative to the baseline.

TABLE IV–27—CHANGE IN SAFETY OUTCOMES ACROSS ALTERNATIVES RELATIVE TO THE NO-ACTION ALTERNATIVE

[CY 2022–2050]

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	0	1	6

TABLE IV–27—CHANGE IN SAFETY OUTCOMES ACROSS ALTERNATIVES RELATIVE TO THE NO-ACTION ALTERNATIVE—Continued

[CY 2022–2050]

Alternative	HDPUV4	HDPUV10	HDPUV14
Non-Fatal Crashes			
Non-Fatal Crash from Mass Changes	0	0	0
Non-Fatal Crash from Rebound Effect	42	1,033	5,360
Non-Fatal Crash from Sales/Scrappage	10	−878	−4,493
Total	52	155	867
Property Damaged Vehicles			
Property Damage Vehicles from Mass Changes	0	0	0
Property Damage Vehicles from Rebound Effect	147	3,609	18,609
Property Damage Vehicles from Sales/Scrappage	28	−3,155	−15,845
Total	175	454	2,764

Chapter 7.1.5 of the PRIA accompanying this document contains an in-depth discussion on the effects of the various alternatives on these safety measures, and Draft TSD Chapter 7 contains information regarding the construction of the safety estimates.

D. Sensitivity Analysis

The analysis conducted to support this rulemaking consists of data, estimates, and assumptions, all applied within an analytical framework, the CAFE Model. Just as with all past CAFE and HDPUV FE rulemakings, NHTSA recognizes that many analytical inputs are uncertain, and some inputs are very uncertain. Of those uncertain inputs, 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. Yet making assumptions in the face of that uncertainty is necessary when analyzing possible future events (*e.g.,* consumer and industry responses to fuel economy/efficiency regulation). In other cases, we made assumptions in how we modeled the effects of other existing regulations that affected the costs and benefits of the action alternatives (*e.g.,* state ZEV mandates were included in the No-Action Alternative). To better understand the effect that these assumptions have on the analytical findings, we conducted additional model runs with alternative assumptions. These additional runs were specified in an effort to explore a range of potential inputs and the sensitivity of estimated impacts to changes in these model inputs. Sensitivity cases in this analysis span assumptions related to technology applicability and cost, economic conditions, consumer preferences, externality values, and safety assumptions, among others.[498] A sensitivity analysis can identify two critical pieces of information: *how big of an influence* does each parameter exert on the analysis, and *how sensitive are the model results* to that assumption?

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 reference case (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 fuel prices 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 critical, and the extent to which future deviations from central analysis assumptions could affect costs and benefits of the 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 Section V.D.

Table IV–28 lists and briefly describes the cases that we examined in the sensitivity analysis. Note that 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.,* initial PHEV availability).

TABLE IV–28—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.

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[498] In contrast to an uncertainty analysis, where many assumptions are varied simultaneously, the sensitivity analyses included here 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.

TABLE IV–28—CASES INCLUDED IN THE SENSITIVITY ANALYSIS—Continued

Sensitivity case	Description
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 to MY 2027–2035.
Standard-setting conditions to 2050	Applies standard-setting conditions to MY 2027–2050.
Standard-setting conditions all years	Applies standard-setting conditions to 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.

TABLE IV–28—CASES INCLUDED IN THE SENSITIVITY ANALYSIS—Continued

Sensitivity case	Description
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 light-duty sales projection.
Fixed fleet share (AEO 2023), no price response	Fleet share based on AEO 2023 light-duty 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).

Complete results for the sensitivity cases are summarized in Chapter 9 of the accompanying PRIA, and detailed model inputs and outputs for curious readers are available on NHTSA's website.[499] For purposes of this preamble, the figures in Section IV.D.1 illustrate the relative change of the sensitivity effect of selected inputs on the costs and benefits estimated for this proposed rule for LDVs, while the figures in Section IV.D.2 present the same data for the HDPUV analysis. Each collection of figures groups sensitivity cases by the category of input assumption (*e.g.,* macroeconomic assumptions, technology assumptions, and so on).

While the figures in this section do not show precise values, they give us a sense of which inputs are ones for which a different assumption would have a much different effect on analytical findings, and which ones would not have much effect. For example, assuming a different oil price trajectory would have a relatively large effect, as would doubling, or eliminating the assumed ''payback period.'' The relative magnitude of the effect varies by fleet. Making alternative assumptions about the future costs of battery technology has a relatively large effect on the HDPUV results. Adjusting assumptions related to the tax credits included in the IRA has a significant impact on results for both LDVs and HDPUVs. On the other hand, assumptions about which there has been significant disagreement in the past, like the rebound effect or the sales-scrappage response to changes in vehicle price, appear to cause only relatively small changes in net benefits across the range of analyzed input values. Chapter 9 of the PRIA provides an extended discussion of these findings, and presents net benefits estimated under each of the cases included in the sensitivity analysis.

The results presented in the earlier subsections of Section IV and discussed in Section V reflect NHTSA's best judgments regarding many different factors, and the sensitivity analysis discussed here is simply to illustrate the obvious, that differences in assumptions can lead to differences in analytical outcomes, some of which can be large and some of which may be smaller than expected. Policymaking in the face of future uncertainty is inherently complex. Section V explains how NHTSA balances the statutory factors in light of the analytical findings, the uncertainty that we know exists, and our nation's policy goals, to propose CAFE standards for MYs 2027–2032, and HDPUV fuel efficiency standards for MY 2030 and beyond that NHTSA concludes are maximum feasible.

1. Passenger Cars and Light Trucks

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[499] National Highway Traffic Association. 2023. Corporate Average Fuel Economy. Available at: *https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy.* (Accessed: May 31, 2023).

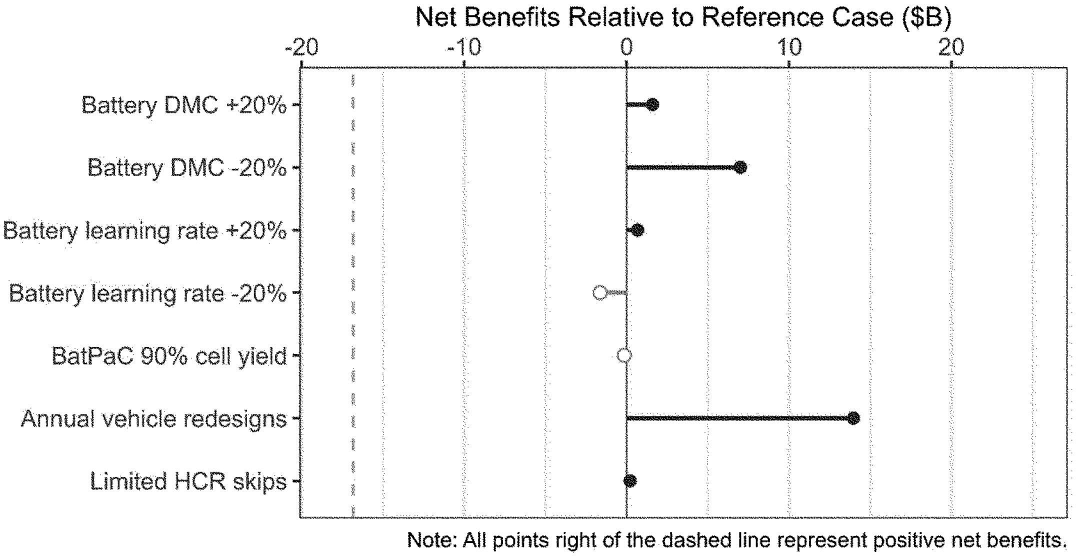


Figure IV-21: Net Social Benefits for Lifetime of Vehicles through MY 2032, Alternative PC2LT4 Relative to the Reference Case, Technology Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)

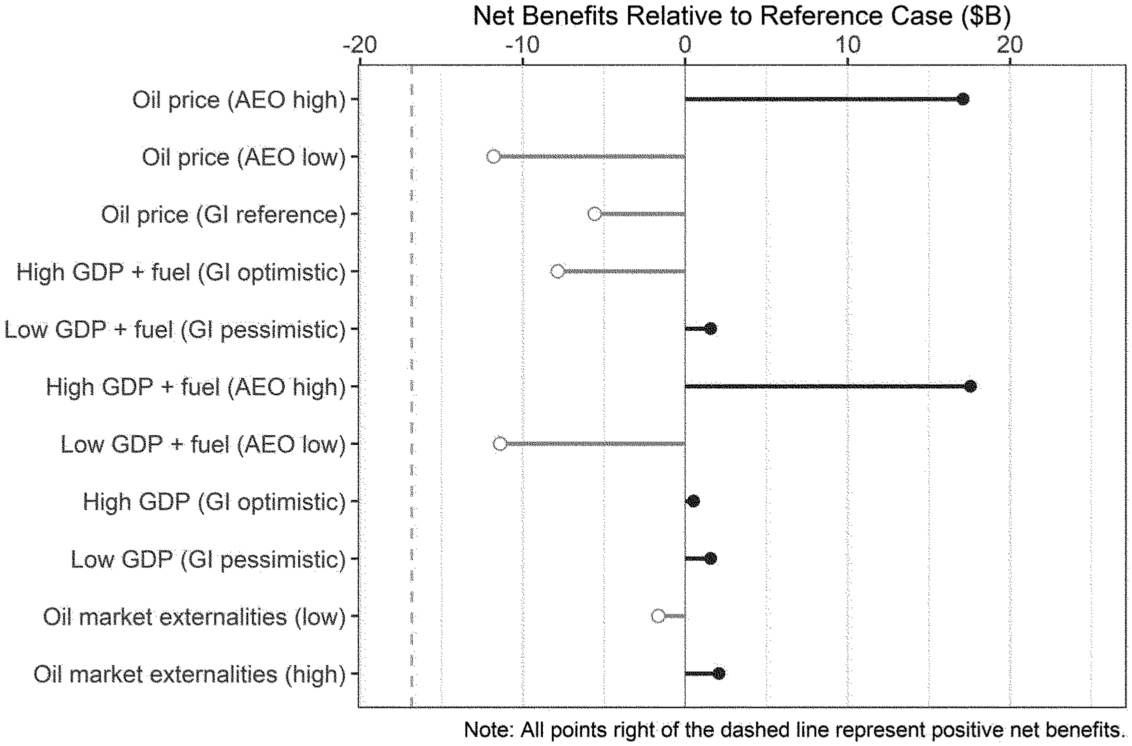
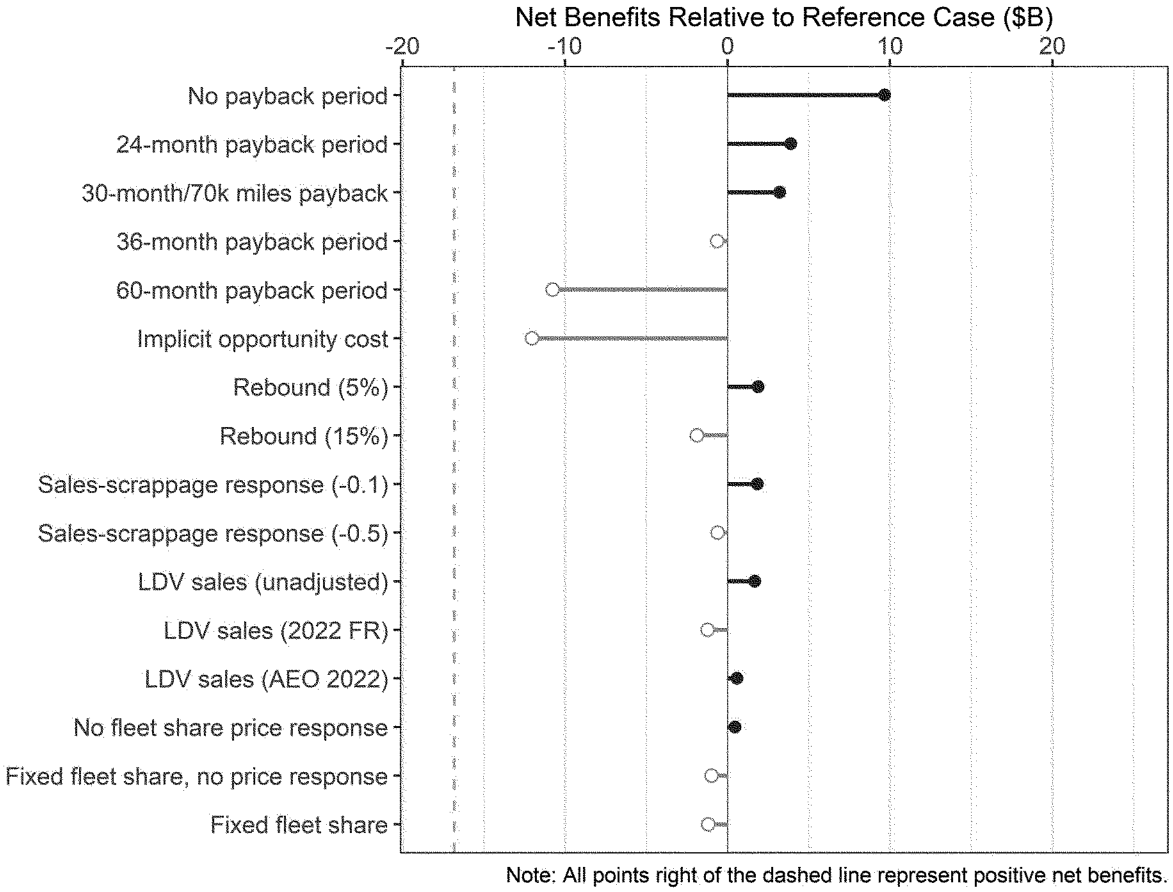


Figure IV-22: Net Social Benefits for Lifetime of Vehicles through MY 2032, Alternative PC2LT4 Relative to the Reference Case, Macroeconomic Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



Note: All points right of the dashed line represent positive net benefits.

Figure IV-23: Net Social Benefits for Lifetime of Vehicles through MY 2032, Alternative PC2LT4 Relative to the Reference Case, Payback and Sales Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)

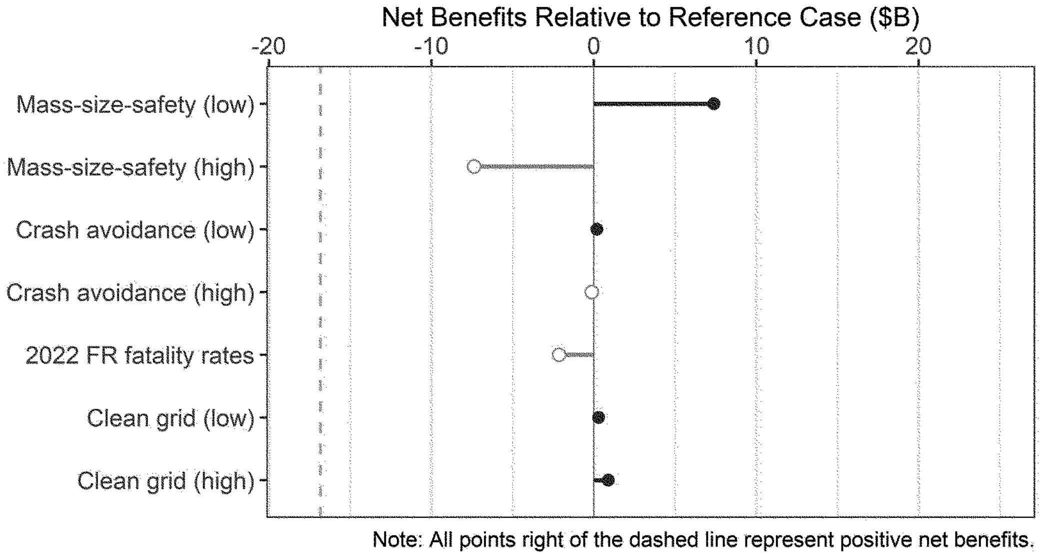


Figure IV-24: Net Social Benefits for Lifetime of Vehicles through MY 2032, Alternative PC2LT4 Relative to the Reference Case, Social and Environmental Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)

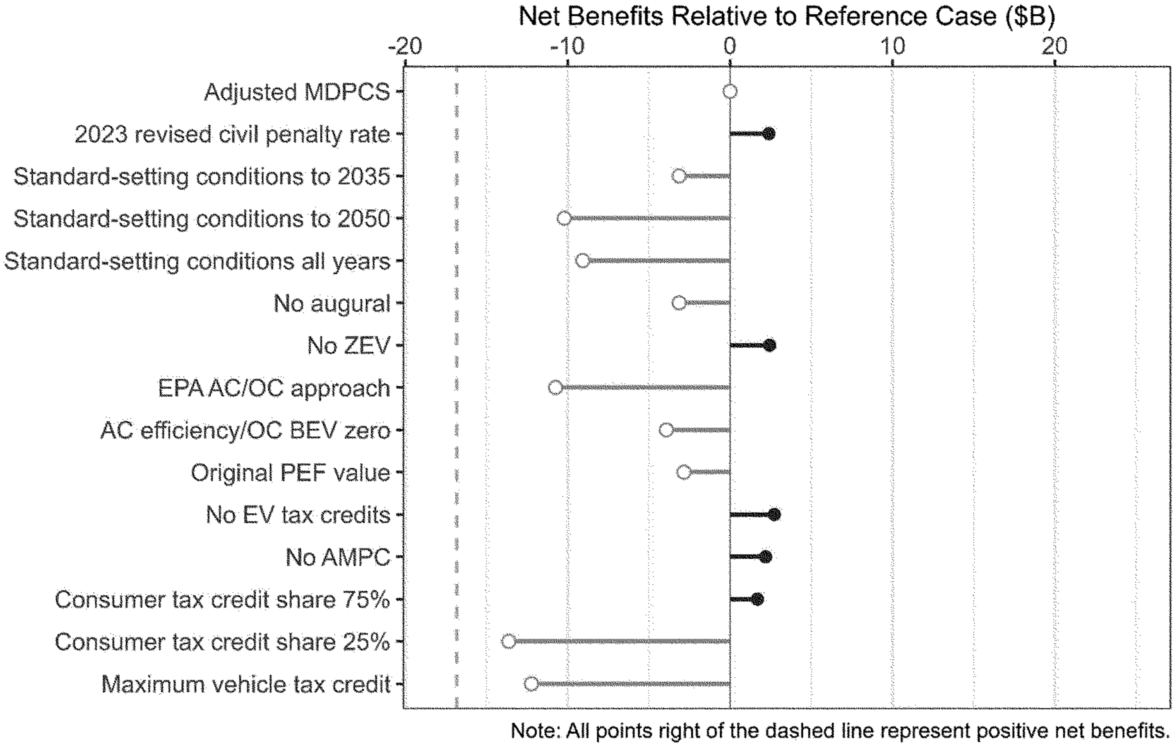


Figure IV-25: Net Social Benefits for Lifetime of Vehicles through MY 2032, Alternative PC2LT4 Relative to the Reference Case, Policy Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)

2. Heavy-Duty Pickups and Vans

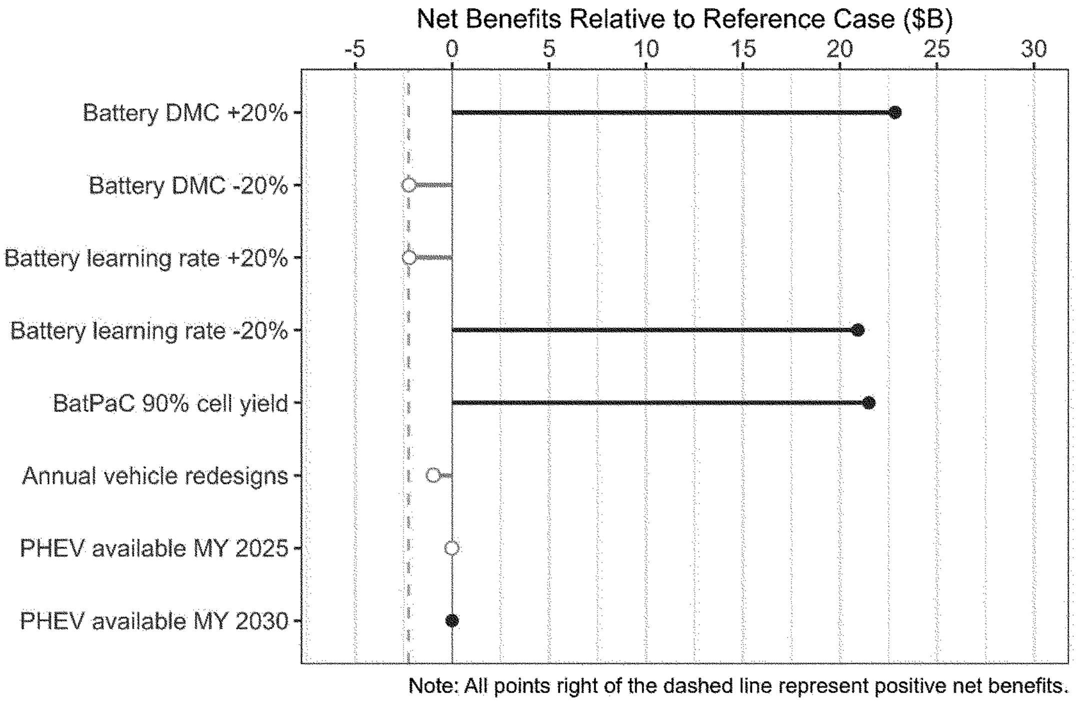
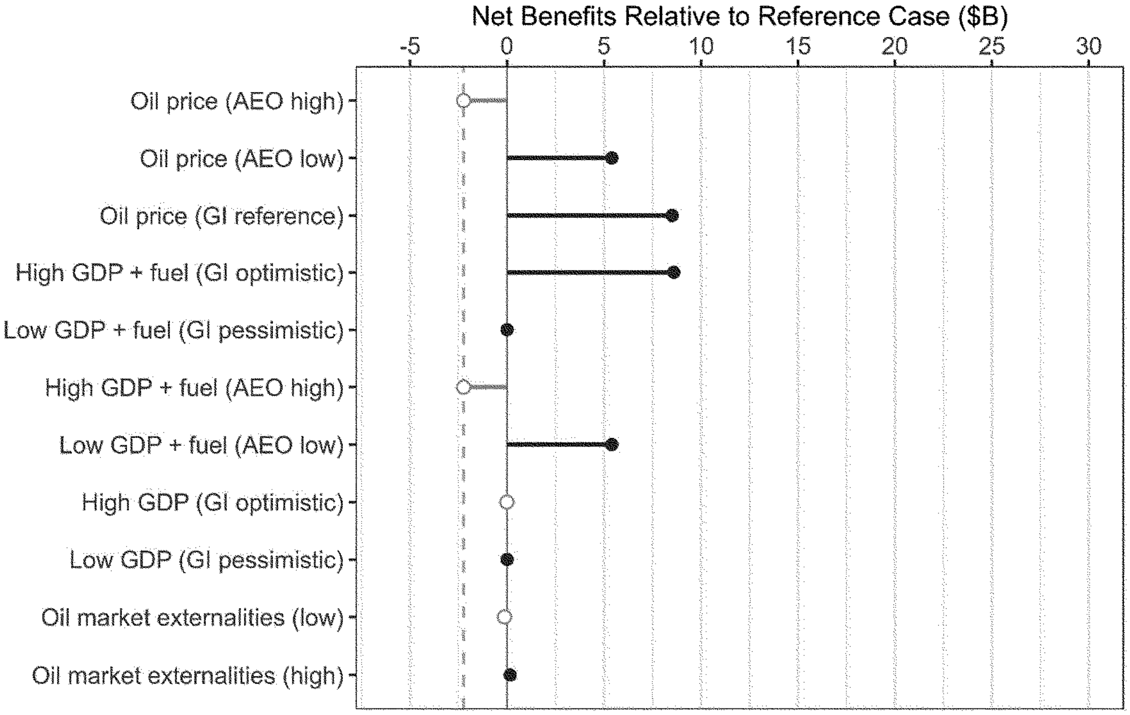


Figure IV-26: Net Social Benefits for the On-Road Fleet CYs 2022-2050, Alternative HDPUV10 Relative to the Reference Case, Technology Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)



Note: All points right of the dashed line represent positive net benefits.

Figure IV-27: Net Social Benefits for the On-Road Fleet CYs 2022-2050, Alternative HDPUV10 Relative to the Reference Case, Macroeconomic Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)

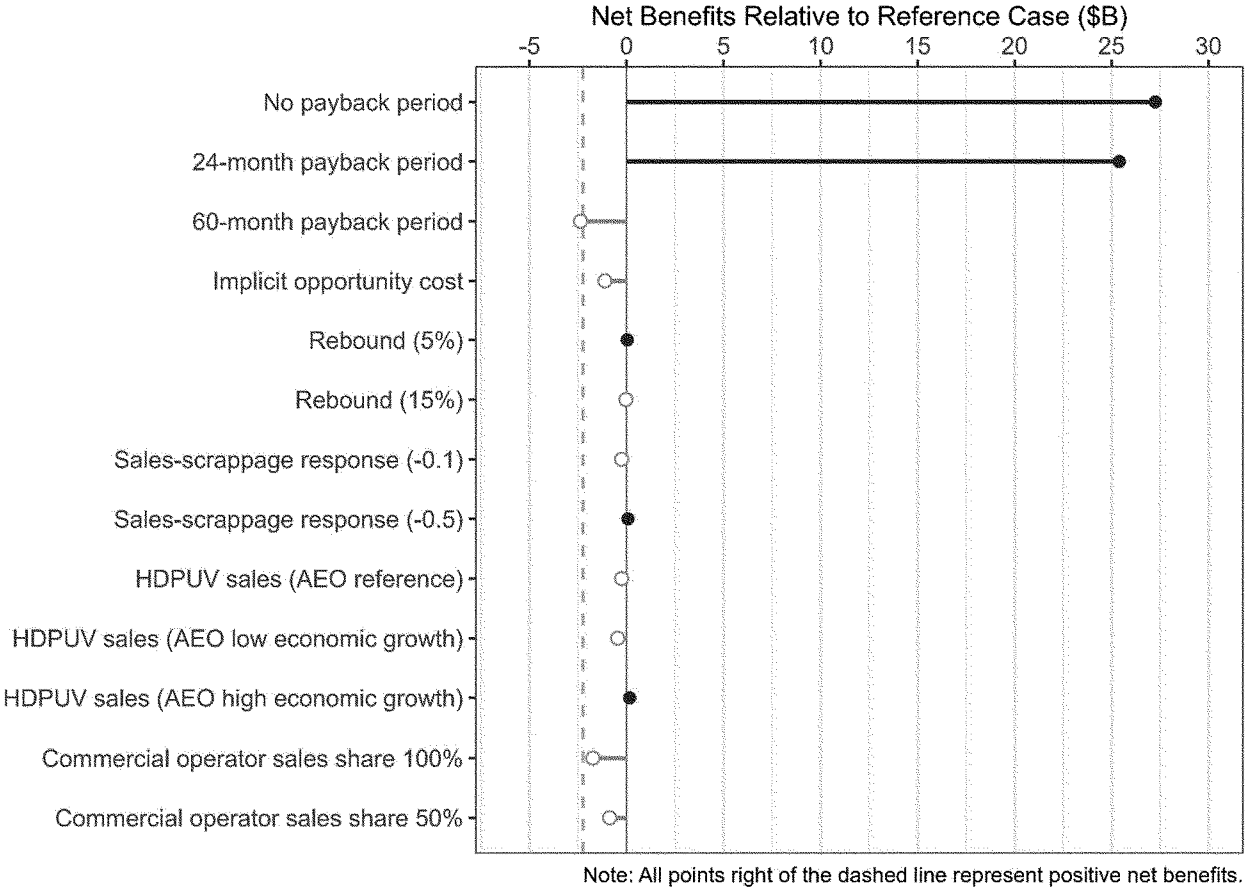


Figure IV-28: Net Social Benefits for the On-Road Fleet CYs 2022-2050, Alternative HDPUV10 Relative to the Reference Case, Sales and Payback Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)

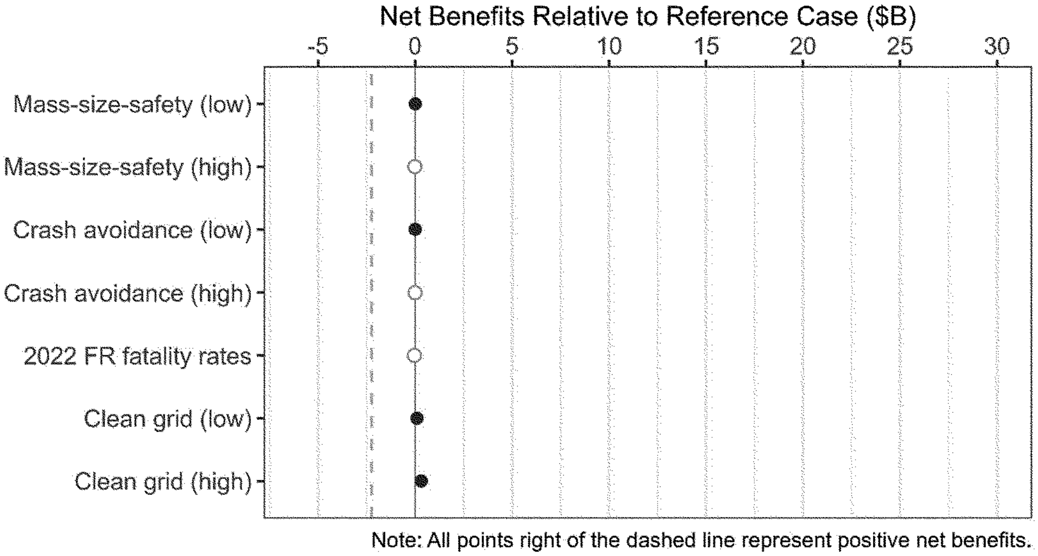


Figure IV-29: Net Social Benefits for the On-Road Fleet CYs 2022-2050, Alternative HDPUV10 Relative to the Reference Case, Social and Environmental Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)

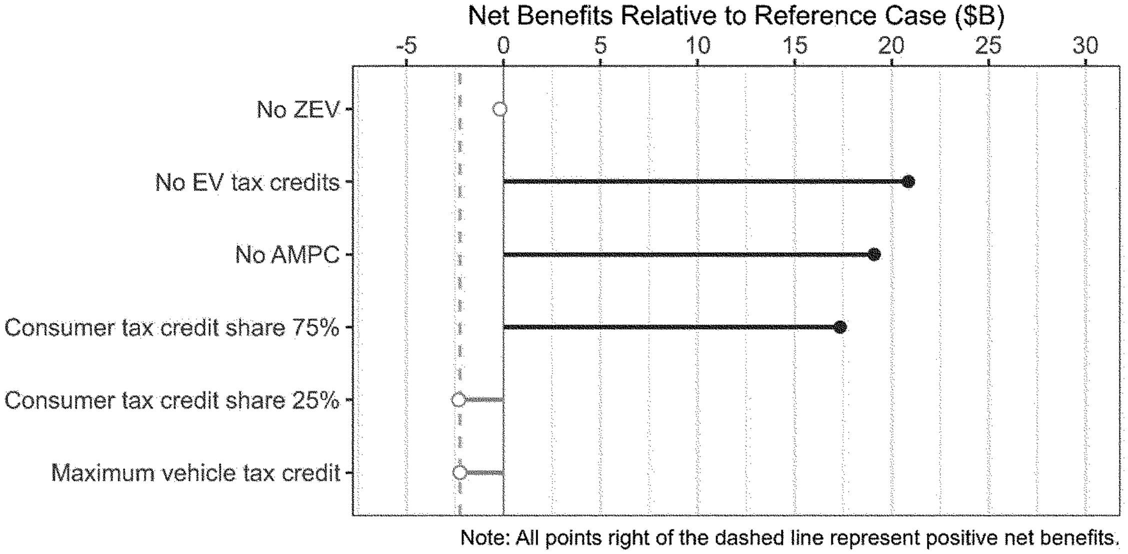


Figure IV-30: Net Social Benefits for the On-Road Fleet CYs 2022-2050, Alternative HDPUV10 Relative to the Reference Case, Policy Assumptions Sensitivity Cases (2021$, 3% social DR, 3% SC-GHG DR)

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V. Basis for NHTSA's Tentative Conclusion That the Proposed Standards Are Maximum Feasible

A. EPCA, as Amended by EISA

EPCA, as amended by EISA, contains provisions establishing how NHTSA must set CAFE standards and fuel efficiency standards for HDPUVs. DOT (by delegation, NHTSA) [500] must establish separate CAFE standards for passenger cars and light trucks [501] for each MY,[502] and each standard must be the maximum feasible that the Secretary (again, by delegation, NHTSA) determines manufacturers can achieve in that MY.[503] In determining the maximum feasible levels of CAFE standards, EPCA requires that NHTSA consider 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.[504] NHTSA must also set separate standards for HDPUVs, and while those standards must also ''achieve the maximum feasible improvement,'' they must be ''appropriate, cost-effective, and technologically feasible'' [505]—factors slightly different from those required to be considered for passenger car and light truck standards. NHTSA has broad discretion to balance the statutory factors in developing fuel consumption standards to achieve the maximum feasible improvement.

In addition, NHTSA has the authority to consider (and typically does consider) other relevant factors, such as the effect of CAFE standards on motor vehicle safety. The ultimate determination of what standards can be considered maximum feasible involves a weighing and balancing of factors, and the balance may shift depending on the information NHTSA has available about the expected circumstances in the MYs covered by the rulemaking. NHTSA's decision must also be guided by the overarching purpose of EPCA, energy conservation, while balancing these factors.[506]

EPCA/EISA also contain several other requirements, as follow.

1. Lead Time

a. Passenger Cars and Light Trucks

EPCA requires that NHTSA prescribe new CAFE standards at least 18 months before the beginning of each MY.[507] Thus, if the first year for which NHTSA is proposing to set CAFE standards is MY 2027, NHTSA interprets this provision as requiring us to issue a final rule covering MY 2027 standards no later than April 2025. Given the aim in E.O. 14037 to issue a final rule by July 2024, NHTSA expects the lead time requirement to be met.

b. Heavy-Duty Pickups and Vans

EISA requires that standards for commercial medium- and HD on-highway vehicles and work trucks (of which HDPUVs are part) provide not less than four full MYs of regulatory lead time.[508] Thus, if the first year for which NHTSA is proposing to set fuel efficiency standards for HDPUVs is MY 2030, NHTSA interprets this provision as requiring us to issue a final rule covering MY 2030 standards no later than October 2025.[509] NHTSA expects this lead time requirement to be met.

EISA contains a related requirement for HDPUVs that the standards provide not only four full MYs of regulatory lead time, but also three full MYs of regulatory stability.[510] As discussed in the Phase 2 final rule, Congress has not spoken directly to the meaning of the words ''regulatory stability.'' NHTSA interprets the ''regulatory stability'' requirement as ensuring that manufacturers will not be subject to new standards in repeated rulemakings too rapidly, given that Congress did not include a minimum duration period for the MD/HD standards.[511] NHTSA further interprets the statutory meaning as reasonably encompassing standards which provide for increasing stringency during the rulemaking time frame to be the maximum feasible. In this statutory context, NHTSA thus interprets the phrase ''regulatory stability'' in section 32902(k)(3)(B) as requiring that the standards remain in effect for three years before they may be increased by amendment. It does not prohibit standards that contain predetermined stringency increases.

2. Separate Standards for Passenger Cars, Light Trucks, and Heavy-Duty Pickups and Vans, and Minimum Standards for Domestic Passenger Cars

EPCA requires NHTSA to set separate standards for passenger cars and light trucks for each MY.[512] Based on the plain language of the statute, NHTSA has long interpreted this requirement as preventing NHTSA from setting a single combined CAFE standard for cars and trucks together. Congress originally required separate CAFE standards for cars and trucks to reflect the different fuel economy capabilities of those different types of vehicles, and over the history of the CAFE program, has never revised this requirement. Even as many cars and trucks have come to resemble each other more closely over time—many crossover and sport-utility models, for example, come in versions today that may be subject to either the car standards or the truck standards depending on their characteristics—it is still accurate to say that vehicles with truck-like characteristics such as 4-wheel drive, cargo-carrying capability, etc., currently consume more fuel per mile than vehicles without these components. While there have been instances in recent rulemakings where NHTSA raised passenger car and light truck standard stringency at the same numerical rate year over year, NHTSA also has precedent for setting passenger car and light truck standards that increase at different numerical rates year over year, as in the 2012 final rule. This underscores that NHTSA's obligation is to set maximum feasible standards separately for each fleet, based on our assessment of each fleet's circumstances as seen through the lens of the four statutory factors that NHTSA must consider.

EPCA, as amended by EISA, also requires another separate standard to be set for domestically manufactured [513] passenger cars. Unlike the generally applicable standards for passenger cars

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[500] EPCA and EISA direct the Secretary of Transportation to develop, implement, and enforce fuel economy standards (*see* 49 U.S.C. 32901 *et seq.*), which authority the Secretary has delegated to NHTSA at 49 FR 1.95(a).

[501] 49 U.S.C. 32902(b)(1) (2007).

[502] 49 U.S.C. 32902(a) (2007).

[503] *Id.*

[504] 49 U.S.C. 32902(f).

[505] 49 U.S.C. 32902(k)(2).

[506] *Center for Biological Diversity* v. *NHTSA,* 538 F.3d 1172, 1197 (9th Cir. 2008) (''Whatever method it uses, NHTSA cannot set fuel economy standards that are contrary to Congress's purpose in enacting the EPCA—energy conservation.''). While this decision applied only to standards for passenger cars and light trucks, NHTSA interprets the admonition as broadly applicable to its actions under section 32902.

[507] 49 U.S.C. 32902(a) (2007).

[508] 49 U.S.C. 32902(k)(3)(A) (2007).

[509] As with passenger cars and light trucks, NHTSA interprets the MY for HDPUVs as beginning with October of the calendar year prior. Therefore, HDPUV MY 2029 would begin in October 2028; therefore, four full MYs prior to October 2028 would be October 2024.

[510] 49 U.S.C. 32902(k)(3)(B) (2007).

[511] In contrast, as discussed below, passenger car and standards must remain in place for ''at least 1, but not more than 5, MYs.'' 49 U.S.C. 32902(b)(3)(B).

[512] 49 U.S.C. 32902(b)(1) (2007).

[513] In the CAFE program, ''domestically manufactured'' is defined by Congress in 49 U.S.C. 32904(b). The definition roughly provides that a passenger car is ''domestically manufactured'' as long as at least 75 percent of the cost to the manufacturer is attributable to value added in thie United States, Canada, or Mexico, unless the assembly of the vehicle is completed in Canada or Mexico *and* the vehicle is imported into the United States more than 30 days after the end of the MY.

and light trucks described above, the compliance obligation of the MDPCS is identical for all manufacturers. The statute clearly states that any manufacturer's domestically manufactured passenger car 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 MY, which projection shall be published in the **Federal Register** when the standard for that MY is promulgated in accordance with [49 U.S.C. 32902(b)].'' [514] Since that statutory requirement was established, the ''92 percent'' has always been greater than 27.5 mpg, and foreseeably will continue to be so in the future. As in the 2020 and 2022 final rules, NHTSA continues to recognize industry concerns that actual total passenger car fleet standards have differed significantly from past projections, perhaps more so when NHTSA has projected significantly into the future. In the 2020 final rule, the compliance data showed that standards projected in 2012 were consistently more stringent than the actual standards, by an average of 1.9 percent. NHTSA has stated that this difference indicates that in rulemakings conducted in 2009 through 2012, NHTSA's and EPA's projections of passenger car vehicle footprints and production volumes, in retrospect, underestimated the production of larger passenger cars over the MYs 2011 to 2018 period.[515]

Unlike the passenger car standards and light truck standards which are vehicle-attribute-based and automatically adjust with changes in consumer demand, the MDPCS are not attribute-based, and therefore do not adjust with changes in consumer demand and production. They are, instead, fixed standards that are established at the time of the rulemaking. As a result, by assuming a smaller-footprint fleet, on average, than what ended up being produced, the MY 2011–2018 MDPCS ended up being more stringent and placing a greater burden on manufacturers of domestic passenger cars than was projected and expected at the time of the rulemakings that established those standards. In the 2020 final rule, therefore, NHTSA agreed with industry concerns over the impact of changes in consumer demand (as compared to what was assumed in 2012 about future consumer demand for greater fuel economy) on manufacturers' ability to comply with the MDPCS and in particular, manufacturers that produce larger passenger cars domestically. Some of the largest civil penalties for noncompliance in the history of the CAFE program have been paid for noncompliance with the MDPCS. NHTSA also expressed concern at that time that consumer demand may shift even more in the direction of larger passenger cars if fuel prices continue to remain low. Sustained low oil prices can be expected to have real effects on consumer demand for additional fuel economy, and if that occurs, consumers may foreseeably be even more interested in 2WD crossovers and passenger-car-fleet SUVs (and less interested in smaller passenger cars) than they are at present.

Therefore, in the 2020 final rule, to help avoid similar outcomes in the 2021 to 2026 time frame to what had happened with the MDPCS over the preceding MYs, NHTSA determined that it was reasonable and appropriate to consider the recent projection errors as part of estimating the total passenger car fleet fuel economy for MYs 2021–2026. NHTSA therefore projected the total passenger car fleet fuel economy using the central analysis value in each MY, and applied an offset based on the historical 1.9 percent difference identified for MYs 2011–2018.

For the 2022 final rule, NHTSA retained the 1.9 percent offset, concluding that it is difficult to predict passenger car footprint trends in advance, which means that, as various stakeholders have consistently noted, the MDPCS may turn out quite different from 92 percent of the ultimate average passenger car standard once a MY is complete. NHTSA also expressed concern, as suggested by the United Automobile, Aerospace, and Agricultural Implement Workers of America (UAW), that automakers struggling to meet the unadjusted MDPCS may choose to import their passenger cars rather than producing them domestically.

NHTSA is proposing to continue employing the 1.9 percent offset for MYs 2027–2032, because NHTSA continues to believe that the reasons presented previously for the offset still apply, and that therefore the offset is appropriate, reasonable, and consistent with Congress' intent. We seek comment on this aspect of the proposal.

For HDPUVs, Congress gave DOT (by delegation, NHTSA) broad discretion to ''prescribe separate standards for different classes of vehicles'' under 49 U.S.C. 32902(k). HDPUVs are defined by regulation as ''pickup trucks and vans with a gross vehicle weight rating between 8,501 pounds and 14,000 pounds (Class 2b through 3 vehicles) manufactured as complete vehicles by a single or final stage manufacturer or manufactured as incomplete vehicles as designated by a manufacturer.'' [516] NHTSA also allows HD vehicles above 14,000 pounds GVWR to be optionally certified as HDPUVs and comply with HDPUV standards ''if properly included in a test group with similar vehicles at or below 14,000 pounds GVWR,'' and ''The work factor for these vehicles may not be greater than the largest work factor that applies for vehicles in the test group that are at or below 14,000 pounds GVWR.'' [517] Incomplete HD vehicles at or below 14,000 pounds GVWR may also be optionally certified as HDPUVs and comply with the HDPUV standards.[518] NHTSA is proposing to set separate standards for ''spark ignition'' (SI, or, gasoline-fueled) and ''compression ignition'' (CI, or, diesel-fueled) HDPUVs, consistent with the existing Phase 2 standards. Each class of vehicles has its own work-factor based target curve; alternative fueled vehicles are subject to the standard for CI vehicles and HEVs and PHEVs are subject to the standard for SI vehicles. We understand that EPA has proposed a single curve for all HDPUVs regardless of fuel type; NHTSA is not proposing to take this approach, for several reasons. First, EPA is proposing to modify the MY 2027 standards set in the 2016 ''Phase 2'' rulemaking, and NHTSA cannot follow suit due to statutory lead time requirements. Second, the stability of the curve designs should allow manufacturers enough lead time to develop technologies not yet fully implemented in the market for this segment that we expect will be needed to meet the standards. And finally, NHTSA is more confident that, given the lead time concerns and the technologies anticipated to be required, retaining separate CI and SI curves will better balance NHTSA's statutory factors for HDPUVs of cost-effectiveness and technological feasibility. We seek comment on this aspect of the proposal.

3. Attribute-Based and Defined by a Mathematical Function

For passenger cars and light trucks, EISA requires NHTSA to set CAFE standards that are ''based on 1 or more attributes related to fuel economy and express[ed] . . . in the form of a mathematical function.'' [519] Historically, NHTSA has based standards on vehicle

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[514] 49 U.S.C. 32902(b)(4) (2007).

[515] *See* 85 FR 25127 (Apr. 30, 2020).

[516] 49 CFR 523.7(a).

[517] 49 CFR 523.7(b).

[518] 49 CFR 523.7(c).

[519] 49 U.S.C. 32902(b)(3)(A) (2007).

footprint, and proposes to continue to do so for MYs 2027–2032. As in previous rulemakings, NHTSA proposes to define the standards in the form of a constrained linear function that generally sets higher (more stringent) targets for smaller-footprint vehicles and lower (less stringent) targets for larger-footprint vehicles. As discussed above in Section II.B, NHTSA seeks comment on these aspects of the proposal.

In the 2022 final rule, NHTSA discussed the concept of ''backstop'' standards in response to broad industry-wide growth in vehicle size and mix shifts from cars to trucks and SUVs over time. A number of commenters requested that NHTSA set additional backstop standards to ensure that those vehicles achieve certain minimum fuel economy levels. While NHTSA continues to believe that we do have authority to set such standards, we propose to address the concerns by setting light truck standards that increase at a more rapid rate, 4 percent year over year, than the 2-percent-per-year passenger car standards over the same timeframe. We believe that this will minimize regulatory complexity, as compared to creating entire new standards with which manufacturers would have to comply simultaneously, and it should achieve a similar aim of requiring the fleet that consumes more fuel—light trucks—to continue improving rather than backsliding. We seek comment on this approach.

For HDPUVs, NHTSA also sets attribute-based standards defined by a mathematical function. HDPUV standards have historically been set in units of gallons per 100 miles, rather than in mpg,[520] and the attribute for HDPUVs has historically been ''work factor,'' which is a function of a vehicle's payload capacity and towing capacity.[521] While NHTSA does not interpret EISA as requiring NHTSA to set attribute-based standards defined by a mathematical function for HDPUVs, given that 49 U.S.C. 32902(b)(3)(A) refers specifically to fuel economy standards for passenger and non-passenger automobiles, NHTSA has still previously concluded that following that approach for HDPUVs is reasonable and appropriate, as long as the work performed by HDPUVs is accounted for. NHTSA proposes to continue to set work-factor based gallons-per-100-miles standards for HDPUVs for MYs 2027–2032.

4. Number of Model Years for Which Standards May Be Set at a Time

For passenger cars and light trucks, EISA also states that NHTSA shall ''issue regulations under this title prescribing average fuel economy standards for at least 1, but not more than 5, MYs.'' [522] For this proposal, NHTSA is proposing CAFE standards for passenger cars and light trucks for MYs 2027–2031, and to facilitate longer-term product planning by industry and in the interest of harmonization, NHTSA is also presenting proposed augural standards for MY 2032 as representative of what levels of stringency NHTSA currently believes could be appropriate in that MY, based on the information before us today. We emphasize that the augural standards are informational, and we recognize that they cannot be finalized as part of an action to finalize standards for MYs 2027–2031, and that a future rulemaking consistent with all applicable law will be necessary in order for NHTSA to establish final CAFE standards for MY 2032 passenger cars and light trucks. Nevertheless, for brevity, information about the impacts of the standards will be provided throughout the documents without distinguishing between the proposed standards and the augural standards. We seek comment on the value of presenting augural standards for MY 2032 as part of this action and including their presentation in the final rule. NHTSA notes that it also conducted a sensitivity analysis removing the augural year, MY 2032. The results of that sensitivity analysis showed slightly lower costs, benefits, and net benefits for each regulatory alternative, and no change in the relative ordering of net benefits amongst the alternatives.[523] NHTSA tentatively concludes that the presentation of MY 2032 throughout these documents would not change our decision as to which alternative is maximum feasible.

The five-year statutory limit on average fuel economy standards that applies to passenger cars and light trucks does not apply to the HD pickup and van standards. NHTSA has previously stated that ''it is reasonable to assume that if Congress intended for the [MD/HD] regulatory program to be limited by the timeline prescribed in [49 U.S.C. 32902(b)(3)(B)], it would have either mentioned [MD/HD] vehicles in that subsection or included the same timeline in [49 U.S.C. 32902(k)].'' [524] [525] Additionally, ''in order for [49 U.S.C. 32902(b)(3)(B) to be interpreted to apply to [49 U.S.C. 32902(k)], the agency would need to give less than full weight to the . . . phrase in [49 U.S.C. 32902(b)(1)(C)] directing the Secretary to prescribe standards for 'work trucks and commercial MD or HD on-highway vehicles in accordance with Subsection (k).' Instead, this direction would need to be read to mean 'in accordance with Subsection (k) and the remainder of Subsection (b).' NHTSA believes this interpretation would be inappropriate. Interpreting 'in accordance with Subsection (k)' to mean something indistinct from 'in accordance of this Subsection' goes against the canon that statutes should not be interpreted in a way that 'render[s] language superfluous.' *Dobrova* v. *Holder,* 607 F.3d 297, 302 (2d Cir. 2010), quoting *Mendez* v. *Holder,* 566 F.3d 316, 321–22 (2d Cir. 2009).'' [526] As a result, the standards previously set remain in effect indefinitely at the levels required in the last MY, until amended by a future rulemaking action.

5. Maximum Feasible Standards

As discussed above, EPCA requires NHTSA to consider four factors in determining what levels of CAFE standards (for passenger cars and light trucks) would be maximum feasible—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. For determining what levels of fuel efficiency standards (for HDPUVs) would be maximum feasible, EISA requires NHTSA to consider three factors—whether a given fuel efficiency standard would be appropriate, cost-effective, and technologically feasible. NHTSA presents in the sections below its understanding of the meanings of all those factors in their respective decision-making contexts.

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[520] NHTSA has long interpreted ''fuel economy standards'' in the context of 49 U.S.C. 32902(k) as referring not specifically to mpg, as in the LDV context, but instead more broadly to account as accurately as possible for MD/HD fuel efficiency. NHTSA considered setting standards for HDPUVs (and other MD/HD vehicles) in mpg, but concluded that that would not be an appropriate metric given the work that MD/HD vehicles are manufactured to do. *See* 76 FR 57106, 57112, fn. 19 (Sep. 15, 2011).

[521] *See* 49 CFR 535.5(a)(2).

[522] 49 U.S.C. 32902(b)(3)(B) (2007).

[523] See Chapter 9 of the PRIA for more information.

[524] ''[W]here Congress includes particular language in one section of a statute but omits it in another section of the same Act, it is generally presumed that Congress acts intentionally and purposely in the disparate inclusion or exclusion.'' *Russello* v. *United States,* 464 U.S. 16, 23 (1983), quoting *U.S.* v. *Wong Kim Bo,* 472 F.2d 720, 722 (5th Cir. 1972). *See also Mayo* v. *Questech, Inc.,* 727 F.Supp. 1007, 1014 (E.D. Va. 1989) (conspicuous absence of provision from section where inclusion would be most logical signals Congress did not intend for it to be implied).

[525] 76 FR 57106, 57131 (Sep. 15, 2011).

[526] *Id.*

a. Passenger Cars and Light Trucks

(1) Technological Feasibility

''Technological feasibility'' refers to whether a particular method of improving fuel economy is available for deployment in commercial application in the MY for which a standard is being established. Thus, NHTSA is not limited in determining the level of new standards to technology that is already being applied commercially at the time of the rulemaking. For this proposal, NHTSA has considered a wide range of technologies that improve fuel economy, while considering the need to account for which technologies have already been applied to which vehicle mode/configuration, as well as the need to estimate, realistically, the cost and fuel economy impacts of each technology as applied to different vehicle models/configurations. NHTSA believes that the range of technologies considered, as well as how the technologies are defined for purposes of the analysis, is reasonable, based on our technical expertise, our independent research, and our interactions with stakeholders. NHTSA has not, however, attempted to account for every technology that might conceivably be applied to improve fuel economy, nor does NHTSA believe it is necessary to do so, given that many technologies address fuel economy in similar ways.[527]

NHTSA notes that the technological feasibility factor allows NHTSA to set standards that force the development and application of new fuel-efficient technologies, but this factor does not require NHTSA to do so.[528] In the 2012 final rule, NHTSA stated that ''[i]t is important to remember that technological feasibility must also be balanced with the other of the four statutory factors. Thus, while 'technology feasibility' can drive standards higher by assuming the use of technologies that are not yet commercial, 'maximum feasible' is also defined in terms of economic practicability, for example, which might caution the agency against basing standards (even fairly distant standards) entirely on such technologies.'' [529] NHTSA further stated that ''as the 'maximum feasible' balancing may vary depending on the circumstances at hand for the MY in which the standards are set, the extent to which technological feasibility is simply met or plays a more dynamic role may also shift.'' [530]

For purposes of MYs 2027–2032, NHTSA tentatively concludes that sufficient technology exists to meet the proposed standards. NHTSA has grappled with whether the ''available for deployment in commercial application'' language of our historical interpretation of technological feasibility is appropriately read as ''available for deployment in the world'' or ''available for deployment given the restrictions of 32902(h).'' In the overall balancing of factors for determining maximum feasible, the above interpretive question may not matter, because it is clear that the very high cost of the most stringent alternatives likely puts them out of range of economic practicability, especially if manufacturers appear to be resorting to payment of civil penalties rather than complying through technology application. Effectively, given the statutory constraints under which NHTSA must operate, NHTSA does not see a technology path to reach the higher fuel economy levels that would be required by the more stringent alternatives. Moreover, even if technological feasibility were not a barrier, that does not mean that requiring that technology to be added would be economically practicable.

(2) Economic Practicability

''Economic practicability'' has consistently referred to whether a standard is one ''within the financial capability of the industry, but not so stringent as to'' lead to ''adverse economic consequences, such as a significant loss of jobs or unreasonable elimination of consumer choice.'' [531] In evaluating economic practicability, NHTSA considers the uncertainty surrounding future market conditions and consumer demand for fuel economy alongside consumer demand for other vehicle attributes. There is not necessarily a bright-line test for whether a regulatory alternative is economically practicable, but there are several metrics that we discuss below that we find can be useful for making this assessment. In determining whether standards may or may not be economically practicable, NHTSA considers:

Application rate of technologies—whether it appears that a regulatory alternative would impose undue burden on manufacturers in either or both the near and long term in terms of how much and which technologies might be required. This metric connects to the next two metrics, as well.

Other technology-related considerations—related to the application rate of technologies, whether it appears that the burden on several or more manufacturers might cause them to respond to the standards in ways that compromise, for example, vehicle safety, or other aspects of performance that may be important to consumer acceptance of new products.

Cost of meeting the standards—even if the technology exists and it appears that manufacturers can apply it consistent with their product cadence, if meeting the standards is estimated to raise per-vehicle cost more than we believe consumers are likely to accept, which could negatively impact sales and employment in the automotive sector, the standards may not be economically practicable. While consumer acceptance of additional new vehicle cost associated with more stringent CAFE standards is uncertain, NHTSA still finds this metric useful for evaluating economic practicability.

Sales and employment responses—as discussed above, sales and employment responses have historically been key to NHTSA's understanding of economic practicability.

Uncertainty and consumer acceptance [532] of technologies—considerations not accounted for expressly in our modeling analysis, but important to an assessment of economic practicability given the timeframe of this rulemaking. Consumer acceptance can involve consideration of anticipated consumer response not just to increased vehicle cost and consumer valuation of fuel economy, but also the way manufacturers may change vehicle models and vehicle sales mix in response to CAFE standards.

Over time, NHTSA has tried different methods to account for economic practicability. NHTSA has long abandoned the ''least capable manufacturer'' approach to ensuring economic practicability, of setting standards at or near the level of the manufacturer whose fleet mix was, on average, the largest and heaviest, generally having the highest capacity (for passengers and/or cargo) and capability (in terms of ability to perform their intended function(s)) so as not to limit the availability of those types of

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[527] For example, NHTSA has not considered high-speed flywheels as potential energy storage devices for hybrid vehicles; while such flywheels have been demonstrated in the laboratory and even tested in concept vehicles, commercially available hybrid vehicles currently known to NHTSA use chemical batteries as energy storage devices, and the agency has considered a range of hybrid vehicle technologies that do so.

[528] *See* 77 FR 63015 (Oct. 12, 2012).

[529] *Id.*

[530] *Id.*

[531] 67 FR 77015, 77021 (Dec. 16, 2002).

[532] See, *e.g., Center for Auto Safety* v. *NHTSA* (CAS), 793 F.2d 1322 (D.C. Cir. 1986) (Administrator's consideration of market demand as component of economic practicability found to be reasonable).

vehicles to consumers.[533] NHTSA does not believe that such an approach would be consistent with our root interpretation of economic practicability. Economic practicability focuses on the capability of the industry and seeks to avoid adverse consequences such as (inter alia) a significant loss of jobs or unreasonable elimination of consumer choice. If the overarching purpose of EPCA is energy conservation, NHTSA believes that it is reasonable to expect that maximum feasible standards may be harder for some automakers than for others, and that they need not be keyed to the capabilities of the least capable manufacturer. Indeed, keying standards to the least capable manufacturer may disincentivize innovation by rewarding laggard performance, and it will very foreseeably result in less energy conservation than an approach that looks at the abilities of the industry as a whole.

NHTSA has also sought to account for economic practicability by applying marginal cost-benefit analysis since the first rulemakings establishing attribute-based standards, considering both overall societal impacts and overall consumer impacts. Whether the standards maximize net benefits has thus been a relevant, albeit not dispositive, factor in the past for NHTSA's consideration of economic practicability. E.O. 12866 states that agencies should "select, in choosing among alternative regulatory approaches, those approaches that maximize net benefits . . ." As the E.O. further recognizes, agencies, including NHTSA, must acknowledge that the modeling of net benefits does not capture all considerations relevant to economic practicability, and moreover that the uncertainty of input assumptions makes perfect foresight impossible. As in past rulemakings, NHTSA is considering our estimates of net societal impacts, net consumer impacts, and other related elements in the consideration of economic practicability. We emphasize, however, that it is well within our discretion to deviate from the level at which modeled net benefits appear to be maximized if we conclude that the level would not represent the maximum feasible level for future CAFE standards, given all relevant and statutorily-directed considerations, as well as unquantifiable benefits.[534] Economic practicability is complex, and like the other factors must be considered in the context of the overall balancing and EPCA's overarching purpose of energy conservation.

(3) The Effect of Other Motor Vehicle Standards of the Government on Fuel Economy

"The effect of other motor vehicle standards of the Government on fuel economy" involves analysis of the effects of compliance with emission, safety, noise, or damageability standards on fuel economy capability, and thus on the industry's ability to meet a given level of CAFE standards. In many past CAFE rulemakings, NHTSA has said that it considers the adverse effects of other motor vehicle standards on fuel economy. It said so because, from the CAFE program's earliest years[535] until recently, compliance with these other types of standards has had a negative effect on fuel economy. For example, safety standards that have the effect of increasing vehicle weight thereby lowers fuel economy capability (because a heavier vehicle must work harder to travel the same distance, and in working harder, consumes more energy), thus decreasing the level of average fuel economy that NHTSA can determine to be feasible. NHTSA has also accounted for Federal Tier 3 and California LEV III criteria pollutant standards within its estimates of technology effectiveness in this proposal.[536]

In other cases, the effect of other motor vehicle standards of the Government on fuel economy may be neutral, or positive. Since the Obama Administration, NHTSA has considered the GHG standards set by EPA as "other motor vehicle standards of the Government." In the 2012 final rule, NHTSA stated that "[t]o the extent the GHG standards result in increases in fuel economy, they would do so almost exclusively as a result of inducing manufacturers to install the same types of technologies used by manufacturers in complying with the CAFE standards."[537] NHTSA concluded in 2012 that "no further action was needed" because "the agency had already considered EPA's [action] and the harmonization benefits of the National Program in developing its own [action]."[538] In the 2020 final rule, NHTSA reinforced that conclusion by explaining that a textual analysis of the statutory language made it clear that EPA's GHG standards are literally "other motor vehicle standards of the Government" because they are standards set by a Federal agency that apply to motor vehicles. NHTSA and EPA are obligated by Congress to exercise their own independent judgment in fulfilling their statutory missions, even though both agencies' regulations affect both fuel economy and CO_2 emissions. There are differences between the two agencies' programs that make NHTSA's CAFE standards and EPA's GHG standards not perfectly one-to-one (even besides the fact that EPA regulates other GHGs besides CO_2, EPA's CO_2 standards also differ from NHTSA's in a variety of ways, often because NHTSA is bound by statute to a certain aspect of CAFE regulation). NHTSA creates standards that meet our statutory obligations, including through considering EPA's standards as other motor vehicle standards of the Government.[539] Specifically, NHTSA has considered EPA's standards for this proposal by including the baseline (*i.e.,* the MYs 2024–2026) GHG standards in our analytical baseline for the main analysis. Because the EPA and NHTSA programs were developed in coordination, and stringency decisions were made in coordination, NHTSA has not incorporated EPA's proposed CO_2 standards for MYs 2027–2032 as part of the analytical baseline for this proposal's main analysis. NHTSA recognizes that the proposed CAFE standards thus sit alongside EPA's light-duty vehicle multipollutant emission

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[533] NHTSA has not used the "least capable manufacturer" approach since prior to the MY 2005–2007 rulemaking (68 FR 16868, Apr. 7, 2003) under the non-attribute-based (fixed) CAFE standards.

[534] Even E.O. 12866 acknowledges that "Nothing in this order shall be construed as displacing the agencies' authorities or responsibilities, as authorized by law." E.O. 12866, Sec. 9.

[535] 43 FR 63184, 63188 (Dec. 15, 1977). *See also* 42 FR 33534, 33537 (Jun. 30, 1977).

[536] For most ICE vehicles on the road today, the majority of vehicle-based NO_X, NMOG, and CO emissions occur during "cold-start," before the three-way catalyst has reached higher exhaust temperatures (*e.g.,* approximately 300 °C), at which point it is able to convert (through oxidation and reduction reactions) those emissions into less harmful derivatives. By limiting the amount of those emissions, vehicle-level smog standards require the catalyst to be brought to temperature rapidly, so modern vehicles employ cold-start strategies that intentionally release fuel energy into the engine exhaust to heat the catalyst to the right temperature as quickly as possible. The additional fuel that must be used to heat the catalyst is typically referred to as a "cold-start penalty," meaning that the vehicle's fuel economy (over a test cycle) is reduced because the fuel consumed to heat the catalyst did not go toward the goal of moving the vehicle forward. The Autonomie work employed to develop technology effectiveness estimates for this proposal accounts for cold-start penalties, as discussed in the Chapter "Cold-start Penalty" of the "CAFE Analysis Autonomie Documentation".

[537] 77 FR 62624, 62669 (Oct. 15, 2012).

[538] *Id.*

[539] *Massachusetts* v. *EPA,* 549 U.S. 497, 532 (2007) ("[T]here is no reason to think that the two agencies cannot both administer their obligations and yet avoid inconsistency.").

standards that were proposed in April. NHTSA's intention is to finalize regulations that achieve energy conservation per its statutory mandate and consistent with its statutory constraints, that work in harmony with EPA's regulations addressing air pollution. NHTSA believes that these statutory mandates can be met while ensuring that manufacturers have the flexibility they need to achieve cost-effective compliance. Between proposed and final rules, NHTSA will continue to coordinate with EPA to optimize the effectiveness of NHTSA's standards while minimizing compliance costs, informed by public comments from all stakeholders and consistent with the statutory factors. NHTSA seeks input to help inform these objectives.

With regard to state standards, NHTSA has also considered and accounted for the impacts of anticipated manufacturer compliance with California's ZEV mandate (and its adoption by the Section 177 states), incorporating them into the baseline No-Action Alternative as other regulatory requirements foreseeably applicable to automakers during the rulemaking time frame. In so doing, we are not taking a position on whether or not these programs are preempted under EPCA, nor does NHTSA even have authority to make such determinations with the force of law. NHTSA is also not taking a position on whether these regulatory requirements are or are not other motor vehicle standards of the Government; in either event, it is still appropriate to include these requirements in the regulatory baseline because they are foreseeable legal obligations applying to the automakers during the rulemaking time frame and are therefore relevant to understanding the state of the world absent any further regulatory action by NHTSA. NHTSA continues not to model state-level GHG standards, as discussed in the 2022 final rule.[540]

(4) The Need of the U.S. To Conserve Energy

NHTSA has consistently interpreted ''the need of the United States to conserve energy'' to mean ''the consumer cost, national balance of payments, environmental, and foreign policy implications of our need for large quantities of petroleum, especially imported petroleum.'' [541] The following sections discuss each of these elements in more detail.

(c) Consumer Costs and Fuel Prices

Fuel for vehicles costs money for vehicle owners and operators, so all else equal, consumers benefit from vehicles that need less fuel to perform the same amount of work. Future fuel prices are a critical input into the economic analysis of potential CAFE standards because they determine the value of fuel savings both to new vehicle buyers and to society; the amount of fuel economy that the new vehicle market is likely to demand in the absence of regulatory action; and they inform NHTSA about the ''consumer cost . . . of our need for large quantities of petroleum.'' For this proposal, NHTSA relied on fuel price projections from the EIA AEO for 2022. Federal Government agencies generally use EIA's price projections in their assessment of future energy-related policies.

Raising fuel economy standards can reduce consumer costs on fuel—this has long been a major focus of the CAFE program and was one of the driving considerations for Congress in establishing the CAFE program originally. Over time, as average VMT has increased and more and more Americans have come to live farther and farther from their workplaces and activities, fuel costs have become even more important. Even when gasoline prices, for example, are relatively low, they can still add up quickly for consumers whose daily commute measures in hours, like many Americans in economically disadvantaged and historically underserved communities. When vehicles can go farther on a gallon of gasoline, consumers save money, and for lower-income consumers the savings may represent a larger percentage of their income and overall expenditures than for more-advantaged consumers. Of course, when fuel prices spike, lower-income consumers suffer disproportionately. Thus, clearly, the need of the United States to conserve energy is well-served by helping consumers save money at the gas pump.

NHTSA and the DOT are committed to improving equity in transportation. Helping economically disadvantaged and historically underserved Americans save money on fuel and get where they need to go is an important piece of this puzzle, and it also improves energy conservation, thus implementing Congress' intent in EPCA. All of the action alternatives considered in this proposal improve fuel economy as compared to the baseline standards, with the most stringent alternatives saving consumers the most on fuel costs.

That said, in many previous CAFE rulemakings, discussions of fuel prices have always been intended to reflect the price of motor gasoline. However, a growing set of vehicle offerings that rely in part, or entirely, on electricity suggests that gasoline prices are no longer the only fuel prices relevant to evaluations of the effects of different possible CAFE standards. In the analysis supporting this proposal, NHTSA considers the energy consumption from the entire on-road fleet, which already contains a number of plug-in hybrid and fully electric vehicles that are part of the fleet independent of proposed CAFE standards.[542] While the current national average electricity price is significantly higher than that of gasoline, on an energy equivalent basis ($/MMBtu),[543] electric motors convert energy into propulsion much more efficiently than ICEs. This means that, even though the energy-equivalent prices of electricity are higher, electric vehicles still produce fuel savings for their owners. EIA's AEO 2022 also projects some amount of rise in real gasoline prices over the next three decades,[544] while projecting real electricity prices to decrease slightly.[545] As the reliance on electricity grows in the LD fleet, NHTSA will continue to monitor the trends in electricity prices and their implications, if any, for CAFE standards.

(b) National Balance of Payments

NHTSA has consistently included consideration of the ''national balance of payments'' as part of the need of the U.S. to conserve energy because of concerns that importing large amounts of oil created a significant wealth transfer to oil-exporting countries and

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[540] *See* 87 FR at 25982 (May 2, 2022).

[541] *See, e.g.,* 42 FR 63184, 63188 (Dec. 15, 1977); 77 FR 62624, 62669 (Oct. 15, 2012).

[542] Higher CAFE standards encourage manufacturers to improve fuel economy; at the same time, manufacturers will foreseeably seek to continue to maximize profit, and to the extent that plug-in hybrids and fully-electric vehicles are cost-effective to build and desired by the market, manufacturers may well build more of these vehicles, even though NHTSA does not expressly consider them as a compliance option when we are determining maximum feasible CAFE stringency. Due to forces other than CAFE standards, however, we do expect continued growth in electrification technologies (and we reflect those forces in the analytical baseline).

[543] See AEO. 2022. Table 3: Energy Prices by Sector and Source. Available at: *https://www.eia.gov/outlooks/aeo/data/browser/#/?id=3-AEO2022&cases=ref2022&sourcekey=0.* (Accessed: May 31, 2023).

[544] See AEO. 2022. Table 12: Petroleum and Other Liquids Prices. Available at: *https://www.eia.gov/outlooks/aeo/data/browser/#/?id=12-AEO2022&cases=ref2022&sourcekey=0.* (Accessed: May 31, 2023).

[545] See AEO. 2022. Table 8: Electricity Supply, Disposition, Prices, and Emissions. Available at: *https://www.eia.gov/outlooks/aeo/data/browser/#/?id=8-AEO2022&cases=ref2022&sourcekey=0.* (Accessed May 31, 2023).

left the U.S. economically vulnerable.[546] According to EIA, the net U.S. petroleum trade value deficit peaked in 2008, but it has fallen over the past decade as volumes of U.S. petroleum exports increased to record-high levels and imports decreased.[547] The 2020 net U.S. petroleum trade value deficit was $3 billion, the smallest on record, partially because of less consumption amid COVID mitigation efforts.[548] In 2020 and 2021, annual total petroleum net imports were actually negative, the first years since at least 1949. For petroleum that was imported in 2021, 51 percent came from Canada, 8 percent came from Mexico, 8 percent came from Russia, 5 percent came from Saudi Arabia, and 2 percent came from Colombia.[549] While transportation demand is expected to continue to increase as the economy recovers from the pandemic, it is foreseeable that the trend of trade in consumer goods and services continuing to dominate the national balance of payments, as compared to petroleum, will continue during the rulemaking time frame.[550] Regardless, the U.S. does continue to rely on oil imports. Moreover, because the oil market is global in nature, the U.S. is still subject to price volatility, as recent global events have demonstrated. NHTSA recognizes that reducing the vulnerability of the U.S. to possible oil price shocks remains important. This proposal aims to improve fleet-wide fuel efficiency and to help reduce the amount of petroleum consumed in the U.S., and therefore aims to improve this part of the U.S. balance of payments as well as to protect consumers from global price shocks.

(c) Environmental Implications

Higher fleet fuel economy reduces U.S. emissions of CO_2 as well as various other pollutants by reducing the amount of oil that is produced and refined for the U.S. vehicle fleet but can also potentially increase emissions by reducing the cost of driving, which can result in increased vehicle miles traveled (*i.e.,* the rebound effect). Thus, the net effect of more stringent CAFE standards on emissions of each pollutant depends on the relative magnitudes of its reduced emissions in fuel refining and distribution and any increases in emissions from increased vehicle use. Fuel savings from CAFE standards also result in lower emissions of CO_2, the main GHG emitted as a result of refining, distribution, and use of transportation fuels.

NHTSA has considered environmental issues, both within the context of EPCA and the context of NEPA, in making decisions about the setting of standards since the earliest days of the CAFE program. As courts of appeal have noted in three decisions stretching over the last 20 years,[551] NHTSA defined ‘‘the need of the United States to conserve energy’’ in the late 1970s as including, among other things, environmental implications. In 1988, NHTSA included climate change considerations in its CAFE notices and prepared its first environmental assessment addressing that subject.[552] It cited concerns about climate change as one of the reasons for limiting the extent of its reduction of the CAFE standard for MY 1989 passenger cars.[553]

NHTSA also considers EJ issues as part of the environmental considerations under the need of the United States to conserve energy, consistent with E.O.s and DOT Order 5610.2(c), ‘‘U.S. [DOT] Actions to Address EJ in Minority Populations and Low-Income Populations.’’ [554] The affected environment for EJ is nationwide, with a focus on areas that could contain communities with EJ concerns who would most likely be exposed to the environmental and health effects of oil production, distribution, and consumption, or the impacts of climate change. This includes areas where oil production and refining occur, areas near roadways, coastal flood-prone areas, and urban areas that are subject to the heat island effect.

Numerous studies have found that some environmental hazards are more prevalent in areas where minority and low-income populations represent a higher proportion of the population compared with the general population. In terms of effects due to criteria pollutants and air toxics emissions, the body of scientific literature points to disproportionate representation of minority and low-income populations in proximity to a range of industrial, manufacturing, and hazardous waste facilities that are stationary sources of air pollution, although results of individual studies may vary. While the scientific literature specific to oil refineries is limited, disproportionate exposure of minority and low-income populations to air pollution from oil refineries is suggested by other broader studies of racial and socioeconomic disparities in proximity to industrial facilities generally. Studies have also consistently demonstrated a disproportionate prevalence of minority and low-income populations living near mobile sources of pollutants (such as roadways) and therefore are exposed to higher concentrations of criteria air pollutants in multiple locations across the United States. Lower-positioned socioeconomic groups are also generally more exposed to air pollution, and thus generally more vulnerable to effects of exposure.

In terms of exposure to climate change risks, the literature suggests that across all climate risks, low-income communities, some communities of color, and those facing discrimination are disproportionately affected by climate events. Communities overburdened by poor environmental quality experience increased climate risk due to a combination of sensitivity and exposure. Urban populations experiencing inequities and health issues have greater susceptibility to climate change, including substantial temperature increases. Some communities of color facing cumulative exposure to multiple pollutants also live in areas prone to climate risk. Indigenous peoples in the United States face increased health disparities that cause increased sensitivity to extreme heat and air pollution. Together, this information indicates that climate impacts disproportionately affect minority and low-income populations because of socioeconomic circumstances, including location of lower-income housing, histories of discrimination, and inequity. Furthermore, high temperatures can exacerbate poor air quality, further compounding the risk to overburdened communities. Finally, health-related sensitivities in low-income and minority populations increase risk of damaging impacts from poor air quality under climate change, underscoring the potential benefits of improving air quality to communities overburdened by poor environmental quality. Chapter

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[546] For the earliest discussion of this topic, *see* 42 FR 63184, 63192 (Dec. 15, 1977).

[547] EIA. Today in Energy: U.S. energy trade lowers the overall 2020 U.S. trade deficit for the first time on record. September 22, 2021. Available at *https://www.eia.gov/todayinenergy/detail.php?id=49656#.* (Accessed: May 31, 2023).

[548] EIA. Oil and Petroleum Products explained, Oil imports and exports. Updated Nov. 2, 2022. Available at *https://www.eia.gov/energyexplained/oil-and-petroleum-products/imports-and-exports.php.* (Accessed May 31, 2023).

[549] *Id.*

[550] *Id.*

[551] CAS, 793 F.2d 1322, 1325 n. 12 (D.C. Cir. 1986); Public Citizen, 848 F. 2d 256, 262–63 n. 27 (D.C. Cir. 1988) (noting that ‘‘NHTSA itself has interpreted the factors it must consider in setting CAFE standards as including environmental effects’’); CBD, 538 F.3d 1172 (9th Cir. 2007).

[552] 53 FR 33080, 33096 (Aug. 29, 1988).

[553] 63 FR 39275, 39302 (Oct. 6, 1988).

[554] Department Of Transportation. 2021. Updated Environmental Justice Order 5610.2(c).

7 of the Draft EIS discusses EJ issues in more detail.

In the Draft EIS, Chapters 3 through 5 discuss the connections between oil production, distribution, and consumption, and their health and environmental impacts. Electricity production and distribution also have health and environmental impacts, discussed in those chapters as well.

All of the action alternatives in this NPRM reduce carbon dioxide emissions and, thus, the effects of climate change, as compared to the baseline. Effects on criteria pollutants and air toxics emissions are more varied, with more stringent standards generally reducing downstream emissions but potentially increasing upstream emissions of certain pollutants due to greater electricity use (in the standard-setting analysis, by PHEVs during the standard setting years). Chapters 4 and 5 of the Draft EIS discuss this in more detail.

As discussed above, while our analysis suggests that the majority of LDVs will continue to be powered by ICEs in the near- to mid-term under all regulatory alternatives, greater electrification in the mid- to longer-term is foreseeable. While NHTSA is prohibited from considering the fuel economy of EVs in determining maximum feasible CAFE standards, EVs (which appear both in NHTSA's baseline and which may be produced in MYs following the period of regulation as an indirect effect of more stringent standards, or in response to other non-NHTSA standards, or in response to tax incentives and other government incentives, or in response to market demand) produce few to zero combustion-based emissions. As a result, electrification contributes meaningfully to the decarbonization of the transportation sector, in addition to having additional environmental, health, and economic development benefits, although these benefits may not yet be equally distributed across society. They also present new environmental (and social) questions, like the consequences of upstream electricity production, minerals extraction for battery components, and ability to charge an EV. The upstream environmental effects of extraction and refining for petroleum are well-recognized; minerals extraction and refining can also have significant downsides. NHTSA's Draft EIS discusses these and other effects (such as production and end-of-life issues) in more detail in Chapter 6, and NHTSA will continue to monitor these issues going forward insofar as CAFE standards may end up causing increased electrification levels even if NHTSA does not consider electrification in setting those standards, because NHTSA does not control what technologies manufacturers use to meet those standards, and because NHTSA is required to consider the environmental effects of its standards under NEPA.

NHTSA carefully considered the environmental effects of this rulemaking, both quantitative and qualitative, as discussed in the Draft EIS and in Sections V.C and V.D of this preamble.

(d) Foreign Policy Implications

U.S. consumption and imports of petroleum products impose costs on the domestic economy that are not reflected in the market price for crude petroleum or in the prices paid by consumers for petroleum products such as gasoline. These costs include (1) higher prices for petroleum products resulting from the effect of U.S. oil demand on world oil prices; (2) the risk of disruptions to the U.S. economy, and the effects of those disruptions on consumers, caused by sudden increases in the global price of oil and its resulting impact of fuel prices faced by U.S. consumers; (3) expenses for maintaining the Strategic Petroleum Reserve (SPR) to provide a response option should a disruption in commercial oil supplies threaten the U.S. economy, to allow the U.S. to meet part of its International Energy Agency obligation to maintain emergency oil stocks, and to provide a national defense fuel reserve; and (4) the threat of significant economic disruption, and the underlying effect on U.S. foreign policy, if an oil-exporting country threatens the United States and uses, as part of its threat, its power to upend the U.S. economy. Reducing U.S. consumption of crude oil or refined petroleum products (by reducing motor fuel use) can reduce these external costs.

In addition, a 2006 report by the Council on Foreign Relations identified six foreign policy costs that it said arose from U.S. consumption of imported oil: (1) The adverse effect that significant disruptions in oil supply will have for political and economic conditions in the U.S. and other importing countries; (2) the fears that the current international system is unable to secure oil supplies when oil is seemingly scarce and oil prices are high; (3) political realignment from dependence on imported oil that limits U.S. alliances and partnerships; (4) the flexibility that oil revenues give oil-exporting countries to adopt policies that are contrary to U.S. interests and values; (5) an undermining of sound governance by the revenues from oil and gas exports in oil-exporting countries; and (6) an increased U.S. military presence in the Middle East that results from the strategic interest associated with oil consumption.

CAFE standards over the last few decades have conserved significant quantities of oil, and the petroleum intensity of the U.S. fleet has decreased significantly. Continuing to improve energy conservation and reduce U.S. oil consumption by raising CAFE standards further has the potential to continue to help with all of these considerations. Even if the energy security picture has changed since the 1970s, due in no small part to the achievements of the CAFE program itself in increasing fleetwide fuel economy, energy security in the petroleum consumption context remains extremely important. Congress' original concern with energy security was the impact of supply shocks on American consumers in the event that the U.S.'s foreign policy objectives lead to conflicts with oil-producing nations or that global events more generally lead to fuel disruptions. Moreover, oil is produced, refined, and sold in a global marketplace, so events that impact it anywhere, impact it everywhere. The world is dealing with these effects currently. Oil prices have fluctuated dramatically in recent years and reached over $100/barrel in 2022. A motor vehicle fleet with greater fuel economy is better able to absorb increased fuel costs, particularly in the short-term, without those costs leading to a broader economic crisis, as had occurred in the 1973 and 1979 oil crises. Ensuring that the U.S. fleet is positioned to take advantage of cost-effective technology innovations will allow the U.S. to continue to base its international activities on foreign policy objectives that are not limited, at least not completely, by petroleum issues. Further, when U.S. oil consumption is linked to the globalized and tightly interconnected oil market, as it is now, the only means of reducing the exposure of U.S. consumers to global oil shocks is to reduce their oil consumption and the overall oil intensity of the U.S. economy. Thus, the reduction in oil consumption driven by fuel economy standards creates an energy security benefit.

This benefit is the original purpose behind the CAFE standards. Oil prices are inherently volatile, in part because geopolitical risk affects prices. International conflicts, sanctions, civil conflicts targeting oil production infrastructure, pandemic-related economic upheaval, cartels, all of these have had dramatic and sudden effects on oil prices in recent years. For all of these reasons, energy security remains quite relevant for NHTSA in determining maximum feasible CAFE standards.[555] There are extremely important energy security benefits associated with raising CAFE stringency that are not discussed in the Draft TSD Chapter 6.2.4, and which are difficult to quantify, but have weighed importantly for NHTSA in developing the proposed standards in this NPRM.

(5) Factors That NHTSA Is Prohibited From Considering

EPCA also provides that in determining the level at which it should set CAFE standards for a particular MY, NHTSA may not consider the ability of manufacturers to take advantage of several EPCA provisions that facilitate compliance with CAFE standards and thereby reduce the costs of compliance.[556] NHTSA cannot consider the trading, transferring, or availability of compliance credits that manufacturers earn by exceeding the CAFE standards and then use to achieve compliance in years in which their measured average fuel economy falls below the standards. NHTSA also must consider dual fueled automobiles to be operated only on gasoline or diesel fuel, and it cannot consider the possibility that manufacturers would create new dedicated alternative fueled automobiles—including battery-electric vehicles—to comply with the CAFE standards in any MY for which standards are being set. EPCA encourages the production of AFVs by specifying that their fuel economy is to be determined using a special calculation procedure; this calculation results in a more-generous fuel economy assignment for alternative-fueled vehicles compared to what they actually achieve under a strict energy efficiency conversion calculation. Of course, manufacturers are free to use dedicated and dual-fueled AFVs and credits in achieving compliance with CAFE standards.

The effect of the prohibitions against considering these statutory flexibilities (like the compliance boosts for dedicated and dual-fueled alternative vehicles, and the use and availability of overcompliance credits) in setting the CAFE standards is that NHTSA cannot set standards that assume the use of these flexibilities in response to those standards—in effect, that NHTSA cannot set standards as stringent as NHTSA would if NHTSA *could* account for the availability of those flexibilities. For example, NHTSA cannot set standards based on an analysis that modeled technology pathway that includes additional BEV penetration specifically in response to more stringent CAFE standards.

In contrast, for the non-statutory fuel economy improvement value program that NHTSA developed by regulation, NHTSA has determined that these fuel economy adjustments are not subject to the 49 U.S.C. 32902(h) prohibition. The statute is very clear as to which flexibilities are not to be considered in determining maximum feasible CAFE standards. When NHTSA has introduced additional compliance mechanisms such as AC efficiency and ‘‘off-cycle’’ technology fuel improvement values, NHTSA has considered those technologies as available in the analysis. Thus, the analysis for this proposal includes assumptions about manufacturers' use of those technologies, as detailed in Chapter 2 of the accompanying Draft TSD.

NHTSA recognizes that some stakeholders have requested that we interpret 32902(h) to erase completely all knowledge of BEVs' existence from the analysis, not only restricting their application during the standard-setting years, but restricting their application entirely, for any reason, and deleting them from the existing fleet that NHTSA uses to create an analytical baseline. PHEVs would correspondingly be counted simply as strong hybrids, considered only in ‘‘charge-sustaining’’ mode. NHTSA continues to restrict the application of BEVs (and other dedicated alternative fueled vehicles) during standard-setting years (except as is necessary to model compliance with state ZEV mandates), and to count PHEVs only in charge-sustaining mode during that time frame, which for this proposal is MYs 2027–2032. NHTSA's analysis also mandates the same compliance solution (based on compliance with the baseline standards) for all regulatory alternatives for the MYs 2022–2026 period. This ensures that the model does not simulate manufacturers creating new BEVs prior to the standard-setting years in anticipation of the need to comply with the CAFE standards during those standard-setting years. Additionally, because the model is restricted (for purposes of the standard-setting analysis) from applying BEVs during MYs 2027–2032 (again, except as is necessary to model compliance with state ZEV mandates), it literally cannot apply BEVs in those MYs in an effort to reach compliance in subsequent MYs. NHTSA has not taken the additional step of removing BEVs from the baseline fleet, and we continue to assume that manufacturers will meet their California ZEV obligations whether or not NHTSA sets new CAFE standards. We reflect those manufacturer efforts in the baseline fleet. We interpret the 32902(h) prohibition as preventing NHTSA from setting CAFE standards that effectively require *additional* application of dedicated alternative fueled vehicles in response to those standards, not as preventing NHTSA from being aware of the existence of dedicated alternative fueled vehicles that are already being produced for other reasons besides CAFE standards. Modeling the application of BEV technology in MYs outside the standard-setting years allows NHTSA to account for BEVs that manufacturers may produce for reasons other than the CAFE standards, without accounting for those BEVs that would be produced *because of* the CAFE standards. This is consistent with Congress' intent, made evident in the statute, that NHTSA does not consider the potential for manufacturers to comply with CAFE standards by producing additional dedicated alternative fuel automobiles. Moreover, OMB Circular A–4 directs agencies to conduct cost-benefit analyses against a baseline that represents the world in the absence of further regulatory action. An artificial baseline that pretends that dedicated alternative fueled vehicles do not exist would not be consistent with that directive, and we could not fulfill our statutory mandate to set maximum feasible CAFE standards without understanding these real-world baseline effects. NHTSA is aware of challenges to this approach in *Natural Resources Defense Council* v. *NHTSA,* No. 22–1080 (D.C. Cir.), and our analysis will account for any judgment in that case that may be final before the issuance of the final rule.

In order to test the possible effects of this interpretation on NHTSA's analysis, NHTSA conducted several sensitivity cases: one which applied the EPCA restrictions from MYs 2027–2035, one which applied the EPCA restrictions from MYs 2027–2050, and one which applied the EPCA restrictions for all MYs covered by the analysis. Even under the most extreme scenario, applying the restrictions to all MYs in the analysis, fuel consumption (both gasoline and electricity) fell relative to the RC: gasoline consumption did not fall by as much as the RC, and electricity consumption increased by

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[555] Draft TSD Chapter 6.2.4 also discusses emerging energy security considerations associated with vehicle electrification, but NHTSA only considers these effects for decision-making purposes within the framework of the statutory restrictions applicable to NHTSA's determination of maximum feasible CAFE standards.

[556] 49 U.S.C. 32902(h).

less than the RC, but this should be foreseeable in a scenario where fewer BEVs are available to be applied over time. The amount of carbon dioxide reduced also fell compared to the RC, and per-vehicle regulatory costs and fuel savings also dropped—but even so, the net impact on consumers was really not that much different (still slightly positive), and the order of alternatives, in terms of results for all of these metrics, did not change from the RC. Chapter 9 of the PRIA describes the results in much more detail. NHTSA does not believe that the results of this sensitivity analysis are significant enough to change our position on what regulatory alternative is maximum feasible for purposes of this proposal, as will be discussed further in Section V.D.

(6) Other Considerations in Determining Maximum Feasible CAFE Standards

NHTSA has historically considered the potential for adverse safety effects in setting CAFE standards. This practice has been upheld in case law.[557] NHTSA's findings are discussed in Section IV.B of this preamble and in Chapter 8.2.4.5 of the accompanying PRIA, and NHTSA discusses its consideration of these effects in Section V.D below.

b. Heavy-Duty Pickups and Vans

Statutory authority for the fuel consumption standards proposed in this document for HDPUVs is found in Section 103 of EISA, codified at 49 U.S.C. 32902(k). That section authorizes a fuel efficiency improvement program, designed to achieve the maximum feasible improvement, to be created for (among other things) HDPUVs. Congress directed that the standards, test methods, measurement metrics, and compliance and enforcement protocols for HDPUVs be ''appropriate, cost-effective, and technologically feasible,'' while achieving the ''maximum feasible improvement'' in fuel efficiency. These three factors are similar to and yet somewhat different from the four factors that NHTSA considers for passenger car and light truck standards, but they still modify ''feasible'' in ''maximum feasible'' in the context of the HDPUV proposal beyond a plain meaning of ''capable of being done.''[558] Importantly, NHTSA interprets them as giving NHTSA similarly broad authority to weigh potentially conflicting priorities to determine maximum feasible standards.[559] Thus, as with passenger car and light truck standards, NHTSA believes that it is firmly within our discretion to weigh and balance the HDPUV factors in a way that is technology-forcing, as evidenced by this proposal, but not in a way that requires the application of technology that will not be available in the lead time provided by this proposal, or that is not cost-effective.

While NHTSA has sought in the past to set HDPUV standards that are maximum feasible by balancing the considerations of whether standards are appropriate, cost-effective, and technologically feasible, NHTSA has not sought to interpret those factors more specifically. In the interest of helping NHTSA ground the elements of its analysis in the words of the statute, without intending to restrict NHTSA's consideration of any important factors, NHTSA proposes to interpret the 32902(k)(2) factors as follows.

(1) Appropriate

Given that the overarching purpose of EPCA is energy conservation, the amount of energy conserved by standards should inform whether standards are appropriate. When considering energy conservation, NHTSA may consider things like average estimated fuel savings to consumers, average estimated total fuel savings, and benefits to our nation's energy security, among other things. Environmental benefits are another facet of energy conservation, and NHTSA may consider carbon dioxide emissions avoided, criteria pollutant and air toxics emissions avoided, and so forth. Given NHTSA's additional mission as a safety agency, NHTSA may also consider the possible safety effects of different potential standards in determining whether those standards are appropriate. Effects on the industry that do not relate directly to ''cost-effectiveness'' may be encompassed here, such as estimated effects on sales and employment, and effects *in* the industry that appear to be happening for reasons other than NHTSA's regulations may also be encompassed. NHTSA interprets ''appropriate'' broadly, as not prohibiting consideration of any relevant elements that are not already considered under one of the other factors.

(2) Cost-Effective

Congress' use of the term ''cost-effective'' in 32902(k) appears to have a more specific aim than the broader term ''economic practicability'' in 32902(f). In past rulemakings covering HDPUVs, NHTSA has considered the ratio of estimated technology (or regulatory) costs to the estimated value of GHG emissions avoided, and also to estimated fuel savings. In setting passenger car and light truck standards, NHTSA often looks at consumer costs and benefits, like the estimated additional upfront cost of the vehicle (as above, assuming that the cost of additional technology required to meet standards gets passed forward to consumers) and the estimated fuel savings. Another way to consider cost-effectiveness could be total industry-wide estimated compliance costs compared to estimated societal benefits. Other similar comparisons of costs and benefits may also be relevant. NHTSA interprets ''cost-effective'' as encompassing these kinds of comparisons.

(3) Technologically Feasible

Technological feasibility in the HDPUV context is similar to how NHTSA interprets it in the passenger car and light truck context. NHTSA has previously interpreted ''technological feasibility'' to mean ''whether a particular method of improving fuel economy can be available for commercial application in the MY for which a standard is being established,'' as discussed above. NHTSA has further clarified that the consideration of technological feasibility ''does not mean that the technology must be available or in use when a standard is proposed or issued.''[560] Consistent with these previous interpretations, NHTSA believes that a technology does not necessarily need to be currently available or already in use for all regulated parties to be ''technologically feasible'' for these proposed standards,

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[557] As courts have recognized, ''NHTSA has always examined the safety consequences of the CAFE standards in its overall consideration of relevant factors since its earliest rulemaking under the CAFE program.'' *Competitive Enterprise Institute* v. *NHTSA,* 901 F.2d 107, 120 n. 11 (D.C. Cir. 1990) (''CEI–I'') (citing 42 FR 33534, 33551 (Jun. 30, 1977)). Courts have consistently upheld NHTSA's implementation of EPCA in this manner. See, *e.g., Competitive Enterprise Institute* v. *NHTSA,* 956 F.2d 321, 322 (D.C. Cir. 1992) (''CEI–II'') (in determining the maximum feasible standard, ''NHTSA has always taken passenger safety into account'') (citing CEI–I, 901 F.2d at 120 n. 11); *Competitive Enterprise Institute* v. *NHTSA,* 45 F.3d 481, 482–83 (D.C. Cir. 1995) (''CEI–III'') (same); *Center for Biological Diversity* v. *NHTSA,* 538 F.3d 1172, 1203–04 (9th Cir. 2008) (upholding NHTSA's analysis of vehicle safety issues associated with weight in connection with the MYs 2008–2011 CAFE rulemaking).

[558] *See Center for Biological Diversity* v. *NHTSA,* 538 F. 3d 1172, 1194 (9th Cir. 2008).

[559] Where Congress has not directly spoken to a potential issue related to such a balancing, NHTSA's interpretation must be a ''reasonable accommodation of conflicting policies . . . committed to the agency's care by the statute.'' *Id.* at 1195.

[560] *Center for Auto Safety* v. *NHTSA,* 793 F.2d 1322, 1325 n. 12 (D.C. Cir. 1986), quoting 42 FR 63, 184 (1977).

as long as it is reasonable to expect, based on the evidence before us, that the technology will be available in the MY in which the relevant standard takes effect.

B. Administrative Procedure Act

The APA governs agency rulemaking generally and provides the standard of judicial review for agency actions. To be upheld under the ''arbitrary and capricious'' standard of judicial review under the APA, an agency rule must be rational, based on consideration of the relevant factors, and within the scope of authority delegated to the agency by statute. The agency must examine the relevant data and articulate a satisfactory explanation for its action, including a ''rational connection between the facts found and the choice made.'' [561] The APA also requires that agencies provide notice and comment to the public when proposing regulations,[562] as NHTSA is doing with this NPRM and its accompanying materials.

C. National Environmental Policy Act

The National Environmental Policy Act (NEPA) directs that environmental considerations be integrated into Federal decision making process, considering the purpose and need for agencies' actions.[563] As discussed above, EPCA requires NHTSA to determine the level at which to set CAFE standards for passenger cars and light trucks by considering the four factors of technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the U.S. to conserve energy, and to set fuel efficiency standards for HDPUVs by adopting and implementing appropriate test methods, measurement metrics, fuel economy standards,[564] and compliance and enforcement protocols that are appropriate, cost-effective, and technologically feasible.[565] To explore the potential environmental consequences of this proposal, NHTSA prepared a Draft EIS for this NPRM. The purpose of an EIS is to ''. . . provide full and fair discussion of significant environmental impacts and [to] inform decision makers and the public of reasonable alternatives that would avoid or minimize adverse impacts or enhance the quality of the human environment.'' [566] This section of the preamble describes results from NHTSA's Draft EIS, which is being publicly issued simultaneously with this NPRM.

EPCA and EISA require that the Secretary of Transportation determine the maximum feasible levels of CAFE standards in a manner that sets aside the potential use of CAFE credits or application of alternative fuel technologies toward compliance in MYs for which NHTSA is issuing new standards. NEPA, however, does not impose such constraints on analysis; instead, its purpose is to ensure that ''Federal agencies consider the environmental impacts of their actions in the decision-making process.'' [567] As the environmental impacts of this action depend on manufacturer's actual responses to proposed standards, and those responses are not constrained by the adoption of alternative fueled technologies or the use of compliance credits, the Draft EIS is based on ''unconstrained'' modeling rather than ''standard setting'' modeling. The ''unconstrained'' analysis considers manufacturers' potential use of CAFE credits and application of alternative fuel technologies in order to disclose and allow consideration of the real-world environmental consequences of the Proposed Action and alternatives.

NHTSA conducts modeling both ways in order to reflect the various statutory requirements of EPCA/EISA and NEPA. The rest of the preamble, and importantly, NHTSA's balancing of relevant EPCA/EISA factors explained in Section V.D, employs the ''standard setting'' modeling in order to aid the decision-maker in avoiding consideration of the prohibited items in 49 U.S.C. 32902(h) in determining maximum feasible standards, but as a result, the impacts reported here may differ from those reported elsewhere in the preamble.[568] However, NHTSA is informed by the impacts reported in the Draft EIS, in addition to the other information presented in this preamble, the Draft TSD, and the PRIA, as part of its decision-making process.

NHTSA's overall EIS-related obligation is to ''take a 'hard look' at the environmental consequences'' as appropriate.[569] Significantly, ''[i]f the adverse environmental effects of the proposed action are adequately identified and evaluated, the agency is not constrained by NEPA from deciding that other values outweigh the environmental costs.'' [570] The agency must identify the ''environmentally preferable'' alternative but need not adopt it.[571] ''Congress in enacting NEPA . . . did not require agencies to elevate environmental concerns over other appropriate considerations.'' [572] Instead, NEPA requires an agency to develop and consider alternatives to the proposed action in preparing an EIS.[573] The statute and implementing regulations do not command an agency to favor an environmentally preferable course of action, only that it make its decision to proceed with the action after taking a hard look at the potential environmental consequences and consider the relevant factors in making a decision among alternatives.[574]

When preparing an EIS, NEPA requires an agency to compare the potential environmental impacts of its proposed action and a reasonable range of alternatives. Because NHTSA intends to set standards for passenger cars, light trucks, and HDPUVs,[575] and because evaluating the environmental impacts of this rulemaking requires consideration of the impacts of the standards for all three vehicle classes, the main analyses of direct and indirect effects of the action alternatives presented in the Draft EIS reflect: (1) the environmental

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[561] *Burlington Truck Lines, Inc.* v. *United States,* 371 U.S. 156, 168 (1962).

[562] 5 U.S.C. 553.

[563] NEPA is codified at 42 U.S.C. 4321–47. The Council on Environmental Quality (CEQ) NEPA implementing regulations are codified at 40 CFR parts 1500 through 1508.

[564] In the Phase 1 HD Fuel Efficiency Improvement Program rulemaking, NHTSA, aided by the National Academies of Sciences report, assessed potential metrics for evaluating fuel efficiency. NHTSA found that fuel economy would not be an appropriate metric for HD vehicles. Instead, NHTSA chose a metric that considers the amount of fuel consumed when moving a ton of freight (*i.e.,* performing work). As explained in the Phase 2 HD Fuel Efficiency Improvement Program Final Rule, this metric, delegated by Congress to NHTSA to formulate, is not precluded by the text of the statute. The agency concluded that it is a reasonable way by which to measure fuel efficiency for a program designed to reduce fuel consumption. Greenhouse Gas Emissions and Fuel Efficiency Standards for Medium- and Heavy-Duty Engines and Vehicles—Phase 2; Final Rule, 81 FR 73478, 73520 (Oct. 25, 2016).

[565] 49 U.S.C. 32902(k)(2).

[566] 40 CFR 1502.1.

[567] 40 CFR 1500.1(a).

[568] ''Unconstrained'' modeling results are presented for comparison purposes only in some sections of the PRIA and accompanying databooks.

[569] *Baltimore Gas & Elec. Co.* v. *Natural Resources Defense Council, Inc.,* 462 U.S. 87, 97 (1983).

[570] *Robertson* v. *Methow Valley Citizens Council,* 490 U.S. 332, 350 (1989).

[571] *See* 40 CFR 1505.2(a)(2). *Vermont Yankee Nuclear Power Corp.* v. *Nat. Res. Def. Council, Inc.,* 435 U.S. 519, 558 (1978).

[572] Baltimore Gas, 462 U.S. at 97.

[573] 42 U.S.C. 4332(2)(c)(iii).

[574] *See* 40 CFR 1505.2(a)(2).

[575] Under EPCA, as amended by EISA, NHTSA is required to set the fuel economy standards for passenger cars in each MY at the maximum feasible level and to do so separately for light trucks. Separately, and in accordance with EPCA, as amended by EISA, NHTSA is required to set FE standards for HDPUVs in each MY that are ''designed to achieve the maximum feasible improvement'' (49 U.S.C. 32902(k)(2)).

impacts associated with the proposed CAFE standards for LDVs, and (2) the environmental impacts associated with the proposed HDPUV FE standards. The analyses of cumulative impacts of the action alternatives presented in this Draft EIS reflect the cumulative or combined impact of the two sets of standards that are being proposed by NHTSA in this NPRM.

In the Draft EIS, NHTSA has analyzed a CAFE No-Action Alternative and four action alternatives for passenger car and light truck standards, along with a HDPUV FE No-Action Alternative and three action alternatives for HDPUV FE standards. The alternatives represent a range of potential actions NHTSA could take, and they are described more fully in Section III of this preamble, Chapter 1 of the Draft TSD, and Chapter 3 of the PRIA. The estimated environmental impacts of these alternatives, in turn, represent a range of potential environmental impacts that could result from NHTSA's setting maximum feasible fuel economy standards for passenger cars and light trucks and fuel efficiency standards for HDPUVs.

To derive the direct, indirect, and cumulative impacts of the CAFE standard action alternatives and the HDPUV FE standard action alternatives, NHTSA compared each action alternative to the relevant No-Action Alternative, which reflects baseline trends that would be expected in the absence of any further regulatory action. More specifically, the CAFE No-Action Alternative in the Draft EIS assumes that the CAFE standards set in the 2022 final rule for MYs 2024–2026 passenger cars and light trucks would remain in effect. The HDPUV FE No-Action Alternative in the Draft EIS assumes that the fuel efficiency standards set in the 2016 ''Phase 2'' final rule for MYs 2027 and later HDPUVs would remain in effect. Like all of the action alternatives, the No-Action Alternatives also include other considerations that will foreseeably occur during the rulemaking time frame, as discussed in more detail in Section III above. The No-Action Alternatives assume that manufacturers will comply with ZEV mandates set by California and other Section 177 states.[576] The No-Action Alternatives also assume that manufacturers would make production decisions in response to estimated market demand for fuel economy or fuel efficiency, considering estimated fuel prices; estimated product development cadence; estimated availability, applicability, cost, and effectiveness of fuel-saving technologies; and available tax credits. The No-Action Alternatives further assume the applicability of recently passed tax credits for battery-based vehicle technologies, which improve the attractiveness of those technologies to consumers. The No-Action Alternatives provide a baseline (*i.e.,* an illustration of what would be occurring in the world in the absence of new Federal regulations) against which to compare the environmental impacts of other alternatives presented in the Draft EIS.[577]

The range of CAFE and HDPUV FE standard action alternatives, as well as the relevant No-Action Alternative in the Draft EIS, encompasses a spectrum of possible fuel economy and fuel efficiency standards that NHTSA could determine were maximum feasible based on the different ways NHTSA could weigh the applicable statutory factors. NHTSA analyzed four CAFE standard action alternatives, Alt. PC1LT3, Alt. PC2LT4, Alt. PC3LT5, and Alt. PC6LT8 for passenger cars and light trucks, and three HDPUV FE standard action alternatives, Alt. HDPUV4, Alt. HDPUV10, and Alt. HDPUV14 for HDPUVs. Under PC1LT3, fuel economy stringency would increase, on average, 1 percent per year, year over year for MY 2027–2032 passenger cars, and 3 percent per year, year over year for MY 2027–2032 light trucks. Under PC2LT4, fuel economy stringency would increase, on average, 2 percent per year, year over year for MY 2027–2032 passenger cars, and 4 percent per year, year over year for MY 2027–2032 light trucks (PC2LT4 is NHTSA's Preferred Alternative for CAFE standards). Under PC3LT5, fuel economy stringency would increase, on average, 3 percent per year, year over year for MY 2027–2032 passenger cars, and 5 percent per year, year over year for MY 2027–2032 light trucks. Under PC6LT8, fuel economy stringency would increase, on average, 6 percent per year, year over year for MY 2027–2032 passenger cars, and 8 percent per year, year over year for MY 2027–2032light trucks. Under HDPUV4, FE stringency would increase, on average, 4 percent per year, year over year, for MY 2030–2035 HDPUVs. Under HDPUV10, FE stringency would increase, on average, 10 percent per year, year over year, for MY 2030–2035 HDPUVs (HDPUV10 is NHTSA's Preferred Alternative for HDPUV FE standards). Under HDPUV14, FE stringency would increase on average, 14 percent per year, year over year, for MY 2030–2035 HDPUVs. NHTSA also analyzed three CAFE and HDPUV FE alternative combinations for the cumulative impacts analysis, Alternatives PC1LT3 and HDPUV4 (the lowest stringency CAFE and HDPUV FE alternatives), Alternatives PC2LT4 and HDPUV10 (the Preferred CAFE and HDPUV FE alternatives), and Alternatives PC6LT8 and HDPUV14 (the highest stringency CAFE and HDPUV FE alternatives). Throughout the Draft EIS, estimated impacts were shown for all of these action alternatives, as well as for the relevant No-Action Alternative. For a more detailed discussion of the environmental impacts associated with the alternatives, see Chapters 3–8 of the Draft EIS, as well as Section IV.C of this preamble.

The Draft EIS describes potential environmental impacts to a variety of resources, including fuel and energy use, air quality, climate, land use and development, hazardous materials and regulated waste, EJ, and historic and cultural resources. The Draft EIS also describes how climate change resulting from global GHG emissions (including CO_2 emissions attributable to the U.S. LD transportation sector under the alternatives considered) could affect certain key natural and human resources. Resource areas are assessed qualitatively and quantitatively, as appropriate, in the Draft EIS, and the findings of that analysis are summarized here. As explained above, the qualitative impacts presented below come from the Draft EIS' ''unconstrained'' modeling so that NHTSA is appropriately informed about the potential environmental impacts of this action. Qualitative discussions of impacts related to life-cycle assessment of vehicle materials, EJ, and historic and cultural resources are located in the Draft EIS, while the impacts summarized here focus on energy, air quality, and climate change.

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[576] Section 177 of the CAA allows states to adopt motor vehicle emissions standards California has put in place to make progress toward attainment of national ambient air quality standards. At the time of writing, Colorado, Connecticut, Maine, Maryland, Massachusetts, New Jersey, New York, Oregon, Rhode Island, Vermont, and Washington have adopted California's ZEV mandate. See CARB. States that have Adopted California's Vehicle Standards under section 177 of the Federal CAA. Available at: *https://ww2.arb.ca.gov/resources/documents/states-have-adopted-californias-vehicle-standards-under-section-177-federal.* (Accessed: May 31, 2023).

[577] *See* 40 CFR 1502.2(e), 1502.14(d). CEQ has explained that ''[T]he regulations require the analysis of the No-Action Alternative even if the agency is under a court order or legislative command to act. This analysis provides a benchmark, enabling decision makers to compare the magnitude of environmental effects of the action alternatives [*See* 40 CFR 1502.14(c).] . . . Inclusion of such an analsyis in the EIS is necessary to inform Congress, the public, and the President as intended by NEPA. [*See* 40 CFR 1500.1(a).]'' Forty Most Asked Questions Concerning CEQ's NEPA Regulations, 46 FR 18026 (Mar. 23, 1981).

1. Environmental Consequences

a. Energy

(1) Direct and Indirect Impacts

As the stringency of the CAFE standard alternatives increases, total U.S. passenger car and light truck fuel consumption for the period of 2022 to 2050 decreases. Total LDV fuel consumption from 2022 to 2050 under the No-Action Alternative is projected to be 2,761 billion gasoline gallon equivalents (GGE). LDV fuel consumption from 2022 to 2050 under the action alternatives is projected to range from 2,744 billion GGE under PC1LT3 to 2,548 billion GGE under PC6LT8. Under PC2LT4, LDV fuel consumption from 2022 to 2050 is projected to be 2,727 billion GGE. Under PC3LT5, LDV fuel consumption from 2022 to 2050 is projected to be 2,688 billion GGE. All of the CAFE standard action alternatives would decrease fuel consumption compared to the relevant No-Action Alternative, with fuel consumption decreases that range from 17 billion GGE under PC1LT3 to 212 billion GGE under PC6LT8. For the preferred alternative, fuel consumption decreases by 34 billion GGE.

As the stringency of the HDPUV FE standard alternatives increases, total U.S. HDPUV fuel consumption for the period of 2022 to 2050 decreases. Total HDPUV vehicle fuel consumption from 2022 to 2050 under the No-Action Alternative is projected to be 412.2 billion GGE. HDPUV fuel consumption from 2022 to 2050 under the action alternatives is projected to range from 412.1 billion GGE under HDPUV4 to 403.3 billion GGE under HDPUV14. Under HDPUV10, HDPUV vehicle fuel consumption from 2022 to 2050 is projected to be 410.3 billion GGE. All of the HDPUV standard action alternatives would decrease fuel consumption compared to the relevant No-Action Alternative, with fuel consumption decreases that range from 0.1 billion GGE under HDPUV4 to 8.9 billion GGE under HDPUV14. For the preferred alternative, fuel consumption decreases by 1.9 billion GGE.

(2) Cumulative Impacts

Energy cumulative impacts are composed of both LD and HDPUV energy use in addition to other past, present, and reasonably foreseeable future actions. As the CAFE Model includes many foreseeable trends, like gas price projections from AEO 2022's RC, NHTSA examined two AEO 2022 side cases that could proxy a range of future outcomes where oil consumption is lower based on a range of macroeconomic factors. Since the results of the CAFE and HDPUV FE standards are a decline in oil consumption, examining side cases that also result in lower oil consumption while varying macroeconomic factors provides some insights into the cumulative effects of CAFE standards paired other potential future events. Energy production and consumption from those side cases is presented in comparison to the RC qualitatively in the Draft EIS. Below, we present the combined fuel consumption savings from the LD CAFE and HDPUV FE standards.

Total LDV and HDPUV fuel consumption from 2022 to 2050 under the No-Action Alternatives is projected to be 3,173 billion GGE. LDV and HDPUV fuel consumption from 2022 to 2050 under the action alternatives is projected to range from 3,156 billion GGE under Alternatives PC1LT3 and HDPUV4 to 2,952 billion GGE under Alternatives PC6LT8 and HDPUV14. Under Alternatives PC2LT4 and HDPUV10, the total LDV and HDPUV fuel consumption from 2022 to 2050 is projected to be 3,138 billion GGE. All of the action alternatives would decrease fuel consumption compared to the No-Action Alternatives, with decreases ranging from 17 billion GGE under Alternatives PC1LT3 and HDPUV4 to 221 billion GGE under Alternatives PC6LT8 and HDPUV14. For the proposed alternatives, fuel consumption decreases by 36 billion GGE.

Changing CAFE and HDPUV FE standards are expected to reduce gasoline and diesel fuel use in the transportation sector but are not expected to have any discernable effect on energy consumption by other sectors of the U.S. economy because petroleum products account for a very small share of energy use in other sectors. Gasoline and diesel (distillate fuel oil) account for less than 5 percent of energy use in the industrial sector, less than 4 percent of energy use in the commercial building sector, 2 percent of energy use in the residential sector, and only about 0.2 percent of energy use in the electric power sector.

b. Air Quality

(1) Direct and Indirect Impacts

The relationship between stringency and criteria and air toxics pollutant emissions is less straightforward, reflecting the complex interactions among the vehicle-based emissions rates of the various vehicle types (passenger cars and light trucks, HDPUVs, ICE vehicles and EVs, older and newer vehicles, etc.), the technologies assumed to be incorporated by manufacturers in response to CAFE and HDPUV FE standards, upstream emissions rates, the relative proportions of gasoline, diesel, and electricity in total fuel consumption, and changes in VMT from the rebound effect. In general, emissions of criteria and toxic air pollutants increase very slightly in the short term, and then decrease dramatically in the longer term, across all action alternatives, with some exceptions. In addition, the action alternatives would result in decreased incidence of $PM_{2.5}$-related health impacts in most years and alternatives due to the emissions decreases. Decreases in adverse health outcomes include decreased incidences of premature mortality, acute bronchitis, respiratory emergency room visits, and work-loss days.

(e) Criteria Pollutants

In 2035, emissions of NO, $PM_{2.5}$, and SO_2 increase, and emissions of CO and VOCs decrease, under all CAFE standard action alternatives compared to the CAFE No-Action Alternative. Relative to the CAFE No-Action Alternative, the modeling results suggest NO_X, $PM_{2.5}$, and SO_2 emissions increases in 2035 get larger from Alternative PC1LT3 through Alternative PC6LT8 (the most stringent alternative in terms of estimated required mpg). The increases in NO_X, $PM_{2.5}$, and SO_2 emissions reflect the projected increase in EV use in the later years, which would result in greater emissions from fossil-fueled power plants to generate the electricity for charging the EVs even as the electric grid that charges EVs gets progressively cleaner in later years. For CO and VOCs, the emissions decrease in 2035 get larger from Alternative PC1LT3 through Alternative PC6LT8 relative to the CAFE No-Action Alternative.

In 2050, emissions of NO_X and SO_2 increase under some CAFE standard action alternatives and decrease under others, compared to the CAFE No-Action Alternative. NO_X emissions decrease under Alternatives PC1LT3 and PC2LT4 but increase under Alternatives PC3LT5 and PC6LT8, compared to the CAFE No-Action Alternative. SO_2 emissions decrease under Alternative PC1LT3 but increase under Alternatives PC2LT4 through PC6LT8, and the increases get larger from Alternative PC2LT4 through Alternative PC6LT8. $PM_{2.5}$ emissions in 2050 decrease under all action alternatives, but the decrease under Alternative PC3LT5 is less than the decrease under Alternative PC2LT4. As in 2035, emissions in 2050 of CO and VOCs decrease under the action alternatives compared to the CAFE No-Action Alternative. The CO and VOC emissions decreases get larger from Alternative PC1LT3 through Alternative PC6LT8. SO_2 increases are largely due to higher upstream emissions associated with electricity use by greater numbers of electrified vehicles being produced in response to the standards.

Under each CAFE standard action alternative compared to the CAFE No-Action Alternative, the largest relative increases in emissions among the criteria pollutants would occur for SO_2, for which emissions would increase by as much as 16.8 percent under Alternative PC6LT8 in 2035 compared to the CAFE No-Action Alternative. The largest relative decreases in emissions would occur for CO, for which emissions would decrease by as much as 27.8 percent under Alternative PC6LT8 in 2050 compared to the CAFE No-Action Alternative. Percentage increases and decreases in emissions of NO_X, $PM_{2.5}$, and VOCs would be less, as small as less than 1 percent. The smaller differences are not expected to lead to measurable changes in concentrations of criteria pollutants in the ambient air. The larger differences in emissions could lead to changes in ambient pollutant concentrations.

In 2035, emissions of NO_X, $PM_{2.5}$, and SO_2 increase under the HDPUV FE standard action alternatives compared to the HDPUV FE No-Action Alternative, while emissions of CO and VOCs decrease. Relative to the HDPUV FE No-Action Alternative, the modeling results suggest NO_X, $PM_{2.5}$, and SO_2 emissions increases in 2035 get larger from Alternative HDPUV4 through Alternative HDPUV14 (the most stringent alternative in terms of the estimated required fuel consumption [gallons of fuel per 100 ton-mile]). For CO and VOCs, the emissions decrease in 2035 get larger from Alternative HDPUV4 through Alternative HDPUV14 relative to the HDPUV FE No-Action Alternative.

In 2050, emissions of NO_X and SO_2 increase under all HDPUV FE standard action alternatives compared to the HDPUV FE No-Action Alternative, and the increases get larger from Alternative HDPUV4 through Alternative HDPUV14. Emissions of CO, $PM_{2.5}$, and VOCs decrease under all action alternatives compared to the HDPUV FE No-Action Alternative, and the decreases get larger from Alternative HDPUV4 through Alternative HDPUV14. Under each HDPUV FE standard action alternative compared to the HDPUV FE No-Action Alternative, the largest relative increases in emissions among the criteria pollutants would occur for SO_2, for which emissions would increase by as much as 4.2 percent under Alternative HDPUV14 in 2050 compared to the HDPUV FE No-Action Alternative. The largest relative decreases in emissions would occur for CO and VOCs, for which emissions would decrease by as much as 5.7 percent under Alternative HDPUV14 in 2050 compared to the HDPUV FE No-Action Alternative. Percentage increases and reductions in emissions of NO_X and $PM_{2.5}$ would be less, as small as less than 1 percent. The smaller differences are not expected to lead to measurable changes in concentrations of criteria pollutants in the ambient air. The larger differences in emissions could lead to changes in ambient pollutant concentrations.

(f) Toxic Air Pollutants

Under each CAFE standard action alternative in 2035 and 2050 relative to the CAFE No-Action Alternative, decreases in emissions would occur for all toxic air pollutants. The decreases get larger from Alternative PC1LT3 through Alternative PC6LT8. The largest relative decreases in emissions would occur for acetaldehyde, acrolein, 1,3-butadiene, and formaldehyde, for which emissions would decrease by as much as 36 percent under Alternative PC6LT8 in 2050. Percentage decreases in emissions of benzene and diesel particulate matter (DPM) would be less, in some cases less than 1 percent.

Under each HDPUV FE standard action alternative in 2035 and 2050 relative to the HDPUV FE No-Action Alternative, emissions either remain the same or decrease for all toxic air pollutants. The decreases get larger from Alternative HDPUV4 through Alternative HDPUV14. The largest relative decreases in national emissions of toxic air pollutants among the HDPUV FE standard action alternatives, compared to the HDPUV FE No-Action Alternative, generally would occur for acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde, for which emissions would decrease by as much as 7 percent under Alternative HDPUV14 in 2050. Percentage decreases in emissions of DPM would be less, in some cases less than 1 percent.

(g) Health Impacts

In 2035 and 2050, all CAFE standard action alternatives would result in decreases in adverse health impacts (mortality, acute bronchitis, respiratory emergency room visits, and other health effects) nationwide compared to the CAFE No-Action Alternative. The improvements to health impacts (or decreases in health incidences) would get larger from Alternative PC1LT3 to Alternative PC6LT8 in 2035 and 2050. These decreases reflect the generally increasing stringency of the action alternatives as they become implemented.

In 2035 and 2050, all HDPUV FE standard action alternatives would remain the same or decrease nationwide compared to the HDPUV FE No-Action Alternative.

(2) Cumulative Impacts

(h) Criteria Pollutants

In 2035, emissions of NO_X, $PM_{2.5}$, and SO_2 increase under the CAFE and HDPUV FE alternative combinations compared to the No-Action Alternatives, while emissions of CO and VOCs decrease. Relative to the No-Action Alternatives, the modeling results suggest NO_X, $PM_{2.5}$, and SO_2 emissions increases in 2035 get smaller from Alternatives PC1LT3 and HDPUV4 to Alternatives PC2LT4 and HDPUV10, then larger from Alternatives PC2LT4 and HDPUV10 to Alternatives PC6LT8 and HDPUV14 (the combination of the most stringent CAFE and HDPUV FE standard alternatives). For CO and VOCs, the emissions decrease in 2035 get smaller from Alternatives PC1LT3 and HDPUV4 to Alternatives PC2LT4 and HDPUV10, then larger from Alternatives PC2LT4 and HDPUV10 to Alternatives PC6LT8 and HDPUV14, relative to the No-Action Alternatives.

In 2050, emissions of NO_X decrease under Alternatives PC1LT3 and HDPUV4 and Alternatives PC2LT4 and HDPUV10 but increase under Alternatives PC6LT8 and HDPUV14, compared to the No-Action Alternatives. Emissions of SO_2 decrease under Alternatives PC1LT3 and HDPUV4 but increase under Alternatives PC2LT4 and HDPUV10 and Alternatives PC6LT8 and HDPUV14, compared to the No-Action Alternatives. Emissions of CO, $PM_{2.5}$, and VOCs decrease under all CAFE and HDPUV alternative combinations compared to the No-Action Alternatives, and the decreases get larger from Alternatives PC1LT3 and HDPUV4 through Alternatives PC6LT8 and HDPUV14 for CO and VOCs, while the decreases for $PM_{2.5}$ get smaller from Alternatives PC1LT3 and HDPUV4 to Alternatives PC2LT4 and HDPUV10, and then larger from Alternatives PC2LT4 and HDPUV10 to Alternatives PC6LT8 and HDPUV14, compared to the No-Action Alternatives.

Under each CAFE and HDPUV FE alternative combination compared to the No-Action Alternatives, the largest relative increases in emissions among the criteria pollutants would occur for SO_2, for which emissions would increase by as much as 15.2 percent under Alternatives PC6LT8 and HDPUV14 in 2035, compared to the No-Action Alternatives. The largest relative decreases in emissions would occur for CO, for which emissions would decrease by as much as 25.2 percent under Alternatives PC6LT8 and HDPUV14 in 2050, compared to the No-Action Alternatives. Percentage increases and decreases in emissions of NO_X and $PM_{2.5}$ would be less, as small as less than 1 percent. The smaller differences are not expected to lead to measurable changes in concentrations of criteria pollutants in the ambient air. The larger differences in emissions could lead to changes in ambient pollutant concentrations.

(b) Toxic Air Pollutants

Toxic air pollutant emissions across the CAFE and HDPUV FE alternative combinations remain the same or decrease in 2035 and 2050, relative to the No-Action Alternatives. The decreases in 2035 get smaller from Alternatives PC1LT3 and HDPUV4 to Alternatives PC2LT4 and HDPUV10 and then larger from Alternatives PC2LT4 and HDPUV10 to Alternatives PC6LT8 and HDPUV14; the decreases in 2050 get larger from Alternatives PC1LT3 and HDPUV4 through Alternatives PC6LT8 and HDPUV14.

The largest relative decreases in emissions generally would occur for acetaldehyde, acrolein, benzene, 1,3-butadiene, and formaldehyde, for which emissions would decrease by as much as 29 percent under Alternatives PC6LT8 and HDPUV14 in 2050, compared to the No-Action Alternatives. Percentage decreases in emissions of DPM would be less, as small as less than 1 percent.

(c) Health Impacts

Adverse health impacts (mortality, acute bronchitis, respiratory emergency room visits, and other health effects) from criteria pollutant emissions would remain the same or decrease nationwide in 2035 and 2050 under all CAFE and HDPUV FE alternative combinations, relative to the No-Action Alternatives. The improvements to health impacts (or decreases in health incidences) in 2035 would get smaller or stay the same from Alternatives PC1LT3 and HDPUV4 to Alternatives PC2LT4 and HDPUV10 and then get larger from Alternatives PC2LT4 and HDPUV10 to Alternatives PC6LT8 and HDPUV14. In 2050, the improvements would get larger from Alternatives PC1LT3 and HDPUV4 to Alternatives PC6LT8 and HDPUV14. These decreases reflect the generally increasing stringency of the CAFE and HDPUV FE standard action alternatives as they become implemented.

As mentioned above, changes in assumptions about modeled technology adoption; the relative proportions of gasoline, diesel, and other fuels in total fuel consumption changes; and changes in VMT from the rebound effect would alter these health impact results; however, NHTSA believes that these assumptions are reasonable.

c. Greenhouse Gas Emissions and Climate Change

(1) Direct and Indirect Impacts

In terms of climate effects, the action alternatives would decrease both U.S. passenger car and light truck, and HDPUV fuel consumption and CO_2 emissions compared with the relevant No-Action Alternative, resulting in reductions in the anticipated increases in global CO_2 concentrations, temperature, precipitation, sea level, and ocean acidification that would otherwise occur. They would also, to a small degree, reduce the impacts and risks associated with climate change. The impacts of the action alternatives on atmospheric CO_2 concentration, global mean surface temperature, precipitation, sea level, and ocean pH would be small in relation to global emissions trajectories. Although these effects are small, they occur on a global scale and are long lasting; therefore, in aggregate, they can have large consequences for health and welfare and can make an important contribution to reducing the risks associated with climate change.

(a) Greenhouse Gas Emissions

The CAFE standard action alternatives would have the following impacts related to GHG emissions: Passenger cars and light trucks are projected to emit 52,800 million metric tons of carbon dioxide ($MMTCO_2$) from 2027 through 2100 under the CAFE No-Action Alternative. Compared to the No-Action Alternative, projected emissions reductions from 2027 to 2100 under the CAFE action alternatives would range from 300 to 8,600 $MMTCO_2$. Under Alternative PC2LT4, emissions reductions from 2027 to 2100 are projected to be 1,100 $MMTCO_2$. The CAFE action alternatives would reduce total CO_2 emissions from U.S. passenger cars and light trucks by a range of 0.6 to 16.3 percent from 2027 to 2100 compared to the CAFE No-Action Alternative. Alternative PC2LT4 would decrease these emissions by 2.1 percent through 2100. All CO_2 emissions estimates associated with the CAFE standard action alternatives include upstream emissions.

The HDPUV FE standard action alternatives would have the following impacts related to GHG emissions: HDPUVs are projected to emit 9,800 million metric tons of carbon dioxide ($MMTCO_2$) from 2027 through 2100 under the HDPUV FE No-Action Alternative. Compared to the No-Action Alternative, projected emissions reductions from 2027 to 2100 under the HDPUV action alternatives would range from 0 to 400 $MMTCO_2$. Under Alternative HDPUV10, emissions reductions from 2027 to 2100 are projected to be 100 $MMTCO_2$. The action alternatives would decrease these emissions by a range of less than 0.1 percent under HDPUV4 to 4.1 percent under HDPUV14 through 2100. Alternative HDPUV10 would decrease these emissions by 1 percent over the same period. All CO_2 emissions estimates associated with the HDPUV FE standard action alternatives include upstream emissions.

Compared with total projected CO_2 emissions of 559 $MMTCO_2$ from all passenger cars and light trucks under the CAFE No-Action Alternative in the year 2100, the CAFE standard action alternatives are expected to decrease CO_2 emissions from passenger cars and light trucks in the year 2100 less than 1 percent under Alternative PC1LT3, 7 percent under Alternative PC3LT5, and 21 percent under Alternative PC6LT8. Under Alternative PC2LT4, the 2100 total projected CO_2 emissions for all passenger cars and light trucks are 546 $MMTCO_2$, reflecting a 2 percent decrease.

Compared with total projected CO_2 emissions of 115 $MMTCO_2$ from all HDPUVs under the HDPUV FE No-Action Alternative in the year 2100, the HDPUV FE standard action alternatives are expected to decrease CO_2 emissions from HDPUVs in the year 2100 by a range of less than 1 percent under Alternative HDPUV4 to 5 percent under Alternative HDPUV14. Under Alternative HDPUV10, the 2100 total projected CO_2 emissions for all HDPUVs are 113 $MMTCO_2$, reflecting a 2 percent decrease.

To estimate changes in CO_2 concentrations and global mean surface temperature, NHTSA used a reduced-complexity climate model (MAGICC). The reference scenario used in the direct and indirect analysis is the SSP3–7.0 scenario, which the Intergovernmental Panel on Climate Change (IPCC) describes as a high emissions scenario that assumes no successful, comprehensive global actions to mitigate GHG emissions and yields atmospheric CO_2 levels of 800 ppm and an effective radiative forcing (ERF) of 7.0 watts per square meter (W/m^2) in 2100. Compared to SSP3–7.0 total global CO_2 emissions projection of 4,991,547 $MMTCO_2$ under the CAFE No-Action Alternative from 2027 through 2100, the CAFE standard action alternatives are expected to reduce global CO_2 by 0.01 percent under Alternative PC1LT3, 0.02 percent under Alternative PC2LT4, 0.06 percent under Alternative PC3LT5, and 0.17 percent under Alternative PC6LT8 by 2100.

Compared to SSP3–7.0 total global CO_2 emissions projection of 4,991,547 $MMTCO_2$ under the HDPUV No-Action Alternative from 2027 through 2100, the HDPUV action alternatives are expected to reduce global CO_2 by less than 0.01 percent under Alternatives HDPUV4 and HDPUV10, and 0.01 percent under Alternative HDPUV14 by 2100.

The emissions reductions from all passenger cars and light trucks in 2035 compared with emissions under the CAFE No-Action Alternative are approximately equivalent to the annual emissions from 2,481,083 vehicles under Alternative PC1LT3, 4,006,611 vehicles under Alternative PC2LT4, 8,125,856 vehicles under Alternative PC3LT5, and 21,921,146 vehicles under Alternative PC6LT8. (A total of 260,514,221 passenger cars and light trucks are projected to be on the road in 2035 under the No-Action Alternative).

The emissions reductions from HDPUVs in 2032 compared with emissions under the HDPUV FE No-Action Alternative are approximately equivalent to the annual emissions from 2,325 vehicles under Alternative HDPUV4, 59,962 vehicles under Alternative HDPUV10, and 297,812 vehicles under Alternative HDPUV14. (A total of 18,607,101 HDPUVs are projected to be on the road in 2032 under the No-Action Alternative.)

(b) Climate Change Indicators (Carbon Dioxide Concentration, Global Mean Surface Temperature, Sea Level, Precipitation, and Ocean pH)

CO_2 emissions affect the concentration of CO_2 in the atmosphere, which in turn affects global temperature, sea level, precipitation, and ocean pH. For the analysis of direct and indirect impacts, NHTSA used the SSP3–7.0 scenario to represent the RC emissions scenario (*i.e.,* future global emissions assuming no comprehensive global actions to mitigate GHG emissions). NHTSA selected the SSP3–7.0 scenario for its incorporation of a comprehensive suite of GHG and pollutant gas emissions, including carbonaceous aerosols and a global context of emissions with a full suite of GHGs and ozone precursors.

The CO_2 concentrations under the SSP3–7.0 emissions scenario in 2100 are estimated to be 838.31 ppm under the CAFE No-Action Alternative. CO_2 concentrations under the CAFE standard action alternatives could reach 837.48 ppm under Alternative PC6LT8, indicating a maximum atmospheric CO_2 decrease of approximately 0.83 ppm compared to the CAFE No-Action Alternative. Atmospheric CO_2 concentrations under Alternative PC1LT3 would decrease by 0.03 ppm compared with the CAFE No-Action Alternative.

Under the HDPUV FE standard action alternatives, CO_2 concentrations under the SSP3–7.0 emissions scenario in 2100 are estimated to decrease to 838.27 ppm under Alternative HDPUV14, indicating a maximum atmospheric CO_2 decrease of approximately 0.04 ppm compared to the HDPUV FE No-Action Alternative. Atmospheric CO_2 concentrations under Alternative HDPUV4 would decrease by 0.01 ppm compared with the HDPUV FE No-Action Alternative.

Under the SSP3–7.0 emissions scenario, global mean surface temperature is projected to increase by approximately 4.34 °C (7.81 °F) under the CAFE No-Action Alternative by 2100. Implementing the most stringent alternative (Alternative PC6LT8) would decrease this projected temperature rise by 0.004 °C (0.007 °F), while Alternative PC1LT3 would decrease projected temperature rise by 0.001 °C (0.002 °F).

Under the SSP3–7.0 emissions scenario, global mean surface temperature is projected to increase by approximately 4.34 °C (7.81 °F) under the HDPUV FE No-Action Alternative by 2100. The range of temperature increases under the HDPUV FE standard action alternatives would decrease this projected temperature rise by a range of less than 0.0001 °C (0.0002 °F) under Alternative HDPUV4 to 0.0002 °C (0.003 °F) under Alternative HDPUV14.

Under the CAFE standard action alternatives, projected sea-level rise in 2100 under the SSP3–7.0 scenario ranges from a high of 83.24 centimeters (32.77 inches) under the CAFE No-Action Alternative to a low of 83.16 centimeters (32.74 inches) under Alternative PC6LT8. Alternative PC6LT8 would result in a decrease in sea-level rise equal to 0.08 centimeter (0.03 inch) by 2100 compared with the level projected under the CAFE No-Action Alternative. Alternative PC1LT3 would result in a decrease of less than 0.01 centimeter (0.004 inch) compared with the CAFE No-Action Alternative.

Under the HDPUV FE standard action alternatives, projected sea-level rise in 2100 under the SSP3–7.0 scenario varies less than .01 centimeter (.004 inch) from a high of 83.24 centimeters (32.77 inches) under HDPUV FE No-Action Alternative.

Under the SSP3–7.0 scenario, global mean precipitation is anticipated to increase by 7.42 percent by 2100 under the CAFE No-Action Alternative. Under the CAFE standard action alternatives, this increase in precipitation would be reduced by 0.00 to 0.01 percent.

Under the SSP3–7.0 scenario, global mean precipitation is anticipated to increase by 7.42 percent by 2100 under the HDPUV FE No-Action Alternative. HDPUV FE standard action alternatives would see a reduction in precipitation in the range of 0.00 to 0.01 percent.

Under the SSP3–7.0 scenario, ocean pH in 2100 is anticipated to be 8.1937 under Alternative PC6LT8, about 0.0004 more than the CAFE No-Action Alternative. Under Alternative PC1LT3, ocean pH in 2100 would be 8.1933, or less than 0.0001 more than the CAFE No-Action Alternative.

Under the SSP3–7.0 scenario, ocean pH in 2100 is anticipated to be 8.1933 under Alternative HDPUV14, or less than 0.0001 more than the HDPUV FE No-Action Alternative.

The action alternatives for both CAFE and HDPUV FE standards would reduce the impacts of climate change that would otherwise occur under the No-Action Alternative. Although the projected reductions in CO_2 and climate effects are small compared with total projected future climate change, they are quantifiable and directionally consistent and would represent an important contribution to reducing the risks associated with climate change.

(2) Cumulative Impacts

(a) Greenhouse Gas Emissions

The CAFE and HDPUV alternative combinations would have the following impacts related to GHG emissions: Projections of total emissions reductions from 2027 to 2100 under the CAFE and HDPUV alternative combinations and other reasonably foreseeable future actions compared with the No-Action Alternatives range from 300 $MMTCO_2$ under Alternatives PC1LT3 and HDPUV4 to 9,000 $MMTCO_2$ under Alternatives PC6LT8 and HDPUV14. Under Alternatives PC2LT4 and HDPUV10, emissions reductions from 2027 to 2100 are projected to be 1,200 $MMTCO_2$. The action alternatives would decrease total vehicle emissions by between 0.5 percent under Alternatives PC1LT3 and HDPUV4 and 14.4 percent under Alternatives PC6LT8 and HDPUV14 by 2100. Alternatives PC2LT4 and HDPUV10 would decrease these emissions by 1.9 percent over the same period. Compared with projected total global CO_2 emissions of 2,484,191 $MMTCO_2$ from all sources from 2027 to 2100 using the moderate climate scenario, the incremental impact of this rulemaking is expected to decrease global CO_2 emissions between 0.01 percent under Alternatives PC1LT3 and HDPUV4 and 0.36 percent under Alternatives PC6LT8 and HDPUV14 by 2100. Alternatives PC2LT4 and HDPUV10 would decrease these emissions by .05 percent over the same period.

(b) Climate Change Indicators (Carbon Dioxide Concentration, Global Mean Surface Temperature, Sea Level, Precipitation, and Ocean pH)

Estimated atmospheric CO_2 concentrations in 2100 range from 587.78 ppm under the No-Action Alternatives to 587.00 ppm under Alternatives PC6LT8 and HDPUV14 (the combination of the most stringent CAFE and HDPUV FE standard alternatives). This is a decrease of 0.78 ppm compared with the No-Action Alternatives.

Global mean surface temperature decreases for the CAFE and HDPUV alternative combinations compared with the No-Action Alternatives in 2100 range from a low of less than 0.001 °C (0.002 °F) under Alternatives PC1LT3 and HDPUV4 to a high of 0.004 °C (0.007 °F) under Alternatives PC6LT8 and HDPUV14.

Global mean precipitation is anticipated to increase 6.11 percent under the No-Action Alternatives, with the CAFE and HDPUV alternative combinations reducing this effect up to 0.01 percent.

Projected sea-level rise in 2100 ranges from a high of 67.12 centimeters (26.42 inches) under the No-Action Alternatives to a low of 67.03 centimeters (26.39 inches) under Alternatives PC6LT8 and HDPUV14, indicating a maximum decrease in projected sea-level rise of 0.08 centimeter (0.03 inch) by 2100.

Ocean pH in 2100 is anticipated to be 8.3333 under Alternatives PC6LT8 and HDPUV14, about 0.005 less than the No-Action Alternatives.

(c) Health, Societal, and Environmental Impacts of Climate Change

The action alternatives would reduce the impacts of climate change that would otherwise occur under the No-Action Alternatives. The magnitude of the changes in climate effects that would be produced by the most stringent action alternatives combination, which are Alternatives PC6LT8 and HDPUV14. Using the three-degree sensitivity analysis by the year 2100 CO_2 would have a .78 ppm lower concentration, a four-thousandths-of-a-degree increase in the rate of temperature rise, a small percentage change in the rate of precipitation increase, between 0.10 and 0.11 centimeter (0.04 inch) decrease in projected sea-level rise, and an increase of 0.0005 in ocean pH. Although the projected reductions in CO_2 and climate effects are small compared with total projected future climate change, they are quantifiable, directionally consistent, and would represent an important contribution to reducing the risks associated with climate change.

Although NHTSA does quantify the changes in monetized damages that can be attributable to each action alternative, many specific impacts of climate change on health, society, and the environment cannot be estimated quantitatively. Therefore, NHTSA provides a qualitative discussion of these impacts by presenting the findings of peer-reviewed panel reports including those from IPCC, the Global Change Research Program, the Climate Change Science Program, the NRC, and the Arctic Council, among others. While the action alternatives would decrease growth in GHG emissions and reduce the impact of climate change across resources relative to the No-Action Alternative, they would not themselves prevent climate change and associated impacts. Long-term climate change impacts identified in the scientific literature are briefly summarized below, and vary regionally, including in scope, intensity, and directionality (particularly for precipitation). While it is difficult to attribute any particular impact to emissions that could result from this rulemaking, the following impacts are likely to be beneficially affected to some degree by reduced emissions from the action alternatives:

- *Freshwater Resources:* Projected risks to freshwater resources are expected to increase due to changing temperature and precipitation patterns as well as the intensification of extreme events like floods and droughts, affecting water security in many regions of the world and exacerbating existing water-related vulnerabilities.
- *Terrestrial and Freshwater Ecosystems:* Climate change is affecting terrestrial and freshwater ecosystems, including their component species and the services they provide. This impact can range in scale (from individual to population to species) and can affect all aspects of an organism's life, including its range, phenology, physiology, and morphology.
- *Ocean Systems, Coasts, and Low-Lying Areas:* Climate change-induced impacts on the physical and chemical characteristics of oceans (primarily through ocean warming and acidification) are exposing marine ecosystems to unprecedented conditions and adversely affecting life in the ocean and along its coasts. Anthropogenic climate change is also worsening the impacts on non-climatic stressors, such as habitat degradation, marine pollution, and overfishing.
- *Food, Fiber, and Forest Products:* Through its impacts on agriculture, forestry and fisheries, climate change adversely affects food availability, access, and quality, and increases the number of people at risk of hunger, malnutrition, and food insecurity.
- *Urban Areas:* Extreme temperatures, extreme precipitation events, and rising sea levels are increasing risks to urban communities, their health, wellbeing, and livelihood, with the economically and socially marginalized being most vulnerable to these impacts.
- *Rural Areas:* A high dependence on natural resources, weather-dependent livelihood activities, lower opportunities for economic diversity, and limited infrastructural resources subject rural communities to unique vulnerabilities to climate change impacts.
- *Human Health:* Climate change can affect human health, directly through mortality and morbidity caused by heatwaves, floods and other extreme weather events, changes in vector-borne diseases, changes in water and food-borne diseases, and impacts on air quality as well as through indirect pathways such as increased malnutrition and mental health impacts on communities facing climate-induced migration and displacement.
- *Human Security:* Climate change threatens various dimensions of human security, including livelihood security, food security, water security, cultural identity, and physical safety from conflict, displacement, and violence. These impacts are interconnected and unevenly distributed across regions and within societies based on differential exposure and vulnerability.
- *Stratospheric Ozone:* There is strong evidence that anthropogenic influences, particularly the addition of GHGs and ozone-depleting substances to the atmosphere, have led to a detectable reduction in stratospheric ozone concentrations and contributed to tropospheric warming and related

cooling in the lower stratosphere. These changes in stratospheric ozone have further influenced the climate by affecting the atmosphere's temperature structure and circulation patterns.

- *Compound events:* Compound events consist of combinations of multiple hazards that contribute to amplified societal and environmental impacts. Observations and projections show that climate change may increase the underlying probability of compound events occurring. To the extent the Proposed Action and alternatives would decrease the rate of CO_2 emissions relative to the relevant No-Action Alternative, they would contribute to the general decreased risk of extreme compound events. While this rulemaking alone would not necessarily decrease compound event frequency and severity from climate change, it would be one of many global actions that, together, could reduce these effects.
- *Tipping Points and Abrupt Climate Change:* Tipping points represent thresholds within Earth systems that could be triggered by continued increases in the atmospheric concentration of GHGs, incremental increases in temperature, or other relatively small or gradual changes related to climate change. For example, the melting of the Greenland ice sheet, Arctic sea-ice loss, destabilization of the West Antarctic ice sheet, and deforestation in the Amazon and dieback of boreal forests are seen as potential tipping points that can cause large-scale, abrupt changes in the climate system and lead to significant impacts on human and natural systems. We note that all of these adverse effects would be mitigated to some degree by our proposed standards.

2. Conclusion

In most cases, NHTSA presents the findings of a literature review of scientific studies in the Draft EIS, such as in Chapter 6, where NHTSA provides a literature synthesis focusing on existing credible scientific information to evaluate the most significant lifecycle environmental impacts from some of the technologies that may be used to comply with the alternatives. In Chapter 6, NHTSA describes the life-cycle environmental implications related to the vehicle cycle phase considering the materials and technologies (*e.g.,* batteries) that NHTSA forecasts vehicle manufacturers might use to comply with the CAFE and HDPUV FE standards. In Chapter 7, NHTSA discusses EJ and qualitatively describes potential disproportionate impacts on low-income and minority populations. In Chapter 8, NHTSA qualitatively describes potential impacts on historic and cultural resources. In these chapters, NHTSA concludes that impacts would vary between the action alternatives. Based on the foregoing, NHTSA concludes from the Draft EIS that Alternative PC6LT8 is the overall environmentally preferable alternative for MYs 2027–2032 CAFE standards and Alternative HDPUV14 is the overall environmentally preferable alternative for MYs 2030–2035 HDPUV FE standards because, assuming full compliance were achieved regardless of NHTSA's assessment of the costs to industry and society, it would result in the largest reductions in fuel use and CO_2 emissions among the alternatives considered. In addition, Alternative PC6LT8 and Alternative HDPUV14 would result in lower overall emissions levels over the long term of criteria air pollutants and of the toxic air pollutants studied by NHTSA. Impacts on other resources would be proportional to the impacts on fuel use and emissions, as further described in the Draft EIS, with Alternative PC6LT8 and Alternative HDPUV10 being expected to have the fewest negative environmental impacts. Although the CEQ regulations require NHTSA to identify the environmentally preferable alternative, NHTSA need not adopt it, as described above. The following section explains how NHTSA balanced the relevant factors to determine which alternative represented the maximum feasible standards, including why NHTSA does not believe that the environmentally preferable alternative is maximum feasible.

NHTSA is informed by the discussion above and the Draft EIS in arriving at its tentative conclusion that Alternative PC2LT4 and HDPUV10 is maximum feasible, as discussed below. The following section (Section VI.D) explains how NHTSA balanced the relevant factors to determine which alternatives represented the maximum feasible standards for passenger cars, light trucks, and HDPUVs.

D. Evaluating the EPCA/EISA Factors and Other Considerations To Arrive at the Proposed Standards

Accounting for all of the information presented in this preamble, in the Draft TSD, in the PRIA, and in the Draft EIS, consistent with our statutory authorities, NHTSA continues to approach the decision of what standards would be "maximum feasible" as a balancing of relevant factors and information, both for passenger cars and light trucks, and for HDPUVs. The different regulatory alternatives considered in this proposal represent different balancings of the factors—for example, PC1LT3, an alternative less stringent than the preferred alternative, would represent a balancing in which NHTSA determined that economic practicability significantly outweighed the need of the U.S. to conserve energy for purposes of the rulemaking time frame. By contrast, PC6LT8, a more stringent alternative, would represent a balancing in which NHTSA determined that the need of the U.S. to conserve energy significantly outweighed economic practicability during the same period. Because the statutory factors that NHTSA must consider are slightly different between passenger cars and light trucks on the one hand, and HDPUVs on the other, the following sections separate the segments and describe NHTSA's balancing approach for each proposal.

1. Passenger Cars and Light Trucks

NHTSA's purpose in setting CAFE standards is to conserve energy, as directed by EPCA/EISA. Energy conservation provides many benefits to the American public, including better protection for consumers against changes in fuel prices, significant fuel savings and reduced impacts from harmful pollution. NHTSA continues to believe that strong fuel economy standards function as an important insurance policy against oil price volatility, particularly to protect consumers even as the U.S. has improved its energy independence over time. The U.S. participates in the global market for oil and petroleum fuels. As a market participant—on both the demand and supply sides—the nation is exposed to fluctuations in that market. The fact that the U.S. may produce more petroleum in a given period does not in and of itself protect the nation from the consequences of these fluctuations. Accordingly, the nation must conserve petroleum and reduce the oil intensity of the economy to insulate itself from the effects of market volatility. The primary mechanism for doing so in the transportation sector is to continue to improve fleet fuel economy. In addition, better fuel economy saves consumers money at the gas pump. For example, our preferred alternative would reduce fuel consumption by 88 billion gallons through CY 2050 and save buyers of new MY 2032 vehicles an average of $1,043 in gasoline over the lifetime of the vehicle. Moreover, as climate change progresses, the U.S. may face new energy-related security risks if climate effects exacerbate geopolitical tensions and destabilization. Thus, mitigating climate effects by increasing fuel economy standards, as all of the action alternatives in this proposal would do, can also potentially improve energy security.

Maximum feasible CAFE standards look to balance the need of the U.S. to conserve energy with the technological feasibility and economic impacts of more stringent standards, while also considering other motor vehicle standards of the Government that may affect automakers' ability to meet CAFE standards. In order to comply with our statutory constraints, NHTSA disallows the application of BEVs (and other dedicated AFVs) in our analysis in response to potential new CAFE standards, and PHEVs are applied only with their charge-sustaining mode fuel economy.

In considering this proposal, NHTSA is mindful of the fact that the standards for MYs 2024–2026 included year-by-year improvements compared to the standards established in 2020 that were faster than had been typical since the inception of the CAFE program in the late 1970s and early 1980s. Those standards were intended to correct for the lack of adequate consideration of the need for energy conservation in the 2020 rule and were intended to reestablish the appropriate level of consideration of these effects that had been included in the initial 2012 rule. Thus, though the standards increased significantly when compared to the 2020 rule, they were comparable to the standards that were initially projected as augural standards for the MYs included in the 2012 final rule. The world has changed considerably in some ways, but less so in others. Since May 2022, the U.S. economy continues to have strengths and weaknesses; the auto industry remains in the middle of a major transition for a variety of reasons besides the CAFE program. Similarly, our technical analysis has changed considerably in some ways, but less so in others. Since May 2022, NHTSA has updated technologies considered in our analysis (removing some, adding others); updated macroeconomic input assumptions as with each round of analysis; improved user control of various input parameters; updated its approach to modeling the ZEV program; expanded accounting for Federal incentives; expanded procedures for estimating new vehicle sales and fleet shares; updated inputs for projecting aggregate LD VMT; and added various output values and options. Further stringency increases at a comparable rate, immediately on the heels of the increases for MYs 2024–2026, may therefore be beyond maximum feasible for MYs 2027–2032.

NHTSA tentatively concludes Alternative PC2LT4 is the maximum feasible alternative that best balances all relevant factors for passenger cars and light trucks built in MYs 2027–2032. Energy conservation is still our paramount objective, for the consumer benefits, energy security benefits, and environmental benefits that it provides. NHTSA believes that a large percentage of the fleet will remain propelled by ICEs through 2032, despite the potential significant transformation being driven by reasons other than the CAFE standards. NHTSA believes that the alternative we are proposing will encourage those ICE vehicles produced during the standard-setting time frame to achieve and maintain significant fuel economies, improve energy security, and reduce GHG emissions and other air pollutants. At the same time, NHTSA is proposing standards that our estimates suggest will continue to reduce petroleum dependence, saving consumers money and fuel over the lifetime of their vehicles, particularly light truck buyers, among other benefits, while being economically practicable for manufacturers to achieve.

Although Alternatives PC3LT5 and PC6LT8 would conserve more energy and provide greater fuel savings benefits and carbon dioxide emissions reductions, NHTSA currently estimates that those alternatives may simply not be achievable for many manufacturers in the rulemaking time frame, particularly given NHTSA's statutory restrictions on the technologies we may consider when determining maximum feasible standards. Additionally, compliance with those more stringent alternatives would impose significant costs on individual consumers without corresponding fuel savings benefits large enough to, on average, offset those costs. Within that framework, NHTSA's analysis suggests that the more stringent alternatives could push more technology application than would be economically practicable, given the rate of increase for the MYs 2024–2026 standards, given anticipated baseline activity on which our standards will be building, and given a realistic consideration of the rate of response industry is capable of achieving. In contrast to Alternatives PC3LT5 and PC6LT8, Alternative PC2LT4 comes at a cost we believe the market can bear, appears to be much more achievable, and will still result in consumer net benefits on average. The proposed alternative also achieves large fuel savings benefits and significant reductions in carbon dioxide emissions. NHTSA tentatively concludes Alternative PC2LT4 is a better choice than PC3LT5 and PC6LT8 given these factors.

The following text will walk through the four statutory factors in more detail and discuss NHTSA's decision-making process more thoroughly. The tentative balancing of factors presented here represents NHTSA's thinking at the present time, based on all of the information presented in the record for this proposal. NHTSA acknowledges that a different balancing may turn out to be appropriate for the final rule depending on information that arrives between now and then, both through the public comment process and otherwise. NHTSA seeks comment on this discussion and NHTSA's tentative conclusions.

For context and the reader's reference, here again are the regulatory alternatives among which NHTSA has tentatively chosen maximum feasible CAFE standards for MYs 2027–2032, representing different annual rates of stringency increase over the required levels in MY 2026:

TABLE V–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

TABLE V–1—REGULATORY ALTERNATIVES UNDER CONSIDERATION FOR MYs 2027–2032 PASSENGER CARS AND LIGHT TRUCKS—Continued

Name of alternative	Passenger car stringency increases, year-over-year (%)	Light truck stringency increases, year-over-year (%)
Alternative PC6LT8	6	8

In evaluating the statutory factors to determine maximum feasible standards, EPCA's overarching purpose of energy conservation suggests that NHTSA should begin with the need of the U.S. to conserve energy. According to the analysis presented in Section IV and in the accompanying PRIA, Alternative PC6LT8 is estimated to save consumers the most in fuel costs. Even in the rulemaking time frame of MYs 2027–2032, when many forces other than CAFE standards will foreseeably be driving higher rates of passenger car and light truck electrification, NHTSA believes that gasoline will still likely be the dominant fuel used in LD transportation. This means that consumers, and the economy more broadly, remain subject to fluctuations in gasoline price that impact the cost of travel and, consequently, the demand for mobility. The American economy is largely built around the availability of affordable personal transportation. Vehicles are long-lived assets, and the long-term price uncertainty and volatility of petroleum prices still represents a risk to consumers. By increasing the fuel economy of vehicles in the marketplace, more stringent CAFE standards help to better insulate consumers, and the economy more generally, against these risks over longer periods of time. Fuel economy improvements that reduce demand are an effective hedging strategy against price volatility, because gasoline prices are linked to global oil prices. Continuing to reduce the amount of money that consumers spend on vehicle fuel thus remains an important consideration for the need of the U.S. to conserve energy. Additionally, by reducing U.S. participation in global oil markets, fuel economy standards also improve U.S. energy security and our national balance of payments. Again, by reducing the most fuel consumed, Alternative PC6LT8 would likely best serve the need of the U.S. to conserve energy in these respects.

With regard to pollution effects, Alternative PC6LT8 would also result in the greatest reduction in CO_2 emissions over time, and thus have the largest (relative) impact on climate change. The effects of other pollutants are more mixed—while the emissions of NO_X and $PM_{2.5}$ eventually decrease over time, with effects being greater as stringency increases, SO_X emissions increase in all action alternations as compared to the No-Action Alternative, again with effects being greater as stringency increases.[578] Chapter 8.5 and 8.6 of the PRIA discuss estimated environmental effects of the regulatory alternatives in more detail.

These results are a direct consequence of the input assumptions used for this analysis, as well as the uncertainty surrounding these assumptions. However, both relative and absolute effects for NO_X, $PM_{2.5}$, and SO_X under each regulatory alternative are quite small in the context of overall U.S. emissions of these pollutants, and even in the context of U.S. transportation sector emissions of these pollutants. CAFE standards are not a primary driver for these pollutants; the estimated effects instead come largely from potential changes in travel demand that may result from improved fuel economy, rather than from the standards themselves. NHTSA would thus say, generally speaking, that Alternative PC6LT8 likely best meets the need of the U.S. to conserve energy in terms of environmental effects, because it saves the most fuel, which consequently means that it (1) maximizes consumer savings on fuel costs, (2) reduces a variety of pollutant emissions by the greatest amount, and (3) most reduces U.S. participation in global oil markets, with attendant benefits to energy security and the national balance of payments.

However, even though Alternative PC6LT8 may best meet the need of the U.S. to conserve energy, NHTSA is concerned that it may be beyond maximum feasible in the rulemaking time frame. NHTSA is arriving at the current tentative conclusion based on the other factors that we consider, because all of the statutory factors must be considered in determining maximum feasible CAFE standards. The need of the U.S. to conserve energy nearly always works in NHTSA's balancing to push standards more stringent, while other factors may work in the opposite direction.

Specifically, based on the information currently available, NHTSA is concerned that the more stringent regulatory alternatives considered in this analysis may land past the point of economic practicability in this time frame. In considering economic practicability, NHTSA tries to evaluate where the tipping point in the balancing of factors might be through a variety of metrics and considerations, examined in more detail below. For example, if the amounts of technology or the per-vehicle cost increases required to meet the standards appear to be beyond what we believe the market could bear in the relevant time frame; or sales and employment appear to be unduly impacted, NHTSA could decide that the future standards represented by a regulatory alternative under consideration may not be economically practicable.

We underscore again that the modeling analysis does not dictate the

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[578] We note also that some of the increase in certain pollutants, notably SO_X, results from estimated increases in electricity usage over time, as a result of greater electrification in the fleet, both in the baseline/No-Action Alternative and in the later years of the rulemaking analysis, 2040–2050. While 49 U.S.C. 32902(h) prohibits NHTSA from considering the *fuel economy* of BEVs and the electric-only-operation *fuel economy* of PHEVs during the rulemaking time frame, NHTSA believes it would be remiss to fail to account for the emissions consequences of the energy consumed to power those vehicles. Fuel economy and emissions consequences are actually different things for purposes of this proposal and analysis—fuel economy is simply an input to calculating manufacturer compliance positions, while emissions are estimated based on estimated on-road vehicle use. Emissions are affected by fuel economy, but they are not literally fuel economy. Moreover, as explained, these specific emissions effects from greater electrification are extremely small, and even if the agency retained ''standard setting'' constraints through MY 2050, the effects would not be significant enough to change the agency's tentative determination of which regulatory alternative is maximum feasible for the rulemaking time frame. NHTSA notes that recent projections available since NHTSA finished modeling for this proposal show notable decreases in power sector emissions that would likely affect the CAFE Model emissions result. NHTSA intends to analyze those projections and update them for the final rule. Finally, NHTSA notes that power sector emissions projections using more up-to-date data do not project this increase in SO_X emissions.

''answer,'' it is merely one source of information among others that aids NHTSA's balancing of the standards. We similarly underscore that there is no single bright line beyond which standards might be economically impracticable, and that these metrics are not intended to suggest one; they are simply ways to think about the information before us. The discussion of trying to identify a ''tipping point'' is simply an attempt to grapple with the information, and the ultimate decision rests with the decision-maker's discretion.

While the need of the U.S. to conserve energy may encourage NHTSA to be more technology-forcing in its balancing, regulatory alternatives that can only be achieved by the extensive application of advanced technologies besides BEVs (that may have known or unknown consumer acceptance issues) may not be economically practicable in the MY 2027–2032 time frame and may thus be beyond maximum feasible. Technology application can be considered as ''which technologies, and when''—both the technologies that NHTSA's analysis suggests would be used, and how that application occurs given manufacturers' product lifecycles. NHTSA does not mean to preclude the possibility that future fuel economy standards may be even more technology-forcing than the ones proposed here, because we anticipate that, among other things, consumer acceptance toward advanced fuel economy-improving technologies will continue to grow, as it is clearly doing at the present time. One important question would be how fast that consumer acceptance of advanced technologies grows, which is difficult to know in advance with much certainty. If consumer acceptance is outpaced by technological developments, it is possible that there could be sales impacts unforeseen by our analysis, and thus not accounted for in our decision-making. It is crucially important to remember that NHTSA's decision-making with regard to economic practicability and what standards are maximum feasible overall must be made in the context of the 32902(h) restrictions against considering the fuel economy of BEVs and the full fuel economy of PHEVs. Our results comply with those restrictions, and it is those results that inform NHTSA's decision-making.

Additionally, as discussed in Section V.A, NHTSA is less certain in this proposal that some of the more stringent alternatives are technologically feasible, a point that was not a concern in prior rulemakings due to the state of technology development at that time. NHTSA has historically understood technological feasibility as referring to whether a particular method of improving fuel economy is available for deployment in commercial application in the MY for which a standard is being established. While all of the technology in NHTSA's analysis is already available for deployment, the statutory requirement to exclude fuel economy improvements due to electrification from consideration of maximum feasible standards means that NHTSA must focus on technology available to improve the fuel economy of ICEs, and on the remaining vehicles that are not yet anticipated to be fully electric during the rulemaking time frame. When excluding various forms of electrification, we believe that more stringent standards may not be technologically feasible. NHTSA seeks comment on this question. NHTSA also notes that whether or not such standards would be technologically feasible, they would likely not be economically practicable (and thus beyond maximum feasible).

In terms of the levels of technology required and which technologies those may be, NHTSA's analysis estimates manufacturers' product ''cadence,'' representing them in terms of estimated schedules for redesigning and ''freshening'' vehicles, and assuming that significant technology changes will be implemented during vehicle redesigns—as they historically have been. Once applied, a technology will be carried forward to future MYs until superseded by a more advanced technology. If manufacturers are already applying technology widely and intensively to meet standards in earlier years, requiring them to add yet more technology (which may be less available and/or more expensive) in the MYs subject to the rulemaking may be less economically practicable. Conversely, if the preceding MYs require less technology, more technology during the rulemaking time frame may be more economically practicable.

The tables below illustrate how NHTSA has modeled that process of manufacturers applying technologies to comply with different alternative standards. The Draft TSD accompanying this proposal described the technologies and corresponding input estimates (of, *e.g.,* efficacy and cost) in detail in Chapter 3. The accompanying PRIA and appendices provide extensive detail regarding the estimated application of specific technologies to each manufacturer's fleets of passenger cars and light trucks in each MY. Finally, the underlying model outputs available on NHTSA's website provide estimates of the potential to apply specific technologies to specific vehicle model/configurations in each MY. We remind readers that the analysis represents estimates for purposes of determining feasibility, and that it does not provide ''the answer'' or mandate a specific technology path that industry must follow.

The following two tables show average incremental application rates—that is, levels beyond those projected under the No-Action Alternative—by regulatory alternative for selected technologies, given the statutory constraints under which NHTSA must determine maximum feasible CAFE standards. For example, Alternative PC1LT3 would require hardly any technology application change for passenger cars, while Alternative PC6LT8 would require an additional 37 percent of the fleet to have strong hybrid technology and 49 percent to have advanced levels of MR by MY 2032 and would reduce the percentage of vehicles with advanced engines by 38 percentage points. Alternative PC2LT4 would require strong hybrids to increase by 8 percentage points by MY 2032, would decrease advanced engines by a similar amount, and would increase advanced MR by 19 percentage points.

TABLE V–2—ESTIMATED APPLICATION OF SELECTED TECHNOLOGIES RELATIVE TO NO-ACTION ALTERNATIVE, PASSENGER CARS, STANDARD SETTING ANALYSIS

Technology	Alternative	2022 (%)	2027 (%)	2028 (%)	2029 (%)	2030 (%)	2031 (%)	2032 (%)
Strong Hybrid (all types)	PC1LT3		1%	2%	3%	2%	3%	3%
PHEV (all types)	PC1LT3		0	0	0	0	0	0
Advanced Engines	PC1LT3		−1	−2	−3	−2	−3	−3
Advanced AERO	PC1LT3		0	1	1	1	1	1
Advanced MR	PC1LT3		1	−1	2	4	6	7

TABLE V–2—ESTIMATED APPLICATION OF SELECTED TECHNOLOGIES RELATIVE TO NO-ACTION ALTERNATIVE, PASSENGER CARS, STANDARD SETTING ANALYSIS—Continued

Technology	Alternative	2022 (%)	2027 (%)	2028 (%)	2029 (%)	2030 (%)	2031 (%)	2032 (%)
Strong Hybrid (all types)	PC2LT4	....	2	4	7	8	8	8
PHEV (all types)	PC2LT4	....	0	0	0	0	0	0
Advanced Engines	PC2LT4	....	−2	−4	−7	−8	−8	−8
Advanced AERO	PC2LT4	....	0	1	1	1	1	1
Advanced MR	PC2LT4	....	2	3	6	12	15	19
Strong Hybrid (all types)	PC3LT5	....	2	5	9	10	12	12
PHEV (all types)	PC3LT5	....	0	0	0	0	0	0
Advanced Engines	PC3LT5	....	−2	−5	−9	−10	−12	−12
Advanced AERO	PC3LT5	....	0	2	2	2	2	2
Advanced MR	PC3LT5	....	4	11	15	21	26	32
Strong Hybrid (all types)	PC6LT8	....	2	13	20	25	31	37
PHEV (all types)	PC6LT8	....	0	0	0	1	1	1
Advanced Engines	PC6LT8	....	−2	−14	−20	−26	−33	−38
Advanced AERO	PC6LT8	....	0	10	10	10	10	14
Advanced MR	PC6LT8	....	4	12	16	23	33	49

Advanced Engines: Combined penetration of advanced cylinder deactivation, advanced turbo, variable compression ratio, high compression ratio, and diesel engines.[579]

Advanced AERO: Combined penetration of 15 and 20 percent aerodynamic improvement.

Advanced MR (mass reduction): Combined penetration of MR4 and MR5.

For lighttrucks, Alternative PC1LT3 would require hardly any change in technology application, while Alternative PC6LT8 would require an additional 25 percent of the fleet to have strong hybrid technology and 57 percent to have advanced levels of MR by MY 2032. Alternative PC6LT8 would also reduce the percentage of vehicles with advanced engines by 38 percentage points. Alternative PC2LT4 would require strong hybrids to increase by 18 percentage points by MY 2032, would increase PHEVs[580] by 13 percentage points, would decrease advanced engines by 25 percentage points, and would increase advanced MR by 38 percentage points.

TABLE V–3—ESTIMATED APPLICATION OF SELECTED TECHNOLOGIES RELATIVE TO NO-ACTION ALTERNATIVE, LIGHT TRUCKS, STANDARD SETTING ANALYSIS

Technology	Alternative	2022 (%)	2027 (%)	2028 (%)	2029 (%)	2030 (%)	2031 (%)	2032 (%)
Strong Hybrid (all types)	PC1LT3	....	3%	9%	10%	11%	13%	15%
PHEV (all types)	PC1LT3	....	2	2	3	3	3	5
Advanced Engines	PC1LT3	....	−5	−11	−13	−14	−16	−19
Advanced AERO	PC1LT3	....	0	1	1	1	1	1
Advanced MR	PC1LT3	....	6	6	9	9	17	21
Strong Hybrid (all types)	PC2LT4	....	3	9	11	13	16	18
PHEV (all types)	PC2LT4	....	2	3	5	5	5	7
Advanced Engines	PC2LT4	....	−5	−12	−15	−17	−21	−25
Advanced AERO	PC2LT4	....	1	1	2	2	2	2
Advanced MR	PC2LT4	....	7	10	14	16	23	28
Strong Hybrid (all types)	PC3LT5	....	3	10	13	16	19	22
PHEV (all types)	PC3LT5	....	2	2	4	5	5	7
Advanced Engines	PC3LT5	....	−5	−13	−17	−20	−24	−29
Advanced AERO	PC3LT5	....	1	2	2	2	2	2
Advanced MR	PC3LT5	....	10	15	20	22	31	38
Strong Hybrid (all types)	PC6LT8	....	3	11	14	16	20	25
PHEV (all types)	PC6LT8	....	2	2	5	8	9	13
Advanced Engines	PC6LT8	....	−6	−13	−20	−25	−29	−38
Advanced AERO	PC6LT8	....	1	3	5	5	5	5
Advanced MR	PC6LT8	....	10	15	21	25	39	57

Advanced Engines: Combined penetration of advanced cylinder deactivation, advanced turbo, variable compression ratio, high compression ratio, and diesel engines.[581]

Advanced AERO: Combined penetration of 15 and 20 percent aerodynamic improvement.

Advanced MR: Combined penetration of MR4 and MR5.

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[579] Specifically, this includes technologies with the following codes in the CAFE Model: TURBO0, TURBOE, TURBOD, TURBO1, TURBO2, ADEACD, ADEACS, HCR, HRCE, HCRD, VCR, VTG, VTGE, TURBOAD, ADSL, DSLI.

[580] We note again that PHEVs, for purposes of standard-setting analysis and this discussion of potential maximum feasible CAFE standards, are counted only in charge-sustaining mode, so that their electric-only operation is *not* counted, as required by 49 U.S.C. 32902(h).

[581] Specifically, this includes technologies with the following codes in the CAFE Model: TURBO0, TURBOE, TURBOD, TURBO1, TURBO2, ADEACD, ADEACS, HCR, HRCE, HCRD, VCR, VTG, VTGE, TURBOAD, ADSL, DSLI.

The estimated increases in technology application shown in the preceding two tables are all computed relative to the No-Action Alternative. As discussed above and in the TSD and PRIA accompanying this proposal, the No-Action Alternative includes a considerable amount of fuel-saving technology applied in response to (1) the baseline (set in 2022) CAFE and CO_2 standards, (2) fuel prices and technology cost-effectiveness (which accounts for recently-developed tax incentives), (3) the California Framework Agreements (albeit only for some intervening MYs), and (4) ZEV mandates in place in California and other States. The effects of this baseline application of technology are not attributable to this action, and NHTSA has therefore excluded these from our estimates of the incremental technology application, benefits, and costs that could result from each action alternative considered here. NHTSA's obligation is to understand and evaluate the effects of *potential future CAFE standards, as compared to* what is happening in the baseline. We realize that manufacturers face a combination of regulatory requirements simultaneously, which is why NHTSA seeks to account for those in its analytical baseline, and to determine what the additional incremental effects of different potential future CAFE standards would be, within the context of our statutory restrictions.

Additionally, for both passenger cars and light trucks, NHTSA notes that in considering the various technology penetration rates for fleets, readers (and NHTSA) must keep in mind that due to the statutory restrictions, NHTSA's analysis considers these technologies as applicable to the remaining ICE vehicles that have not yet electrified for reasons reflected in the baseline. This means that the rates apply to only a fraction of each overall fleet, and thus represent a higher rate for that fraction.

Another consideration for economic practicability is the extent to which new standards could increase the average cost to acquire new vehicles. Even though the underlying application of technology leads to reduced fuel costs over the useful lives of the affected vehicles, these per-vehicle cost changes provide both a measure of the degree of effort faced by manufacturers to comply with CAFE standards, and also the degree of adjustment, in the form of potential vehicle price increases, that will ultimately be required of vehicle purchasers. Because our analysis includes estimates of manufacturers' indirect costs and profits, as well as civil penalties that some manufacturers (as allowed under EPCA/EISA) might choose to pay in lieu of achieving compliance with CAFE standards,[582] we report cost increases as estimated average increase in vehicle price (as MSRP).[583] The technology costs described here are what NHTSA elsewhere calls ''regulatory costs,'' which means the combination of additional costs of technology added to meet the standards, plus any civil penalties paid in lieu of meeting standards. NHTSA assumes for purposes of this analysis that all regulatory costs are passed forward to consumers as price increases. If the per-vehicle cost/price increases seem consistent with those previously found to be economically practicable, given what we estimate about conditions during the rulemaking time frame, NHTSA can more readily conclude that the standards causing those increases are economically practicable.

The tables below show additional technology costs estimated to be incurred under each action alternative as compared to the No-Action Alternative, given the statutory restrictions under which NHTSA conducts its ''standard setting'' analysis:

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[582] To be clear, this is not an assessment that manufacturers *will* pay civil penalties, or *will need* to pay civil penalties, it is simply an assumption for purposes of this analysis that some manufacturers *could choose* to pay civil penalties rather than apply additional technology if they deem the former approach more cost-effective. Manufacturers are always free to choose their own compliance path.

[583] These are average values, and the agency does not expect that the prices of every vehicle would increase by the same amount; rather, the agency's underlying analysis shows unit costs varying widely between different vehicle models, as evident in the model output available on NHTSA's website. While we recognize that manufacturers will distribute regulatory costs throughout their fleet to maximize profit, we have not attempted to estimate strategic pricing, having insufficient data (which would likely be CBI) on which to base such an attempt. Additionally, even recognizing that manufacturers will distribute regulatory costs throughout their fleets, NHTSA still believes that average per-vehicle cost is useful for illustrating the possible broad affordability implications of new standards.

Table V-4: Estimated Average Price Change (Regulatory Cost) for Passenger Cars (2021$, vs. No-Action Alternative)

	2027				2028				2029				2030				2031				2032			
Manufacturer	**PC1**	**PC2**	**PC3**	**PC6**	**PC1**	**PC2**	**PC3**	**PC6**	**PC1**	**PC2**	**PC3**	**PC6**	**PC1**	**PC2**	**PC3**	**PC6**	**PC1**	**PC2**	**PC3**	**PC6**	**PC1**	**PC2**	**PC3**	**PC6**
BMW	179	277	365	652	163	230	321	854	101	199	333	1,080	74	234	411	1,468	60	259	470	1,826	0	149	428	2,196
Ford	82	730	730	1,021	80	711	711	1,245	78	695	695	1,514	97	726	999	5,685	133	860	1,191	5,958	165	1,059	1,501	6,399
GM	1,168	1,254	1,355	1,632	1,295	1,480	1,672	2,270	1,949	1,997	2,558	3,386	2,028	2,169	2,838	4,028	1,954	2,111	3,621	5,115	1,974	2,246	5,352	7,320
Honda	89	90	566	841	82	83	578	1,158	75	76	554	1,518	68	69	529	1,467	62	63	501	1,939	58	58	475	2,202
Hyundai Kia - H	1,110	1,198	1,285	1,568	2,088	2,192	2,412	2,765	2,019	2,118	2,326	3,195	1,950	2,042	2,245	3,601	1,812	1,953	2,197	4,090	1,705	1,840	2,138	4,843
Hyundai Kia - K	964	1,038	1,119	1,362	1,087	1,242	1,403	1,985	946	2,957	3,310	4,254	945	2,926	3,393	5,374	907	2,668	3,196	5,339	861	2,485	2,905	5,242
JLR	157	211	270	462	300	423	544	951	456	625	811	1,422	533	766	1,111	1,962	305	606	1,022	2,182	174	558	1,105	2,678
Karma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lucid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mazda	84	100	120	186	81	81	209	332	77	77	10,908	12,991	72	73	10,536	12,465	68	69	9,954	11,734	65	65	9,403	11,711
Mercedes-Benz	170	250	330	566	299	473	650	1,200	193	405	661	1,459	46	102	492	1,678	42	129	588	2,063	40	197	687	2,546
Mitsubishi	118	191	288	583	274	461	651	1,231	430	695	956	1,827	590	945	1,310	2,588	188	202	536	1,972	227	220	541	2,781
Nissan	87	131	210	435	1	181	358	1,052	1	168	436	1,435	0	111	321	1,463	0	114	347	1,932	0	191	477	2,790
Stellantis	40	167	267	597	305	522	716	1,310	161	431	730	1,609	133	537	935	2,140	208	734	1,257	2,661	156	814	1,470	3,248
Subaru	0	4	30	84	1	1	70	436	1	1	65	600	1	1	59	1,027	0	0	54	941	0	0	51	1,064
Tesla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Toyota	0	0	8	71	0	0	10	414	1	1	19	841	0	0	49	1,530	0	0	53	1,889	0	0	50	1,562
Volvo	80	130	190	375	230	346	462	917	313	487	659	1,353	49	134	334	1,427	41	160	385	1,749	72	215	425	2,110
VWA	166	265	370	672	301	505	703	1,357	286	521	794	1,668	71	284	651	1,894	46	137	536	2,065	41	132	562	2,535
Industry Avg.	319	384	501	704	449	554	725	1,204	477	697	984	1,785	460	683	1,004	2,285	434	650	1,058	2,656	419	654	1,205	3,080

Table V-5: Estimated Average Price Change (Regulatory Cost) for Light Trucks (2021$, vs. No-Action Alternative)

	2027				2028				2029				2030				2031				2032			
Manufacturer	**LT3**	**LT4**	**LT5**	**LT8**	**LT3**	**LT4**	**LT5**	**LT8**	**LT3**	**LT4**	**LT5**	**LT8**	**LT3**	**LT4**	**LT5**	**LT8**	**LT3**	**LT4**	**LT5**	**LT8**	**LT3**	**LT4**	**LT5**	**LT8**
BMW	111	176	236	452	136	204	282	734	155	275	405	1,105	132	299	486	1,514	120	346	584	2,001	160	422	723	2,711
Ford	440	549	549	698	757	882	882	1,258	970	1,120	1,120	1,766	948	1,096	1,375	2,431	870	1,178	1,548	2,954	843	1,365	1,831	3,694
GM	723	783	855	1,049	896	1,035	1,175	1,612	1,020	1,180	1,361	2,102	1,232	1,501	1,791	2,866	1,390	1,708	2,055	3,443	1,597	1,998	2,532	4,377
Honda	211	246	427	629	194	254	492	757	178	295	541	1,034	161	361	697	1,278	146	346	668	2,415	136	395	724	2,776
Hyundai Kia - H	1,224	1,295	1,367	1,593	1,548	2,341	1,941	2,276	1,487	2,231	1,862	2,609	1,427	2,127	1,785	3,042	1,313	1,990	1,829	3,432	1,309	2,009	5,398	7,073
Hyundai Kia - K	122	188	260	476	279	427	581	1,136	1,157	1,344	1,579	2,637	1,125	1,357	1,556	3,020	1,165	1,895	2,124	3,651	1,175	1,969	6,708	8,275
JLR	206	264	336	558	410	561	714	1,208	618	838	1,080	1,849	948	1,251	1,587	2,722	776	1,176	1,595	3,082	852	1,388	1,940	3,904
Karma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lucid	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mazda	29	56	4,468	4,955	27	43	4,316	4,816	26	60	4,950	6,794	24	70	4,814	9,881	23	65	4,533	9,296	22	62	4,331	9,180
Mercedes-Benz	138	218	299	544	312	461	619	1,142	247	409	671	1,509	348	445	715	1,926	315	439	706	2,340	292	495	849	2,985
Mitsubishi	93	155	235	502	242	421	612	1,253	422	709	1,014	2,018	642	1,071	1,520	2,963	879	1,072	3,119	3,820	865	1,046	3,012	4,545
Nissan	100	133	202	401	518	823	940	1,341	486	885	1,055	1,652	459	1,016	1,298	1,916	429	961	1,232	2,223	408	923	1,249	2,497
Stellantis	236	304	360	564	404	552	688	1,148	414	790	1,011	1,774	460	904	1,226	3,161	502	999	1,379	3,607	937	1,509	1,994	4,659
Subaru	1	2	16	49	1	1	1	18	0	1	1	740	0	0	0	1,037	0	0	0	948	0	0	0	885
Tesla	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Toyota	0	5	11	57	0	5	174	488	0	7	257	848	0	12	298	1,090	0	13	334	1,541	0	114	554	2,066
Volvo	220	271	332	531	393	524	655	1,184	584	790	997	1,837	442	669	992	2,217	377	635	1,024	2,645	405	696	1,175	3,150
VWA	171	236	305	526	258	368	483	910	246	402	621	1,361	619	939	1,212	2,327	610	919	1,231	2,701	576	958	1,417	3,409
Industry Avg.	306	360	483	647	457	587	750	1,121	535	722	942	1,652	584	819	1,139	2,326	595	885	1,257	2,797	687	1,064	1,795	3,680

It should be clear from the tables above that results vary by manufacturer, by year, and by fleet. NHTSA typically considers average results for a metric like per-vehicle cost, in part because NHTSA has typically approached economic practicability as a question for the industry as a whole, such that standards can still be maximum feasible even if they are harder for some manufacturers than others.[584] The average passenger car cost increase under PC6LT8 is $704 in MY 2027 but rises rapidly thereafter, exceeding $2,000 by MY 2030 and exceeding $3,000 by MY 2032. In contrast, the average passenger car cost increase under PC1LT3 reaches only $419 by MY 2032. This is a fairly stark difference between the least and most stringent action alternatives. The difference between average passenger car costs under PC2LT4 and PC3LT5 is only about $200 in the earlier MYs, but it begins to diverge more in MY 2029, and by MY 2032 the average passenger car cost under PC3LT5 is nearly twice the average passenger car cost under PC2LT4.

For light trucks, the average light truck cost increase under PC6LT8 is $647, and (similarly to cars) rises rapidly thereafter, also exceeding $2,000 by MY 2030 and exceeding $3,000 by MY 2032. In contrast, the average light truck cost increase under PC1LT3 reaches only $687 by MY 2032. As for cars, this is a fairly stark difference between these alternatives. Comparing average light truck cost increases between PC2LT4 and PC3LT5, the divergence over time is actually about the same as for passenger cars, although overall costs are higher (over $1,000 for both alternatives) by MY 2032. As discussed in Section V.A, while NHTSA has no bright-line rule regarding the point at which per-vehicle cost becomes economically impracticable, when considering the stringency increases (and attendant costs) which manufacturers will be facing over the period immediately prior to these proposed standards, in the form of the MYs 2024–2026 standards, the over-$3,000 per vehicle estimated for PC6LT8 by MY 2032 may be too much. Looking at average costs, with $1,205 for passenger cars and $1,795 for light trucks by MY 2032, PC3LT5 may be more likely to be economically feasible.

However, average results may be increasingly somewhat misleading as manufacturers transition their fleets to the BEVs whose fuel economy NHTSA is prohibited from considering when setting the standards. This is because fuel economy in the fleet has historically been more of a normal distribution (*i.e.,* a bell curve), and with more and more BEVs, it becomes more of a bimodal distribution (*i.e.,* a two-peak curve). Attempting to average a bimodal distribution does not necessarily give a clear picture of what non-BEV-specialized manufacturers are capable of doing, and regardless, NHTSA is directed not to consider BEV fuel economy. Thus, in this proposal, NHTSA believes it is appropriate to examine individual manufacturer results more closely. This is not to say that NHTSA wishes to return to a ''least capable manufacturer'' approach to economic practicability—rather to say that because statute prohibits NHTSA from determining maximum feasible standards based on the ''most capable'' manufacturer, we have to find a way to acknowledge their existence without allowing them to drive the answer to what is maximum feasible. If we were to do so, we would impose costs on non-BEV-only manufacturers that we believe would likely be far too high.

Looking at per-manufacturer results for passenger cars, under PC6LT8, nearly every non-BEV-only manufacturer would exceed more than $2,000 per passenger car in regulatory costs by MY 2032, with extremely high costs (well over $4,500) for Ford, GM, Hyundai-Kia, and Mazda. In the standard-setting analysis which NHTSA must consider here, significant levels of advanced MR and advanced engine technologies tend to be driving many of these cost increases. In many MYs, for many manufacturers, the inflection point in cost increases for passenger cars appears to be between PC2LT4 and PC3LT5, with many companies' passenger car costs jumping anywhere from roughly $200 to roughly $500 from PC2LT4 to PC3LT5. Again, these changes are best understood in context—passenger car sales have been falling over recent years while prices have been rising, and most of the new vehicles sold in the last couple of years have been more expensive models.[585] NHTSA does not want to inadvertently burden passenger car sales by requiring too much additional cost for new vehicles, particularly given the performance of the passenger car fleet in comparison to the light truck fleet in terms of mileage gains; every mile driven in passenger cars is, on average, more fuel-efficient than miles driven in light trucks. While the costs of PC2LT4 may challenge some manufacturers of passenger cars, they will do so by much less than PC3LT5.

Looking at per-manufacturer results for light trucks, under PC6LT8, every non-BEV-only manufacturer but Subaru would exceed $2,000 in per-vehicle costs by MY 2032, with nearly all of those exceeding $3,000. This is likely due to a combination of MR4, AERO20, SHEV, and (for PC6LT8, particularly) PHEV technologies being applied to trucks in order to meet PC6LT8. Again, there appears to be a possible inflection point in costs between PC2LT4 and PC3LT5—in MY 2032 light trucks, for example, only one manufacturer exceeds $2,000 per vehicle under PC2LT4, while 5 exceed $2,000 under PC3LT5. Additionally, closer examination of the cost incurred under PC3LT5 versus PC2LT4 shows that under PC3LT5 about one-third of per-vehicle costs originates from civil penalties paid for 'shortfalls,' as discussed below, rather than actual increase in technology (and thus, increased fuel savings). Under PC2LT4, civil penalties represent only a slightly smaller share of costs, however, their magnitude is much smaller, about half the value we find in PC3LT5. Civil penalties only represent a small share of costs in all scenarios except for PC6LT8, the most stringent alternative.

With regard to lead time and timing of technology application, NHTSA acknowledges that there is more lead time for these proposed standards than manufacturers had for the MYs 2024–2026 standards. That said, NHTSA also recognizes that we have previously stated that if the standards in the years immediately preceding the rulemaking time frame do not require significant additional technology application, then more technology should theoretically be available for meeting the standards during the rulemaking time frame—but this is not necessarily the case here. The technology penetration rates shown in Table V–2 and Table V–3 suggest that, at least for purposes of what NHTSA may consider by statute, industry would be running up against the limits of available technology for the more stringent regulatory alternatives, in a way that has not occurred in prior rulemakings. The analysis suggests that in many cases, manufacturers will need to abandon smaller steps in advanced engine technology development and instead begin converting the remaining fleet of ICE vehicles to SHEV with advanced MR, at a high cost for several major manufacturers. Lead time may not be able to overcome the costs of

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[584] *See, e.g.,* 87 FR at 25969 (''If the overarching purpose of EPCA is energy conservation, NHTSA believes that it is reasonable to expect that maximum feasible standards may be harder for some automakers than for others, and that they need not be keyed to the capabilities of the least capable manufacturer. Indeed, keying standards to the least capable manufacturer may disincentivize innovation by rewarding laggard performance.'').

[585] Tucker, S. KBB. 2021. Automakers Carry Tight Inventories: What Does It Mean to Car Buyers? Available at: *https://www.kbb.com/car-advice/automakers-carry-tight-inventories-what-does-it-mean-to-car-buyers/.* (Accessed May 31, 2023).

applying additional technology at a high rate, beyond what is already being applied to the fleet for other reasons during the rule making time frame and, in the years immediately preceding it, when considered in the context of NHTSA's statutory restrictions.

When manufacturers do not achieve required fuel economy levels, NHTSA describes them as ''in shortfall.'' NHTSA's analysis reflects several possible ways that manufacturers could fail to meet required fuel economy levels. For some companies that NHTSA judges willing to pay civil penalties in lieu of compliance, usually based on past history of penalty payment, NHTSA assumes that they will do so as soon as it becomes more cost-effective to pay penalties rather than add technology. For other companies whom NHTSA judges unwilling to pay civil penalties, if they have converted all vehicles available to be redesigned in a given MY to SHEV or PHEV and still cannot meet the required standard, then NHTSA does not assume that these companies will break redesign or refresh cycles to convert even more (of the remaining ICE) vehicles to SHEV or PHEV.[586] In these instances, a manufacturer would be ''in shortfall'' in NHTSA's analysis. Shortfall rates can also be informative for determining economic practicability, because if manufacturers simply are not achieving the required levels, then that suggests that manufacturers have generally judged it more cost-effective *not* to comply by adding technology. Moreover, the standards would not be accomplishing what they set out to accomplish, which would mean that the standards are not meeting the need of the U.S. to conserve energy as originally expected.

The following figures illustrate shortfalls by fleet, MY, manufacturer, and regulatory alternative:

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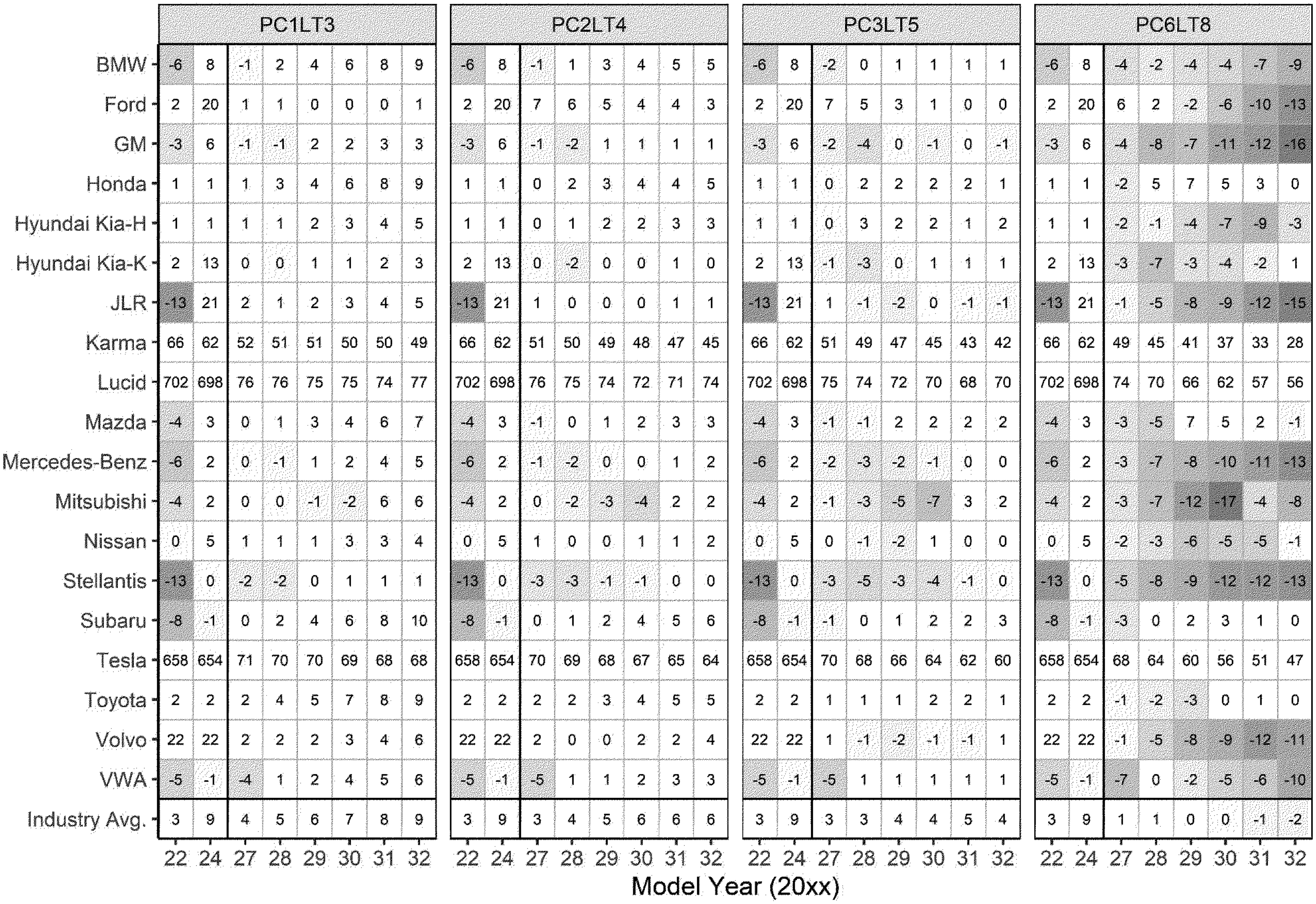
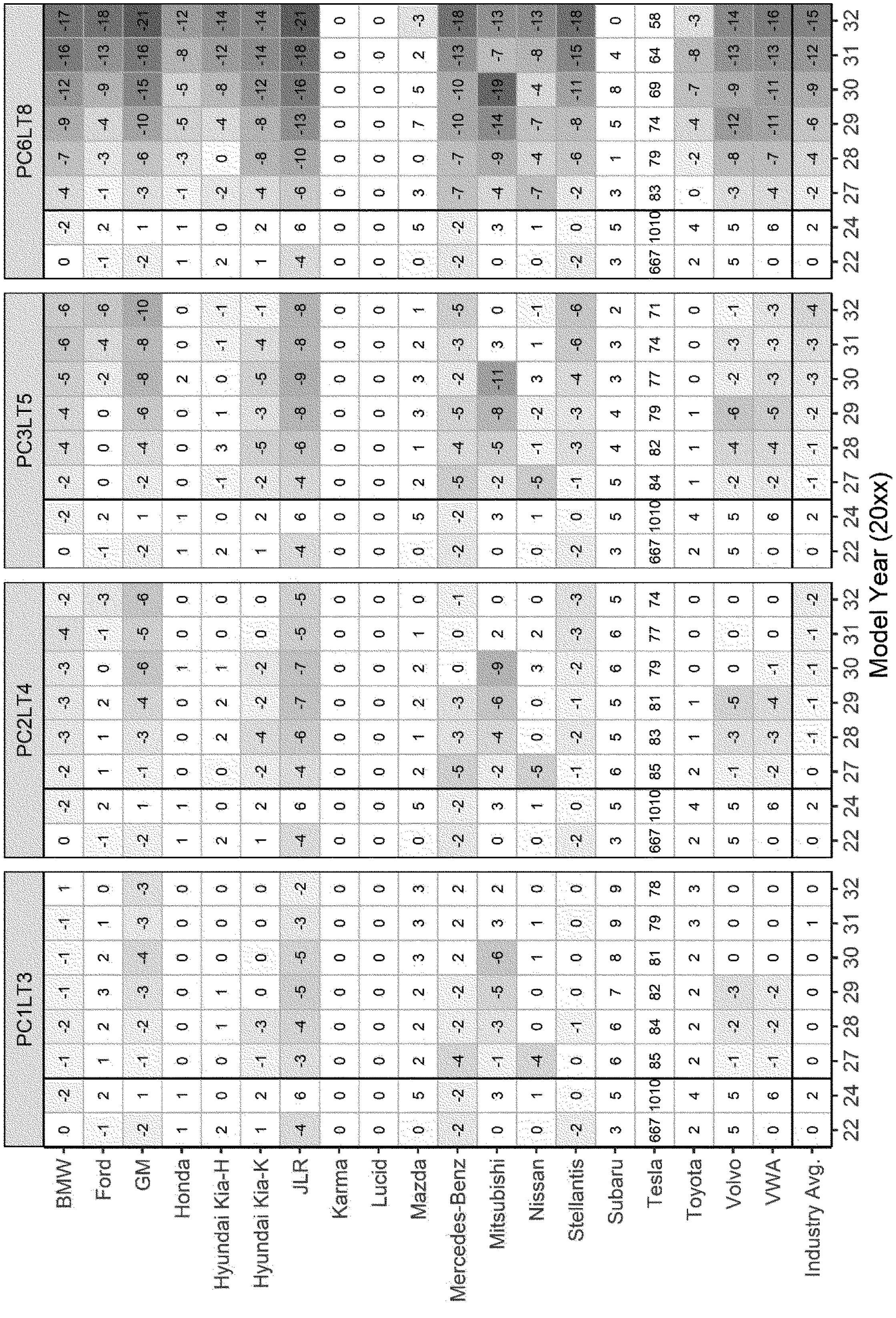
[586] Ensuring that technology application occurs consistent with refresh/redesign schedules is part of how NHTSA accounts for economic practicability. Forcing technology application outside of those schedules would be neither realistic from a manufacturing perspective nor cost-effective. See Chapter 2.2.1.7 of the Draft TSD for more information about product timing cycles.



	PC1LT3								PC2LT4								PC3LT5								PC6LT8							
	22	24	27	28	29	30	31	32	22	24	27	28	29	30	31	32	22	24	27	28	29	30	31	32	22	24	27	28	29	30	31	32
BMW	-6	8	-1	2	4	6	8	9	-6	8	-1	1	3	4	5	5	-6	8	-2	0	1	1	1	1	-6	8	-4	-2	-4	-4	-7	-9
Ford	2	20	1	1	0	0	0	1	2	20	7	6	5	4	4	3	2	20	7	5	3	1	0	0	2	20	6	2	-2	-6	-10	-13
GM	-3	6	-1	-1	2	2	3	3	-3	6	-1	-2	1	1	1	1	-3	6	-2	-4	0	-1	0	-1	-3	6	-4	-8	-7	-11	-12	-16
Honda	1	1	1	3	4	6	8	9	1	1	0	2	3	4	4	5	1	1	0	2	2	2	2	1	1	1	-2	5	7	5	3	0
Hyundai Kia-H	1	1	1	1	2	3	4	5	1	1	0	1	2	2	3	3	1	1	0	3	2	2	1	2	1	1	-2	-1	-4	-7	-9	-3
Hyundai Kia-K	2	13	0	0	1	1	2	3	2	13	0	-2	0	0	1	0	2	13	-1	-3	0	1	1	1	2	13	-3	-7	-3	-4	-2	1
JLR	-13	21	2	1	2	3	4	5	-13	21	1	0	0	0	1	1	-13	21	1	-1	-2	0	-1	-1	-13	21	-1	-5	-8	-9	-12	-15
Karma	66	62	52	51	51	50	50	49	66	62	51	50	49	48	47	45	66	62	51	49	47	45	43	42	66	62	49	45	41	37	33	28
Lucid	702	698	76	76	75	75	74	77	702	698	76	75	74	72	71	74	702	698	75	74	72	70	68	70	702	698	74	70	66	62	57	56
Mazda	-4	3	0	1	3	4	6	7	-4	3	-1	0	1	2	3	3	-4	3	-1	-1	2	2	2	2	-4	3	-3	-5	7	5	2	-1
Mercedes-Benz	-6	2	0	-1	1	2	4	5	-6	2	-1	-2	0	0	1	2	-6	2	-2	-3	-2	-1	0	0	-6	2	-3	-7	-8	-10	-11	-13
Mitsubishi	-4	2	0	0	-1	-2	6	6	-4	2	0	-2	-3	-4	2	2	-4	2	-1	-3	-5	-7	3	2	-4	2	-3	-7	-12	-17	-4	-8
Nissan	0	5	1	1	1	3	3	4	0	5	1	0	0	1	1	2	0	5	0	-1	-2	1	0	0	0	5	-2	-3	-6	-5	-5	-1
Stellantis	-13	0	-2	-2	0	1	1	1	-13	0	-3	-3	-1	-1	0	0	-13	0	-3	-5	-3	-4	-1	0	-13	0	-5	-8	-9	-12	-12	-13
Subaru	-8	-1	0	2	4	6	8	10	-8	-1	0	1	2	4	5	6	-8	-1	-1	0	1	2	2	3	-8	-1	-3	0	2	3	1	0
Tesla	658	654	71	70	70	69	68	68	658	654	70	69	68	67	65	64	658	654	70	68	66	64	62	60	658	654	68	64	60	56	51	47
Toyota	2	2	2	4	5	7	8	9	2	2	2	2	3	4	5	5	2	2	1	1	1	2	2	1	2	2	-1	-2	-3	0	1	0
Volvo	22	22	2	2	2	3	4	6	22	22	2	0	0	2	2	4	22	22	1	-1	-2	-1	-1	1	22	22	-1	-5	-8	-9	-12	-11
VWA	-5	-1	-4	1	2	4	5	6	-5	-1	-5	1	1	2	3	3	-5	-1	-5	1	1	1	1	1	-5	-1	-7	0	-2	-5	-6	-10
Industry Avg.	3	9	4	5	6	7	8	9	3	9	3	4	5	6	6	6	3	9	3	3	4	4	5	4	3	9	1	1	0	0	-1	-2

Figure V-1: Achieved Fuel Economy in MPG Relative to Required Levels under Regulatory Alternatives, Passenger Cars



PC1LT3

	22	24	27	28	29	30	31	32
BMW	0	-2	-1	-2	-1	-1	-1	1
Ford	-1	2	1	2	3	2	1	0
GM	-2	1	-1	-2	-3	-4	-3	-3
Honda	1	1	0	0	0	0	0	0
Hyundai Kia-H	2	0	0	1	1	0	0	0
Hyundai Kia-K	1	2	-1	-3	0	0	0	0
JLR	-4	6	-3	-4	-5	-5	-3	-2
Karma	0	0	0	0	0	0	0	0
Lucid	0	0	0	0	0	0	0	0
Mazda	0	5	2	2	2	3	3	3
Mercedes-Benz	-2	-2	-4	-2	-2	2	2	2
Mitsubishi	0	3	-1	-3	-5	-6	3	2
Nissan	0	1	-4	0	0	1	1	0
Stellantis	-2	0	0	-1	0	0	0	0
Subaru	3	5	6	6	7	8	9	9
Tesla	667	1010	85	84	82	81	79	78
Toyota	2	4	2	2	2	2	3	3
Volvo	5	5	-1	-2	-3	0	0	0
VWA	0	6	-1	-2	-2	0	0	0
Industry Avg.	0	2	0	0	0	0	1	0

PC2LT4

	22	24	27	28	29	30	31	32
BMW	0	-2	-2	-3	-3	-3	-4	-2
Ford	-1	2	1	1	2	0	-1	-3
GM	-2	1	-1	-3	-4	-6	-5	-6
Honda	1	1	0	0	0	1	0	0
Hyundai Kia-H	2	0	0	2	2	1	0	0
Hyundai Kia-K	1	2	-2	-4	-2	-2	0	0
JLR	-4	6	-4	-6	-7	-7	-5	-5
Karma	0	0	0	0	0	0	0	0
Lucid	0	0	0	0	0	0	0	0
Mazda	0	5	2	1	2	2	1	0
Mercedes-Benz	-2	-2	-5	-3	-3	0	0	-1
Mitsubishi	0	3	-2	-4	-6	-9	2	0
Nissan	0	1	-5	0	0	3	2	0
Stellantis	-2	0	-1	-2	-1	-2	-3	-3
Subaru	3	5	6	5	5	6	6	5
Tesla	667	1010	85	83	81	79	77	74
Toyota	2	4	2	1	1	0	0	0
Volvo	5	5	-1	-3	-5	0	0	0
VWA	0	6	-2	-3	-4	-1	0	0
Industry Avg.	0	2	0	-1	-1	-1	-1	-2

PC3LT5

	22	24	27	28	29	30	31	32
BMW	0	-2	-2	-4	-4	-5	-6	-6
Ford	-1	2	0	0	0	-2	-4	-6
GM	-2	1	-2	-4	-6	-8	-8	-10
Honda	1	1	0	0	0	2	0	0
Hyundai Kia-H	2	0	-1	3	1	0	-1	-1
Hyundai Kia-K	1	2	-2	-5	-3	-5	-4	-1
JLR	-4	6	-4	-6	-8	-9	-8	-8
Karma	0	0	0	0	0	0	0	0
Lucid	0	0	0	0	0	0	0	0
Mazda	0	5	2	1	3	3	2	1
Mercedes-Benz	-2	-2	-5	-4	-5	-2	-3	-5
Mitsubishi	0	3	-2	-5	-8	-11	3	0
Nissan	0	1	-5	-1	-2	3	1	-1
Stellantis	-2	0	-1	-3	-3	-4	-6	-6
Subaru	3	5	5	4	4	3	3	2
Tesla	667	1010	84	82	79	77	74	71
Toyota	2	4	1	1	1	0	0	0
Volvo	5	5	-2	-4	-6	-2	-3	-1
VWA	0	6	-2	-4	-5	-3	-3	-3
Industry Avg.	0	2	-1	-1	-2	-3	-3	-4

PC6LT8

	22	24	27	28	29	30	31	32
BMW	0	-2	-4	-7	-9	-12	-16	-17
Ford	-1	2	-1	-3	-4	-9	-13	-18
GM	-2	1	-3	-6	-10	-15	-16	-21
Honda	1	1	-1	-3	-5	-5	-8	-12
Hyundai Kia-H	2	0	-2	0	-4	-8	-12	-14
Hyundai Kia-K	1	2	-4	-8	-8	-12	-14	-14
JLR	-4	6	-6	-10	-13	-16	-18	-21
Karma	0	0	0	0	0	0	0	0
Lucid	0	0	0	0	0	0	0	0
Mazda	0	5	3	0	7	5	2	-3
Mercedes-Benz	-2	-2	-7	-7	-10	-10	-13	-18
Mitsubishi	0	3	-4	-9	-14	-19	-7	-13
Nissan	0	1	-7	-4	-7	-4	-8	-13
Stellantis	-2	0	-2	-6	-8	-11	-15	-18
Subaru	3	5	3	1	5	8	4	0
Tesla	667	1010	83	79	74	69	64	58
Toyota	2	4	0	-2	-4	-7	-8	-3
Volvo	5	5	-3	-8	-12	-9	-13	-14
VWA	0	6	-4	-7	-11	-11	-13	-16
Industry Avg.	0	2	-2	-4	-6	-9	-12	-15

Model Year (20xx)

Figure V-2: Achieved Fuel Economy in MPG Relative to Required Levels under Regulatory Alternatives, Light Trucks

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For passenger cars, the industry average again obscures more serious shortfall trends among individual manufacturers. Many manufacturers' passenger car fleets are estimated to fall significantly short of required levels under PC6LT8. Even for PC3LT5, several non-BEV-only manufacturers still appear to be falling short in most MYs. Passenger car shortfalls are much less widespread under PC2LT4. For light trucks, the shortfalls are extensive under PC6LT8, and about half of non-BEV-only manufacturers fall short in most if not all MYs under PC3LT5. Even PC2LT4 appears challenging under the standard-setting runs for several light truck non-BEV-only manufacturers. Given all of the data examined, NHTSA believes that PC2LT4 may represent the upper limit of economic practicability during the rulemaking time frame.

Of course, CAFE standards are performance-based, and NHTSA does not dictate specific technology paths for meeting them, so it is entirely possible that individual manufacturers and industry as a whole will take a different path from the one that NHTSA presents here.[587] Nonetheless, this is *a* path toward compliance, relying on known, existing technology, and NHTSA believes that our analysis suggests that the levels of technology and cost required by PC2LT4 are reasonable and economically practicable in the rulemaking time frame.

As in past analyses, NHTSA assumes that the cost increases associated with applying technology (or paying civil penalties) in response to more stringent standards would be passed on to consumers as higher retail prices. Higher retail prices are assumed to result in slight decreases in new vehicle sales, with larger price increases (as for more stringent alternatives) resulting in larger (but still relatively minor) sales decreases. While we estimate that the per-vehicle costs and technology penetration rates of Alternative PC2LT4 are reasonable, and while our analysis suggests that it maximizes net benefits in the rulemaking time frame given our statutory restrictions, we note that it produces a slight decline in new vehicle sales (less than 1 percent through MY 2032) as compared to the No-Action Alternative, as a consequence of the higher retail prices that result from additional technology application. NHTSA does not believe that this very minor estimated change in new vehicle sales over the period covered by the rule is a persuasive reason to choose another regulatory alternative, particularly as macroeconomic factors have historically had a far greater impact on sales than CAFE standards. Similarly, the estimated labor impacts within the automotive industry provide no evidence that another alternative should be preferred. On the one hand, when fewer vehicles are sold, manufacturers require fewer labor hours to satisfy demand, but on the other hand, development and deployment of new fuel-economy-improving technologies increase demand for labor. The analysis suggests that technology effects outweigh sales effects, at least for PC1LT3, PC2LT4, and PC3LT5, resulting in slightly higher labor utilization than under the No-Action Alternative. That said, the actual values are quite small in comparison to total auto industry employment, and as with sales, NHTSA does not believe that employment effects provide clear evidence that another alternative should be preferred. Chapter 8.2.2.3 of the PRIA contains more information.

The tables and discussion also illustrate that, in some respects, economic practicability points in the opposite direction of the need of the U.S. to conserve energy. It is within NHTSA's discretion to forgo the potential prospect of additional energy conservation benefits if NHTSA believes that more stringent standards would be economically impracticable, and thus, beyond maximum feasible.

Changes in costs for new vehicles are not the only costs that NHTSA considers in balancing the statutory factors. Fuel costs for consumers are relevant to the need of the U.S. to conserve energy, and NHTSA believes that consumers themselves weigh expected fuel savings against increases in purchase price for vehicles with higher fuel economy, although the extent to which consumers value fuel economy improvements is hotly debated, as discussed in Chapter 4.2 of the Draft TSD. Fuel costs (or savings) continue, for now, to be the largest source of benefits for CAFE standards. Comparing private costs to private benefits, the estimated results for American consumers are as follows:

TABLE V–6—INCREMENTAL PRIVATE BENEFITS AND PRIVATE COSTS OVER THE LIFETIMES OF TOTAL PASSENGER CAR FLEET PRODUCED THROUGH MY 2032 (2021$ BILLIONS), 3 PERCENT DR, BY ALTERNATIVE

Alternative	PC1LT3	PC2LT4	PC3LT5	PC6LT8
Private Costs:				
Technology Costs to Increase Fuel Economy	8.3	10.9	15.7	23.9
Increased Maintenance and Repair Costs	0.0	0.0	0.0	0.0
Opportunity Cost in Other Vehicle Attributes	0.0	0.0	0.0	0.0
Consumer Surplus Loss from Reduced New Vehicle Sales	0.0	0.0	0.1	0.4
Safety Costs Internalized by Drivers	0.3	0.6	1.0	2.3
Subtotal—Incremental Private Costs	8.6	11.5	16.7	26.6
Private Benefits:				
Reduced Fuel Costs	2.3	4.4	6.0	14.4
Benefits from Additional Driving	0.4	0.9	1.5	3.5
Less Frequent Refueling	0.2	0.4	0.5	1.2
Subtotal—Incremental Private Benefits	2.9	5.7	8.0	19.0
Net Incremental Private Benefits	−5.7	−5.8	−8.7	−7.6

TABLE V–7—INCREMENTAL PRIVATE BENEFITS AND PRIVATE COSTS OVER THE LIFETIMES OF TOTAL LIGHT TRUCK FLEET PRODUCED THROUGH MY 2032 (2021$ BILLIONS), 3 PERCENT DR, BY ALTERNATIVE

Alternative	PC1LT3	PC2LT4	PC3LT5	PC6LT8
Private Costs:				
Technology Costs to Increase Fuel Economy	21.6	26.9	35.0	44.9
Increased Maintenance and Repair Costs	0.0	0.0	0.0	0.0
Opportunity Cost in Other Vehicle Attributes	0.0	0.0	0.0	0.0

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[587] NHTSA acknowledges that compliance looks easier and more cost-effective for many manufacturers under the "unconstrained" analysis as compared to the "standard-setting" analysis discussed here, but emphasizes that NHTSA's decision on maximum feasible standards must be based on the standard-setting analysis reflecting the 32902(h) restrictions.

TABLE V–7—INCREMENTAL PRIVATE BENEFITS AND PRIVATE COSTS OVER THE LIFETIMES OF TOTAL LIGHT TRUCK FLEET PRODUCED THROUGH MY 2032 (2021$ BILLIONS), 3 PERCENT DR, BY ALTERNATIVE—Continued

Alternative	PC1LT3	PC2LT4	PC3LT5	PC6LT8
Consumer Surplus Loss from Reduced New Vehicle Sales	0.0	0.1	0.2	0.8
Safety Costs Internalized by Drivers	4.0	4.8	5.6	6.3
Subtotal—Incremental Private Costs	25.6	31.8	40.7	52.0
Private Benefits:				
Reduced Fuel Costs	35.3	43.3	49.1	61.5
Benefits from Additional Driving	6.9	8.1	9.4	10.6
Less Frequent Refueling	1.8	2.3	2.6	3.5
Subtotal—Incremental Private Benefits	43.9	53.7	61.1	75.6
Net Incremental Private Benefits	18.3	21.9	20.4	23.6

Looking simply at the effects for consumers, our analysis suggests that there is no action alternative (again, in the context of the standard-setting analysis) in which private benefits will outweigh private costs for passenger cars, although PC1LT3 and PC2LT4 are the most beneficial, relatively speaking. For light trucks, all of the action alternatives appear net beneficial for consumers, with PC2LT4 and PC6LT8 being the most beneficial. Broadening the scope to consider external/governmental benefits as well, we see the following:

TABLE V–8—INCREMENTAL BENEFITS AND COSTS OVER THE LIFETIMES OF TOTAL PASSENGER CAR FLEET PRODUCED THROUGH MY 2032 (2021$ BILLIONS), 3 PERCENT SOCIAL DR, BY ALTERNATIVE, 3% SC–GHG DR

Alternative	PC1	PC2	PC3	PC6
Private Costs (see Table V–6 above):				
Subtotal—Incremental Private Costs	8.6	11.5	16.7	26.6
External Costs:				
Congestion and Noise Costs from Rebound-Effect Driving	−0.3	0.0	1.4	2.2
Safety Costs Not Internalized by Drivers	−0.3	−0.1	2.4	3.1
Loss in Fuel Tax Revenue	0.4	0.8	1.0	2.5
Subtotal—Incremental External Costs	−0.2	0.6	4.9	7.9
Total Incremental Social Costs	8.4	12.1	21.6	34.5
Private Benefits (see Table V–6 above):				
Subtotal—Incremental Private Benefits	2.9	5.7	8.0	19.0
External Benefits:				
Reduction in Petroleum Market Externality	0.1	0.1	0.2	0.5
Reduced Climate Damages, 3% SC–GHG DR	0.6	1.3	1.7	4.1
Reduced Health Damages	0.0	0.0	−0.1	−0.1
Subtotal—Incremental External Benefits	0.7	1.4	1.8	4.5
Total Incremental Social Benefits, 3% SC–GHG DR	3.6	7.1	9.8	23.5
Net Incremental Social Benefits, 3% SC–GHG DR	−4.7	−5.1	−11.7	−10.9

TABLE V–9—INCREMENTAL BENEFITS AND COSTS OVER THE LIFETIMES OF TOTAL LIGHT TRUCK FLEET PRODUCED THROUGH MY 2032 (2021$ BILLIONS), 3 PERCENT SOCIAL DR, BY ALTERNATIVE, 3% SC–GHG DR

Alternative	LT3	LT4	LT5	LT8
Private Costs (see Table V–7 above):				
Subtotal—Incremental Private Costs	25.6	31.8	40.7	52.0
External Costs:				
Congestion and Noise Costs from Rebound-Effect Driving	3.3	3.6	3.9	3.2
Safety Costs Not Internalized by Drivers	2.0	1.8	2.2	1.8
Loss in Fuel Tax Revenue	7.5	9.3	10.3	13.1
Subtotal—Incremental External Costs	12.8	14.7	16.4	18.1
Total Incremental Social Costs	38.5	46.5	57.1	70.1
Private Benefits (see Table V–7 above):				
Subtotal—Incremental Private Benefits	43.9	53.7	61.1	75.6
External Benefits:				
Reduction in Petroleum Market Externality	1.4	1.7	1.9	2.4
Reduced Climate Damages, 3% SC–GHG DR	10.3	12.7	14.3	18.1
Reduced Health Damages	0.2	0.3	0.3	0.5
Subtotal—Incremental External Benefits	11.9	14.7	16.6	21.0

Table V–9—Incremental Benefits and Costs Over the Lifetimes of Total Light Truck Fleet Produced Through MY 2032 (2021$ Billions), 3 Percent Social DR, by Alternative, 3% SC–GHG DR—Continued

Alternative	LT3	LT4	LT5	LT8
Total Incremental Social Benefits, 3% SC–GHG DR	55.8	68.4	77.7	96.6
Net Incremental Social Benefits, 3% SC–GHG DR	17.4	21.9	20.6	26.5

Adding external/SCs and benefits does not change the direction of NHTSA's analytical findings. Net benefits for passenger cars remain negative across alternatives, with a trough at PC3LT5. Net benefits for light trucks remain positive across alternatives, with a peak at PC6LT8 but with PC2LT4 not so far behind.

Because NHTSA considers multiple DRs in its analysis, and because analysis also includes multiple values for the SC–GHG, we also estimate the following cumulative values for each regulatory alternative:

Table V–10—Summary of Cumulative Benefits and Costs for Model Years through MY 2032 (2021$ Billions), by Alternative, SC–GHG Value, and DR

Alternative	3% Discount rate			7% Discount rate		
	Costs	Benefits	Net benefits	Costs	Benefits	Net benefits
SC–GHG discounted at 5 percent:						
PC1LT3	46.8	51.2	4.4	31.2	29.2	−2.0
PC2LT4	58.6	65.0	6.3	39.1	37.0	−2.1
PC3LT5	78.7	75.5	−3.2	52.2	42.8	−9.4
PC6LT8	104.5	103.4	−1.2	70.3	58.1	−12.2
SC–GHG discounted at 3 percent:						
PC1LT3	46.8	59.5	12.7	31.2	37.5	6.3
PC2LT4	58.6	75.5	16.8	39.1	47.5	8.4
PC3LT5	78.7	87.5	8.8	52.2	54.9	2.7
PC6LT8	104.5	120.1	15.6	70.3	74.8	4.5
SC–GHG discounted at 2.5 percent:						
PC1LT3	46.8	65.3	18.5	31.2	43.3	12.1
PC2LT4	58.6	82.9	24.3	39.1	54.9	15.8
PC3LT5	78.7	96.1	17.4	52.2	63.5	11.3
PC6LT8	104.5	132.0	27.5	70.3	86.7	16.4
SC–GHG discounted at 3 percent, 95th percentile:						
PC1LT3	46.8	81.8	35.0	31.2	59.8	28.7
PC2LT4	58.6	103.9	45.2	39.1	75.9	36.8
PC3LT5	78.7	120.2	41.5	52.2	87.6	35.4
PC6LT8	104.5	165.4	60.9	70.3	120.1	49.8

Table V–11—Summary of Cumulative Benefits and Costs for CY 2022–2050 (2021$ Billions), by Alternative, SC–GHG Value, and DR

Alternative	3% Discount rate			7% Discount rate		
	Costs	Benefits	Net benefits	Costs	Benefits	Net benefits
SC–GHG discounted at 5 percent:						
PC1LT3	116.3	128.2	11.9	64.9	66.0	1.2
PC2LT4	156.8	173.2	16.3	86.7	88.6	1.9
PC3LT5	239.9	221.6	−18.2	130.2	112.5	−17.8
PC6LT8	385.9	369.0	−16.9	206.0	184.4	−21.6
SC–GHG discounted at 3 percent:						
PC1LT3	116.3	150.5	34.2	64.9	88.3	23.4
PC2LT4	156.8	203.3	46.5	86.7	118.8	32.1
PC3LT5	239.9	260.8	21.0	130.2	151.6	21.4
PC6LT8	385.9	436.9	51.0	206.0	252.3	46.4
SC–GHG discounted at 2.5 percent:						
PC1LT3	116.3	166.4	50.1	64.9	104.2	39.3
PC2LT4	156.8	224.8	68.0	86.7	140.3	53.6
PC3LT5	239.9	288.8	49.0	130.2	179.6	49.4
PC6LT8	385.9	485.5	99.7	206.0	301.0	95.0
SC–GHG discounted at 3 percent, 95th percentile:						
PC1LT3	116.3	210.4	94.1	64.9	148.2	83.3
PC2LT4	156.8	284.3	127.5	86.7	199.8	113.1
PC3LT5	239.9	366.1	126.3	130.2	257.0	126.7
PC6LT8	385.9	619.3	233.5	206.0	434.8	228.8

While the results shown in the tables above range widely—underscoring that DR assumptions significantly affect benefits estimates—the ordering of alternatives generally remains the same under most discounting scenarios. In some cases, PC6LT8 appears to have greater net benefits, but in nearly all of those cases, PC2LT4 is the next most net beneficial.

E.O. 12866 and Circular A–4 direct agencies to consider maximizing net benefits in rulemakings whenever possible and consistent with applicable law. Because it can be relevant to balancing the statutory factors and because it is directed by E.O. 12866 and OMB guidance, NHTSA does evaluate and consider net benefits associated with different potential future CAFE standards. As the tables above show, our analysis suggests that for passenger cars, net benefits are higher when standards are less stringent, and for light trucks, net benefits are higher when standards are more stringent, although not consistently. Looking solely at net benefits, PC6LT8 looks best overall and across all DRs, as well as for light truck specifically, although PC1LT3 looks least bad for passenger cars.

That said, while maximizing net benefits is a valid decision criterion for choosing among alternatives, provided that appropriate consideration is given to impacts that cannot be monetized, it is not the only reasonable decision perspective, and we recognize that what we include in our cost-benefit analysis affects our estimates of net benefits. We also note that important benefits cannot be monetized—including the full health and welfare benefits of reducing climate emissions and other pollution, which means that the benefits estimates are underestimates. Thus, given the uncertainties associated with many aspects of this analysis, NHTSA does not rely solely on net benefit maximization, and instead considers it as one piece of information that contributes to how we balance the statutory factors, in our discretionary judgment. NHTSA recognizes that the need of the U.S. to conserve energy weighs importantly in the overall balancing of factors, and thus believes that it is reasonable to at least consider choosing the regulatory alternative that produces the largest reduction in fuel consumption, while still remaining net beneficial. Of course, the benefit-cost analysis is not the sole factor that NHTSA considers in determining the maximum feasible stringency, though it informs NHTSA's tentative conclusion that Alternative PC2LT4 is the maximum feasible stringency. Importantly, the shortfalls discussion above suggests that even if PC6LT8 appears net beneficial, under the constraints of our standard-setting analysis which is the analysis that NHTSA is statutorily required to consider, the majority of manufacturers may simply be unable to achieve the fuel economy levels required by that alternative, which would mean that it would not be accomplishing its goal and thus almost certainly beyond maximum feasible.

As with any analysis of sufficient complexity, there are a number of critical assumptions here that introduce uncertainty about manufacturer compliance pathways, consumer responses to fuel economy improvements and higher vehicle prices, and future valuations of the consequences from higher CAFE standards. Recognizing that uncertainty, NHTSA also conducted more than 70 sensitivity analysis runs for the passenger car and light truck fleet analysis. The entire sensitivity analysis is presented in the PRIA, demonstrating the effect that different assumptions would have on the costs and benefits associated with the different regulatory alternatives. While NHTSA considers dozens of sensitivity cases to measure the influence of specific parametric assumptions and model relationships, only a small number of them demonstrate meaningful impacts to net benefits under the different alternatives.

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Table V-12: Summary of Cumulative Benefits and Costs for Model Years Through MY 2032 (2021$ Billions), by Alternative and DR, 3% SC-GHG DR

Case Name	Costs				Benefits				Net Benefits			
	PC1LT3	PC2LT4	PC3LT5	PC6LT8	PC1LT3	PC2LT4	PC3LT5	PC6LT8	PC1LT3	PC2LT4	PC3LT5	PC6LT8
RC	46.8	58.6	78.7	104.5	59.5	75.5	87.5	120.1	12.7	16.8	8.8	15.6
Oil price (AEO high)	37.2	46.3	60.9	92.7	68.1	80.3	96.0	144.7	31.0	33.9	35.0	52.0
Oil price (AEO low)	48.0	57.5	75.8	105.7	51.5	62.5	73.3	95.6	3.5	5.0	-2.4	-10.1
High GDP + fuel (AEO high)	37.1	46.4	61.1	92.8	68.2	80.8	96.8	145.7	31.1	34.4	35.7	52.8
Low GDP + fuel (AEO low)	47.5	56.9	75.0	104.9	51.3	62.3	73.0	95.5	3.8	5.4	-2.0	-9.4
Standard-setting conditions to 2035	47.4	60.3	81.5	110.2	59.2	74.0	85.2	107.8	11.7	13.7	3.8	-2.4
Standard-setting conditions to 2050	40.9	53.5	80.3	125.0	46.1	60.1	69.9	85.6	5.2	6.6	-10.4	-39.3
Standard-setting conditions all years	26.5	44.8	72.5	119.6	37.5	52.6	68.2	81.9	10.9	7.8	-4.4	-37.8
No ZEV	75.4	90.7	107.9	115.9	95.4	109.9	118.5	128.6	20.1	19.3	10.6	12.6

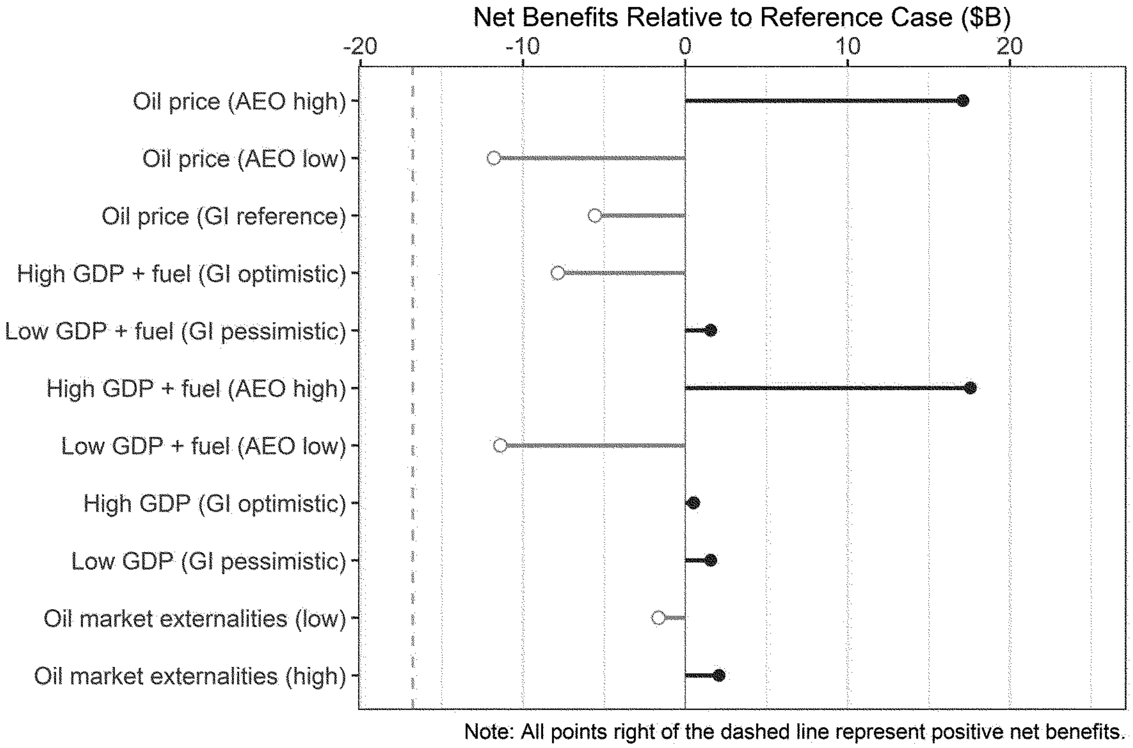


Figure V-3: Net Benefits for the Lifetime of Vehicles through MY 2032, LD Preferred Alternative Relative to the Reference Case, Macroeconomic Assumptions Sensitivity Cases (2021$, in billions, 3% Social DR, 3% SC-GHG DR)

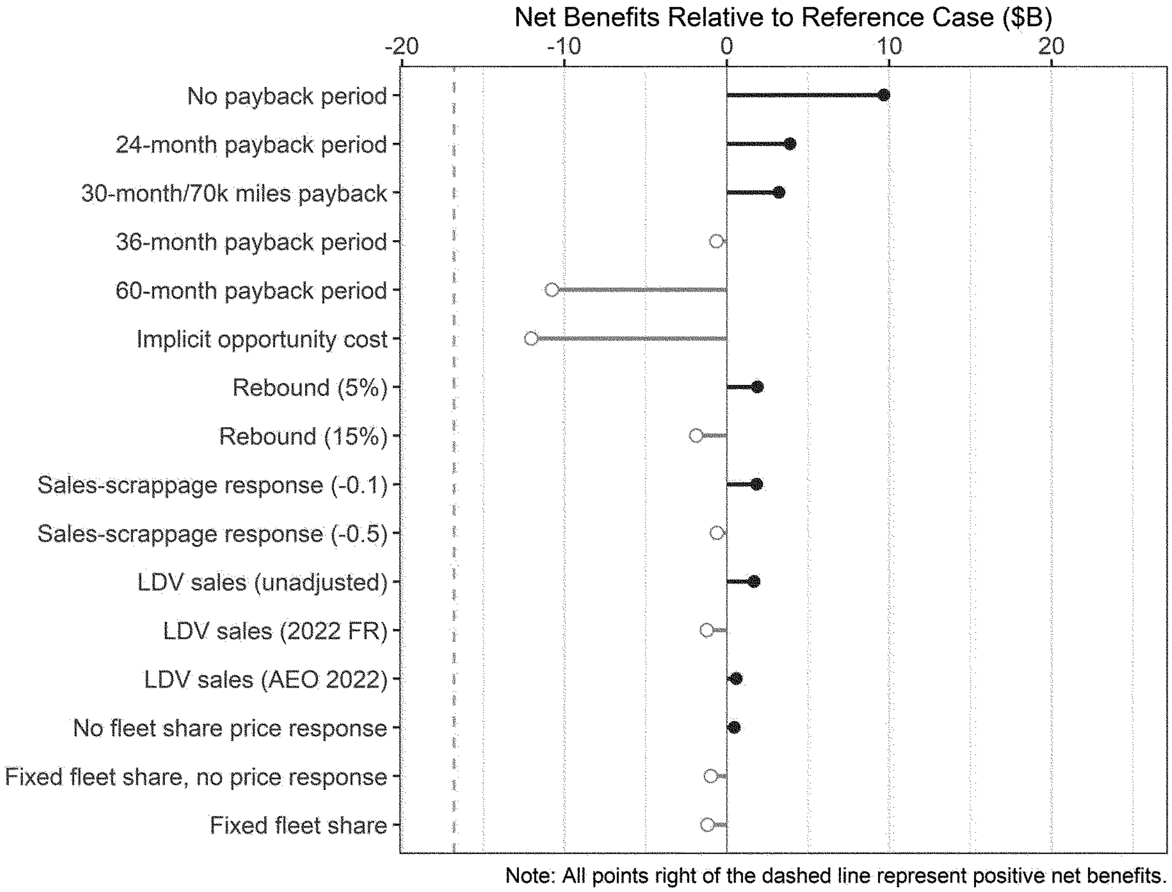


Figure V-4: Net Benefits for the Lifetime of Vehicles through MY 2032, LD Preferred Alternative Relative to the Reference Case, Payback and Sales Assumptions Sensitivity Cases (2021$, in billions, 3% Social DR, 3% SC-GHG DR)

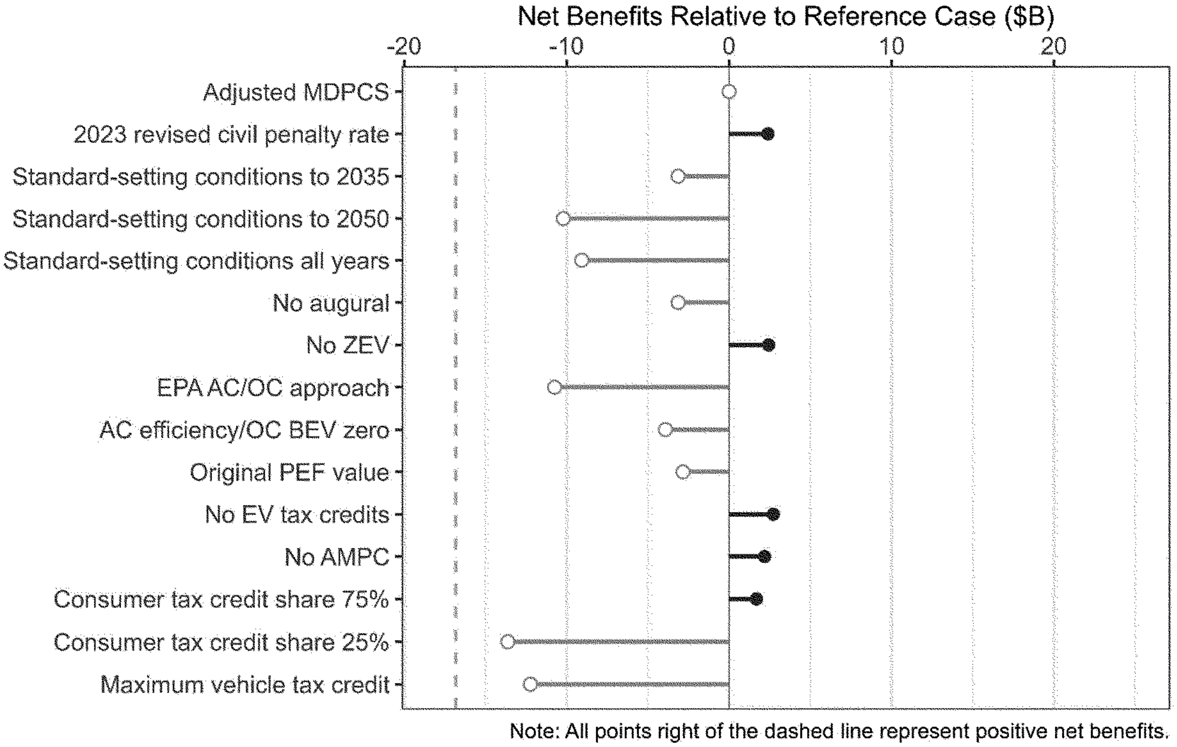


Figure V-5: Net Benefits for the Lifetime of Vehicles through MY 2032, LD Preferred Alternative Relative to the Reference Case, Policy Assumptions Sensitivity Cases (2021$, in billions, 3% Social DR, 3% SC-GHG DR)

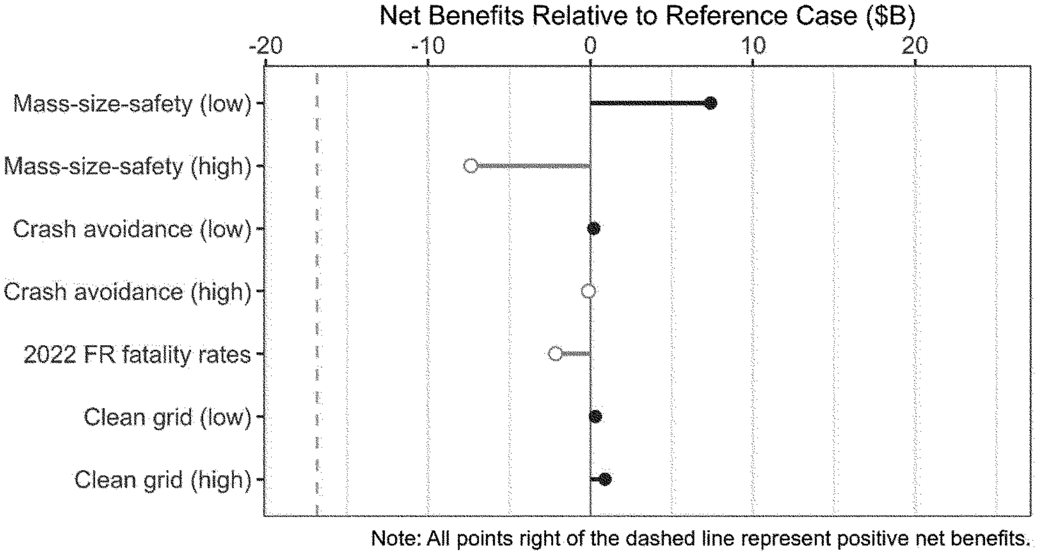
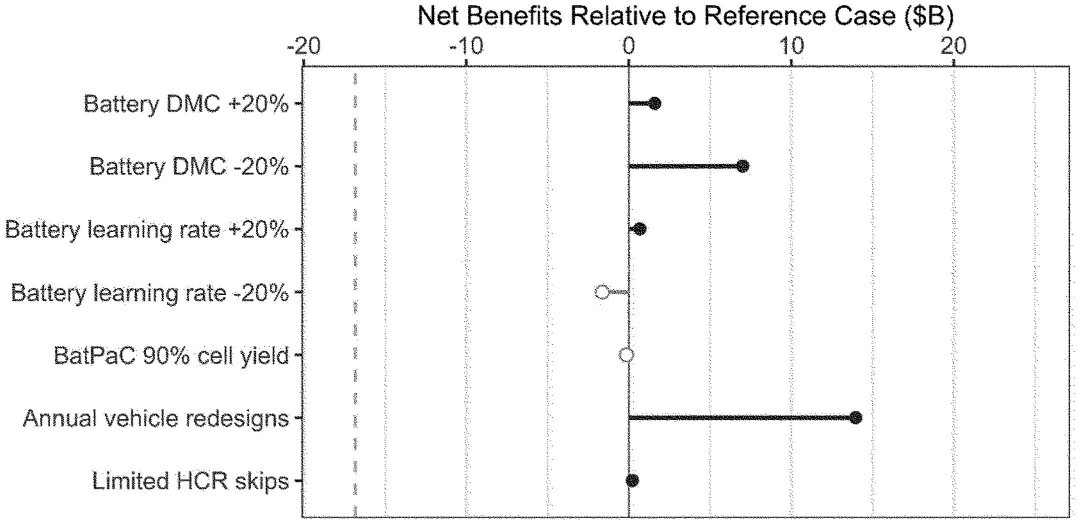


Figure V-6: Net Benefits for the Lifetime of Vehicles through MY 2032, LD Preferred Alternative Relative to the Reference Case, Safety and Environmental Assumptions Sensitivity Cases (2021$, in billions, 3% Social DR, 3% SC-GHG DR)



Note: All points right of the dashed line represent positive net benefits.

Figure V-7: Net Benefits for the Lifetime of Vehicles through MY 2032, LD Preferred Alternative Relative to the Reference Case, Technology Assumptions Sensitivity Cases (2021$, in billions, 3% Social DR, 3% SC-GHG DR)

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The results of the sensitivity analysis runs suggest that relatively few metrics make a major difference to cost and benefit outcomes, and the ones that do, act in relatively predictable ways. Some changes in values (fuel prices, removing ZEV, IRA tax credits) act on the baseline, increasing or reducing the amount of fuel economy improvements available for CAFE standards. Other changes in values (for example, fuel prices) affect benefits, and thus net benefits. Generally, even when costs and benefits change significantly in a sensitivity case, the basic ranking of alternatives in terms of net benefits does not change, and if it does change, it does not change by enough to change NHTSA's tentative conclusion that PC2LT4 is the maximum feasible alternative. The three cases extending the standard-setting conditions to additional MYs do reduce net benefits, but again, to the extent that rankings appear to change between alternatives, the magnitude of the relative difference is not significant enough to change our tentative conclusion. NHTSA is statutorily prohibited from considering the fuel economy of BEVs in determining maximum feasible stringency but notes in passing that the case changing the value of DOE's PEF reduces net benefits somewhat, although not significantly, and that changing assumptions about the value of electrification tax credits that reach consumers reduces net benefits significantly. However, because NHTSA cannot consider the fuel economy of BEVs in determining maximum feasible fuel economy standards, these are effects that happen only in the baseline of our analysis and are not considered in our determination. Moreover, regardless of net benefits, NHTSA believes that its tentative conclusion would be the same that Alternative PC2LT4 is economically practicable, based on per-vehicle costs, technology levels estimated to be required to meet the standards, and manufacturers' apparent ability to even reach compliance in most MYs, as compared to Alternative PC3LT5.

Finally, as discussed in Section IV.A, NHTSA accounts for the effects of other motor vehicle standards of the Government in its balancing, often through their incorporation into our regulatory baseline.[588] NHTSA believes that this approach accounts for these effects reasonably and appropriately. NHTSA recognizes prior arguments from industry stakeholders that any additional investment required to meet CAFE standards beyond what they intended to make to meet EPA's GHG standards would make such CAFE standards "too stringent." [589] As discussed above, even when the standards of the two programs are coordinated closely, it is still foreseeable that there could be situations in which different agencies' programs could be binding for different manufacturers in different MYs. This has been true across multiple CAFE rulemakings over the past decade. Regardless of which agency's standards are binding given a manufacturer's chosen compliance path, manufacturers will choose a path that complies with both standards, and in doing so, will still be able to build a single fleet of vehicles—even if it is not exactly the fleet that the manufacturer might have preferred to build. This remains the case with this proposal.

NHTSA does not believe that it is a reasonable interpretation of Congress' direction to set "maximum feasible" standards, as some commenters might prefer, at the fuel economy level at which no manufacturer need ever apply any additional technology or spend any additional dollar beyond what EPA's standards, with their many flexibilities,

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[588] NHTSA has carefully considered EPA's standards by including the baseline (*i.e.,* MYs 2024–2026) CO_2 standards in our analytical baseline. Because the EPA and NHTSA proposals were developed in coordination jointly, and stringency decisions were made in coordination, NHTSA did not include EPA's proposal for MYs 2027 and beyond CO_2 standards in our analytical baseline for this proposal. The fact that EPA issued its proposal before NHTSA is an artifact of circumstance only.

[589] *See, e.g.,* 87 FR at 26024 (May 2. 2022).

would require. NHTSA believes that CAFE standards can still be consistent with EPA's GHG standards even if they impose additional costs for certain manufacturers, although NHTSA is, of course, mindful of the magnitude of those costs and believes that the preferred alternative would impose minimal additional costs, if any, above compliance with EPA's standards.

NHTSA has also carefully considered CARB's ACC2 program (which includes the ZEV mandate) by including it in the No-Action Alternative. NHTSA continues to believe that this approach is reasonable. Modeling anticipated manufacturer compliance with these programs enables NHTSA to make more realistic projections of how the U.S. vehicle fleet will change in the coming years, which is foundational to our ability to set CAFE standards that reflect the maximum feasible fuel economy level achievable through improvements to internal combustion vehicles. Likewise, by creating a more accurate projection of how manufacturers might modify their fleets even in the absence of new CAFE standards, we are better able to identify the effects of new *CAFE standards,* which is the task properly before us. If NHTSA could not account for the ACC2 program, and could not be informed about the *baseline* effects, then NHTSA could overestimate the availability of vehicles that can be improved to meet potential new CAFE standards, and thus end up setting a fuel economy standard that requires an infeasible level of improvement. Moreover, as the ''No ZEV'' sensitivity case shows, the effect of including the ACC2 program in the baseline is simply to decrease costs and benefits attributable to potential future CAFE standards. Removing anticipated manufacturer compliance with ZEV from the baseline increases costs and benefits for every alternative, but even so, we note that net benefits change relatively little for that sensitivity case, as shown in more detail in Chapter 9 of the PRIA. While PC1LT3 looks slightly more net beneficial than PC2LT4 under that case, it is only very slightly, and it is not so great an effect as to change NHTSA's balancing of the statutory factors in this proposal. NHTSA continues to believe, even under this scenario, that PC2LT4 is maximum feasible for the rulemaking time frame.

Even though NHTSA is statutorily prohibited from considering the possibility that manufacturers would produce additional BEVs to comply with CAFE standards, and even though manufacturers have stated their intention to rely more and more heavily on those BEVs for compliance, CAFE standards still have an important role to play in meeting the country's ongoing need to conserve energy. CAFE standards can also ensure continued improvements in energy conservation by requiring ongoing fuel economy improvements even if demand for more fuel economy flags unexpectedly, or if other regulatory pushes change in unexpected ways. Saving money on fuel and reducing CO_2 and other pollutant emissions by reducing fuel consumption are also important equity goals. Fuel expenditures are a significant budget item for consumers who are part of lower-income and historically disadvantaged communities. Part of our goal in determining maximum feasible CAFE standards is trying to improve fuel savings across the fleet as a whole, rather than for a handful of new vehicle buyers. By maximizing fuel savings to consumers (given estimated effects on new vehicle costs), CAFE standards can help to improve equity.

That said, NHTSA acknowledges the statute-driven cognitive dissonance, and NHTSA's task in approaching the determination of maximum feasible standards is the same as ever, to evaluate potential future CAFE stringencies in light of statutory constraints. NHTSA believes that we have identified a path to meeting the proposed standards that is technologically feasible and economically practicable and consistent with the statutory constraints. Manufacturers may object that it is not the path they believe themselves to be on, but NHTSA's analysis suggests that it is reasonable, and that it properly reflects our constraints. The rate of increase in the standards may be slower than in the last round of rulemaking, but NHTSA believes that is reasonable and appropriate given the likely state of the fleet by MY 2027. Consider, for example, the non-linear relationship between fuel economy and fuel consumption as illustrated below:

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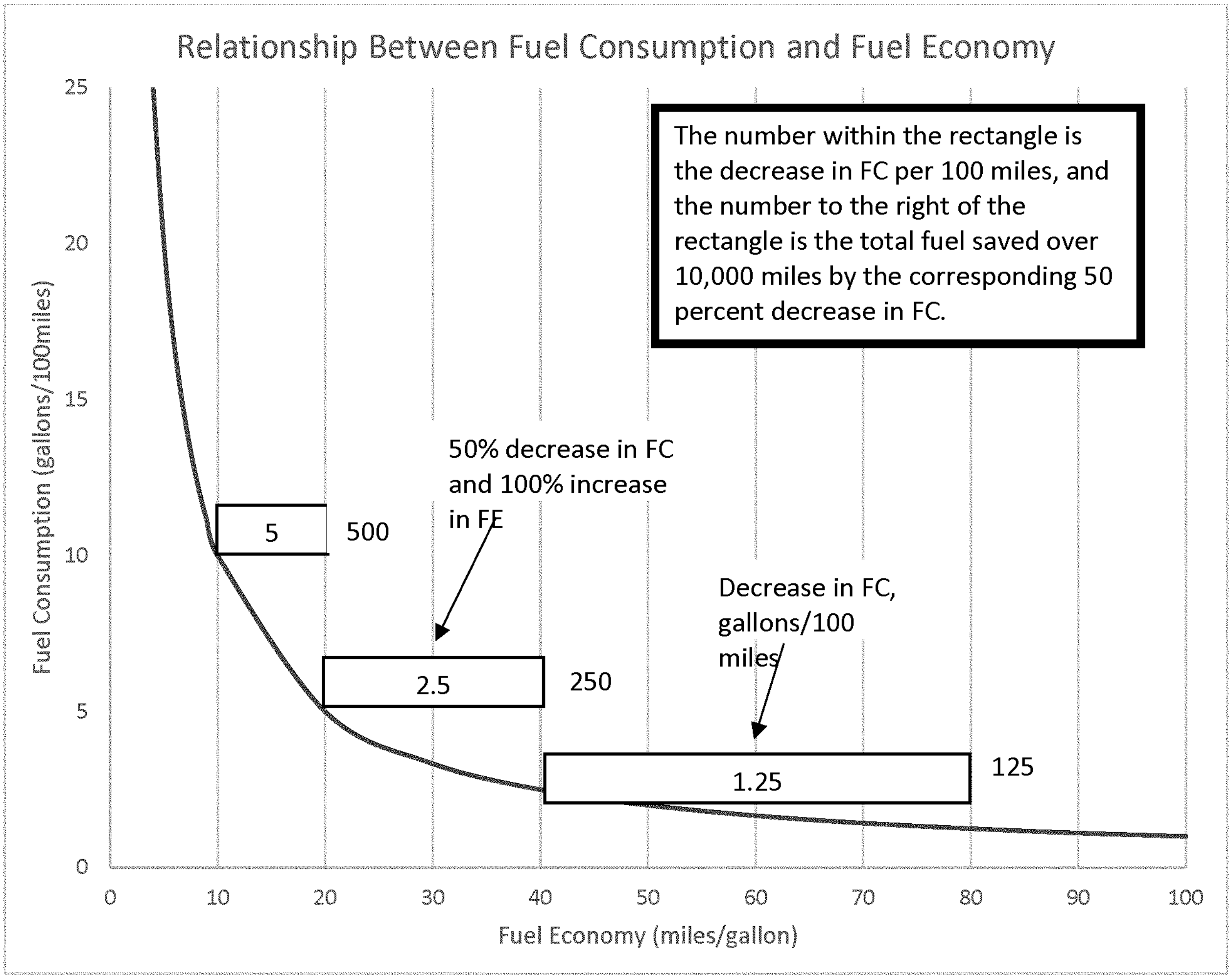

Figure V-8: Relationship Between Fuel Consumption and Fuel Economy

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As fleet fuel economy improves, there are simply fewer further improvements to ICEs available to be made (in the absence of further technological innovation), and the amount of fuel consumers actually save is smaller, *and* the remaining available improvements are increasingly expensive. This is even more true given the statutory restrictions that NHTSA must observe. This is not a bad outcome—in some ways, it is a testament to manufacturer efforts and the success of this program, that we are beginning to reach the limits of fuel economy improvements that can be considered. CAFE standards can still help industry complete that journey, and as such, based on all of the information contained in this record, NHTSA tentatively concludes that PC2LT4 represents the maximum feasible standards for passenger cars and light trucks in the MYs 2027 to 2032 time frame. We seek comment on this tentative conclusion and all aspects of this discussion.

2. Heavy-Duty Pickups and Vans

NHTSA has not set new HDPUV standards since 2016, and the technology offerings on available models in that segment have changed relatively little since then. The redesign cycles in this segment are slightly longer than for passenger cars and light trucks, roughly 6–7 years for pickups and roughly 9 years for vans.[590] To our knowledge, technology for pickups in this segment has been relatively slow to advance compared to in the light truck segment, and there are still no hybrid HD pickups. That said, electrification is beginning to appear among the vans in this segment, perhaps especially among vans typically used for deliveries,[591] and under NHTSA's distinct statutory authority for setting HDPUV standards, expanding BEV technologies are part of NHTSA's standard setting consideration. The Ford E-Transit, for example, is based on the Mach-E platform and uses similar battery architecture;[592] other manufacturers have also shown a willingness to transition to electric vans and away from conventional powertrains.[593]

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[590] See Draft TSD Chapter 2.2.1.7. HDPUVs have limited makes and models. Assumptions about their refresh and redesign schedules have an outsized impact on our modeling of HDPUVs, where a single redesign can have a noticeable effect on technology penetration, costs, and benefits. We seek comment on our approach, specifically if there are additional opportunities for manufacturers to apply technology in the HDPUV space to mitigate costs.

[591] NACFE. 2022. Electric Trucks Have Arrived: The Use Case For Vans and Step Vans. Available at: *https://nacfe.org/research/run-on-less-electric/#vans-step-vans.* (Accessed May 31, 2023).

[592] Martinez, M. 2023. Ford to Sell EVs With 2 Types of Batteries, Depending On Customer Needs. Last revised: Mar. 5, 2023. Available at: *https://www.autonews.com/technology/ford-will-offer-second-ev-battery-type-lower-cost-and-range.* (Accessed: May 31, 2023).

[593] Hawkins, T. 2023. Mercedes-Benz eSprinter Unveiled As BrightDrop Zevo Rival. GM Authority. Available at: *https://gmauthority.com/blog/2023/*

NHTSA is aware that some historic Light truck applications now being offered as BEVs may be heavy enough to fall outside the Light Truck segment and into the HDPUV segment,[594] but NHTSA expects manufacturers to find strategies to return them to the CAFE Light Truck fleet in the coming years. This could include development in battery design or electrified powertrain architecture that could reduce vehicle weight. The vehicles in these segments are purpose-built for key applications and we expect manufactures will cater electrified offerings for businesses that maximize benefits in small volumes. However, until these technologies materialize, NHTSA assumes in its analysis there will continue to be 'spill-over' of vehicles that exist as edge cases.

The following text will walk through the three statutory factors in more detail and discuss NHTSA's decision-making process more thoroughly. The tentative balancing of factors presented here represents NHTSA's thinking at the present time, based on all of the information presented in the record for this proposal. NHTSA acknowledges that a different balancing may turn out to be appropriate for the final rule depending on information that arrives between now and then, both through the public comment process and otherwise.

For the reader's reference, the regulatory alternatives under consideration for HDPUVs are presented again below:

TABLE V–13—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

As discussed in Section V.A, the three statutory factors for HDPUV standards are similar to and yet somewhat different from the four factors that NHTSA considers for passenger car and light truck standards, but they still modify ''feasible'' in ''maximum feasible.'' NHTSA also interprets the HDPUV factors as giving us broad authority to weigh potentially conflicting priorities to determine maximum feasible standards. It is firmly within NHTSA's discretion to weigh and balance the HDPUV factors in a way that is technology-forcing, although NHTSA would find a balancing of the factors in a way that would require the application of technology that will not be available in the lead time provided by this proposal, or that is not cost-effective, to be beyond maximum feasible.

That said, because HDPUV standards are set in accordance with 49 U.S.C. 32902(k), NHTSA is not bound by the 32902(h) factors when it determines maximum feasible HDPUV standards.[595] That means that NHTSA may, and does, consider the full fuel efficiency of BEVs and PHEVs, and that NHTSA may consider the availability and use of overcompliance credits, in this proposal. These considerations thus play a role in NHTSA's balancing of the HDPUV factors, as described below.

In evaluating whether HDPUV standards are appropriate, NHTSA could begin by seeking to isolate the effects of new HDPUV standards from NHTSA, by understanding effects in the industry that appear to be happening for reasons other than potential new NHTSA regulations. NHTSA explained in Chapter 1.4.1 of the Draft TSD that the No-Action Alternative for HDPUV accounts for existing technology on HDPUVs, technology sharing across platforms, manufacturer compliance with existing HDPUV standards from NHTSA and EPA (*i.e.,* those standards set in the Phase 2 final rule in 2016 for MY 2021 to MY 2029), manufacturer compliance with California's ACT and ZEV programs, and foreseeable voluntary manufacturer application of fuel-efficiency-improving technologies (whether because of tax credits or simply because the technologies are estimated to pay for themselves within 30 months). One consequence of accounting for these effects in the No-Action Alternative is that the effects of the different regulatory alternatives under consideration appear less cost-beneficial than they would otherwise. Nonetheless, NHTSA believes that this is reasonable and appropriate to better ensure that NHTSA has 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. All estimates of effects of the different regulatory alternatives presented in this section are thus relative to the No-Action Alternative.

Other information that are relevant to whether HDPUV standards are appropriate could include how much energy we estimate they would conserve; the magnitude of emissions reductions; possible safety effects, if any; and estimated effects on sales and employment. In terms of energy conservation, Alternative HDPUV14 would conserve the most energy and produce the greatest reduction in fuel expenditure, as shown below:

TABLE V–14—FUEL CONSUMPTION UNDER HDPUV REGULATORY ALTERNATIVES, AS COMPARED TO NO-ACTION ALTERNATIVE

[quads, CYs 2022–2050]

Fuel type	HDPUV4	HDPUV10	HDPUV14
Diesel	0	0.001	0.003
E85	0	−0.002	−0.009
Gasoline	−0.013	−0.305	-1.357
Electricity	0.004	0.083	0.345

02/mercedes-benz-esprinter-unveiled-as-brightdrop-zevo-rival/*. (Accessed: May 31, 2023).

[594] Gilboy, J. 2023. The Drive. Massive Weight Could Push Past EPA's Light-Duty Rules. Available at: *https://www.thedrive.com/news/the-2025-ram-1500-revs-massive-weight-could-push-past-epas-light-duty-rules.* (Accessed May 31, 2023). See also Arbelaez, R. 2023. IIHS Insight. As heavy EVs proliferate, their weight may be a drag on safety. Available at: *https://www.iihs.org/news/detail/as-heavy-evs-proliferate-their-weight-may-be-a-drag-on-safety.* (Accessed May 31, 2023).

[595] 49 U.S.C. 32902(h) clearly states that it applies only to actions taken under subsections (c), (f), and (g) of 49 U.S.C. 32902.

TABLE V–14—FUEL CONSUMPTION UNDER HDPUV REGULATORY ALTERNATIVES, AS COMPARED TO NO-ACTION ALTERNATIVE—Continued

[quads, CYs 2022–2050]

Fuel type	HDPUV4	HDPUV10	HDPUV14
Total	−0.009	−0.223	−1.019

TABLE V–15—LIFETIME FUEL EXPENDITURE UNDER HDPUV REGULATORY ALTERNATIVES, AS COMPARED TO NO-ACTION ALTERNATIVE, MYS 2030–2038

[$ In millions, 3% DR]

Model year	2030	2031	2032	2033	2034	2035	2036	2037	2038	Total
HDPUV4	−4.4	−5.0	−4.8	−9.1	−8.8	−8.3	−8.1	−7.6	−7.6	−63.7
HDPUV10	−15.5	−27.4	−26.9	−303.8	−320.9	−313.0	−306.2	−301.5	−295.5	−1,910.7
HDPUV14	−38.4	−622.8	−611.1	−1,146.8	−1,139.8	−1,511.0	−1,478.6	−1,451.6	−1,422.7	−9,422.8

TABLE V–16—PER-VEHICLE LIFETIME FUEL EXPENDITURE UNDER HDPUV REGULATORY ALTERNATIVES, AS COMPARED TO NO-ACTION ALTERNATIVE

[$, 3% DR]

Model Year	2030	2031	2032	2033	2034	2035	2036	2037	2038
HDPUV4	−6	−6	−6	−12	−12	−12	−12	−12	−12
HDPUV10	−19	−34	−35	−400	−427	−430	−433	−437	−439
HDPUV14	−39	−764	−772	−1,505	−1,516	−2,077	−2,092	−2,106	−2,117

Assuming that benefits to energy security correlate directly with fuel consumption avoided, Alternative HDPUV14 would likely also contribute the most to improving U.S. energy security. The discussion about energy security effects of passenger car and light truck standards applies for HDPUVs as well.

In terms of environmental benefits, Alternative HDPUV14 is also estimated to be the most beneficial for most metrics:

TABLE V–17—EMISSIONS EFFECTS UNDER HDPUV REGULATORY ALTERNATIVES, AS COMPARED TO NO-ACTION ALTERNATIVE

	HDPUV4	HDPUV10	HDPUV14
Estimated CO_2 emissions avoided (mmt)	−0.91	−22.28	−101.28
Maximum observed change in criteria pollutant emissions compared to No−Action Alternative:			
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%

The criteria pollutant effects demonstrate that increased electrification (which increases faster under more stringent alternatives) reduces vehicle-based emissions while increasing upstream emissions due to increased demand for electricity.

Some other effects are fairly muted, possibly due to the relatively small size of the HDPUV fleet. The safety effects associated with the HDPUV alternatives are extremely small, too small to affect our decision-making in this proposal. Readers may refer to Chapter 8.3.4.5 of the PRIA for specific information. For sales and employment, readers may refer to Chapter 8.3.2.3 of the PRIA for more specific information, but there is very little difference in sales between HDPUV alternatives, less than one percent relative to the No-Action Alternatives. Employment effects are of similar relative magnitude; HDPUV10 and HDPUV14 both subtract slightly from the baseline employment utilization, as sales declines produce a small decrease in labor utilization that are not offset by technology effects (*i.e.,* that development and deployment of new fuel-efficient technologies increases demand for labor). Estimated safety, sales, and employment effects are thus all too small to be dispositive.

In evaluating whether HDPUV standards are cost-effective, NHTSA could consider different ratios of cost versus the primary benefits of the standards, such as fuel saved and GHG emissions avoided. Table V–18 and Table V–19 include a number of informative metrics of the proposed HDPUV alternatives relative to the No-Action Alternative. None of the proposed action alternatives emerges as a clearly superior option when evaluated along this dimension. When considering aggregate societal effects, as well as when narrowing the focus to private benefits and costs, HDPUV10 produces the highest benefit-cost ratios.

TABLE V–18—COST-EFFECTIVENESS METRICS UNDER HDPUV REGULATORY ALTERNATIVES, AS COMPARED TO NO-ACTION ALTERNATIVE

[$2021, 3% DR]

Ratio	HDPUV4	HDPUV10	HDPUV14
Total societal benefits to total societal costs (CYs 2022–2050, 3% SC–GHG discount rate)	1.29	2.08	1.85
Total private benefits to total private costs (CYs 2022–2050)	1.40	2.23	1.87
Fuel savings to regulatory cost (CYs 2022–2050)	2.57	2.32	2.37
Sales-weighted per-vehicle fuel savings to regulatory cost (MYs 2030–2035)	2.81	2.83	2.65
Sales-weighted per-vehicle fuel savings to regulatory cost (MYs 1983–2038)	3.11	3.01	2.90
Total societal benefits to total regulatory cost (CYs 2022–2050, 3% SC–GHG discount rate)	2.46	3.36	3.00

TABLE V–19—COST-EFFECTIVENESS METRICS UNDER HDPUV REGULATORY ALTERNATIVES, AS COMPARED TO NO-ACTION ALTERNATIVE

[$2021, 7% DR]

Ratio	HDPUV4	HDPUV10	HDPUV14
Total societal benefits to total societal costs (CYs 2022–2050, 3% SC–GHG discount rate)	1.68	2.45	2.17
Total private benefits to total private costs (CYs 2022–2050)	1.00	2.00	1.61
Fuel savings to regulatory cost (CYs 2022–2050)	2.19	2.03	2.03
Sales-weighted per-vehicle fuel savings to regulatory cost (MYs 2030–2035)	2.16	2.18	2.04
Sales-weighted per-vehicle fuel savings to regulatory cost (MYs 1983–2038)	2.39	2.32	2.23
Total societal benefits to total regulatory cost (CYs 2022–2050, 3% SC–GHG discount rate)	3.01	3.79	3.35

Because NHTSA considers multiple DRs in its analysis, and because analysis also includes multiple values for the SC–GHG, we also estimate the following cumulative values for each regulatory alternative:

TABLE V–20—SUMMARY OF CUMULATIVE BENEFITS AND COSTS FOR CY 2022–2050 (2021$ BILLIONS), BY ALTERNATIVE, SC–GHG VALUE, AND DR

Alternative	3% Discount rate			7% Discount rate		
	Costs	Benefits	Net benefits	Costs	Benefits	Net benefits
SC–GHG discounted at 5 percent:						
HDPUV4	0.09	0.08	−0.005	0.04	0.04	−0.001
HDPUV10	2.07	3.58	1.50	0.99	1.69	0.69
HDPUV14	9.43	14.03	4.61	4.67	6.73	2.05
SC–GHG discounted at 3 percent:						
HDPUV4	0.09	0.11	0.03	0.04	0.07	0.03
HDPUV10	2.07	4.32	2.25	0.99	2.43	1.44
HDPUV14	9.43	17.43	8.00	4.67	10.12	5.45
SC–GHG discounted at 2.5 percent:						
HDPUV4	0.09	0.14	0.05	0.04	0.09	0.05
HDPUV10	2.07	4.85	2.78	0.99	2.97	1.97
HDPUV14	9.43	19.87	10.44	4.67	12.56	7.89
SC–GHG discounted at 3 percent, 95th percentile:						
HDPUV4	0.09	0.19	0.11	0.04	0.15	0.11
HDPUV10	2.07	6.31	4.24	0.99	4.42	3.43
HDPUV14	9.43	26.53	17.10	4.67	19.23	14.55

E.O. 12866 and Circular A–4 direct agencies to consider maximizing net benefits in rulemakings whenever possible and consistent with applicable law. Because it can inform NHTSA's consideration of the statutory factors and because it is directed by E.O. 12866 and OMB guidance, NHTSA does evaluate and consider net benefits associated with different potential future HDPUV standards. As Table V–20 shows, our analysis suggests that HDPUV14 produces the largest net benefits, although we note that the step from HDPUV10 to HDPUV14 results in a substantial jump in total costs.

Our analysis also suggests that all alternatives will result in fuel savings for consumers, and that all alternatives will be cost-effective under nearly every listed metric of comparison and at either DR. Overall, avoided climate damages are lower and with each alternative the ratio of cost to benefits for this metric decreases due to increased cost and diminishing climate benefits. As discussed earlier, the HDPUV fleet is a smaller fleet compared to passenger cars and light trucks, and so for a manufacturer to meet standards that are more or less stringent, they must transition a relatively larger portion of that smaller fleet to new technologies. Thus, under many comparisons, HDPUV10 appears the most cost-effective; under others, HDPUV4 appears the most cost-effective.

As discussed above for passenger car and light truck standards, while maximizing net benefits is a valid decision criterion for choosing among alternatives, provided that appropriate consideration is given to impacts that cannot be monetized, it is not the only reasonable decision perspective. We recognize that what we include in our cost-benefit analysis affects our estimates of net benefits. We also note that important benefits cannot be monetized—including the full health and welfare benefits of reducing climate and other pollution, which means that the benefits estimates are underestimates. Thus, given the uncertainties associated with many aspects of this analysis, NHTSA does not rely solely on net benefit maximization, and instead considers it as one piece of information that contributes to how we balance the statutory factors, in our discretionary judgment.

In evaluating whether HDPUV standards are technologically feasible, NHTSA could consider whether the standards represented by the different regulatory alternatives could be met using technology expected to be available in the rulemaking time frame. On the one hand, the HDPUV analysis only employs existing technologies, and our analysis suggests fairly widespread compliance with all regulatory alternatives, which might initially suggest that technological feasibility is not at issue for this proposal. At the industry level, technology penetration rates estimated to meet the different regulatory alternatives in the different MYs would be as follows:

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Table V-21: Estimated Application of Selected Technologies in HDPUV Fleet

Technology	Alternative	2022	2030	2031	2032	2033	2034	2035	2036	2037	2038
Technology Application Levels in the No-Action Alternative											
Strong Hybrid (all types)	No Action	0%	26%	36%	36%	26%	26%	26%	26%	26%	26%
PHEV (all types)	No Action	0%	0%	4%	4%	13%	13%	13%	13%	9%	9%
BEV (all types)	No Action	6%	31%	35%	35%	41%	41%	41%	41%	45%	45%
Advanced Engines	No Action	40%	21%	7%	6%	3%	3%	3%	3%	3%	3%
Advanced AERO	No Action	25%	94%	94%	94%	94%	94%	94%	94%	94%	94%
Technology Application Levels Relative to the No-Action Alternative											
Strong Hybrid (all types)	HDPUV4	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
PHEV (all types)	HDPUV4	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
BEV (all types)	HDPUV4	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Engines	HDPUV4	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced AERO	HDPUV4	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid (all types)	HDPUV10	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
PHEV (all types)	HDPUV10	-	0%	0%	0%	1%	1%	1%	1%	1%	1%
BEV (all types)	HDPUV10	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
Advanced Engines	HDPUV10	-	0%	0%	0%	1%	2%	2%	2%	2%	2%
Advanced AERO	HDPUV10	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
Strong Hybrid (all types)	HDPUV14	-	0%	0%	0%	0%	0%	0%	0%	0%	0%
PHEV (all types)	HDPUV14	-	0%	0%	0%	2%	2%	4%	4%	4%	4%
BEV (all types)	HDPUV14	-	0%	3%	3%	3%	3%	3%	3%	3%	3%
Advanced Engines	HDPUV14	-	0%	-2%	-2%	4%	4%	10%	10%	10%	10%
Advanced AERO	HDPUV14	-	0%	0%	0%	0%	0%	0%	0%	0%	0%

Advanced Engines: Combined penetration of advanced cylinder deactivation, advanced turbo and diesel engines.[596]
Advanced AERO: Combined penetration aerodynamic improvement.

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As Table V–21 shows, it is immediately clear that most technology application between now and MY 2038 would be occurring as a result of baseline efforts and would not be an effect of new NHTSA standards. Under

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[596] The list of these engines is discussed in Draft TSD Chapter 3.1.

the baseline, as early as MY 2033, fully 80 percent of the fleet would be electrified (including SHEV, PHEV, and BEV), with slight shifts over time in the relative percentages of those technologies' representation in the fleet (BEVs taking away some market share from PHEVs by MY 2038). NHTSA believes that these baseline technology penetration rates, while high, may potentially be feasible in this time frame, given projected trends for HD vans in particular. Due to the relatively small number of models in the HDPUV fleet as compared to the passenger car and light truck fleets, just a few models becoming electrified can have large effects in terms of the overall fleet. NHTSA also recognizes that these baseline technology penetration rates result from our assumptions about battery costs and available tax credits, among other things.[597]

Against the backdrop of this baseline, HDPUV4 would require no additional technology at all, on average, which explains why the per-vehicle fuel cost savings associated with it is nearly zero. HDPUV10 could be met with an additional 1 percent increase in PHEVs starting in MY 2033, and a 1 to 2 percent increase in advanced engines in the later years of the rulemaking time frame. HDPUV14 could be met with an additional 4 percent increase in PHEVs, an additional 3 percent increase in BEVs, and an additional 10 percent increase in advanced engines by MY 2038.

As in the analysis for passenger cars and light trucks, however, NHTSA finds manufacturer-level results to be particularly informative for this analysis. Of the six manufacturers modeled for HDPUV, Mercedes-Benz, Nissan, Rivian, and Stellantis would be able to meet all regulatory alternatives with baseline technologies—only Ford and GM show any activity in response to any of the regulatory alternatives. HDPUV14 pushes both Ford and GM to increase their volumes of advanced gasoline engines and PHEVs, and GM to increase its volume of BEVs.

TABLE V–22—TECHNOLOGY AVAILABILITY BY MANUFACTURER FOR SELECTED MODEL YEARS

	HDPUV4		HDPUV10		HDPUV14		MY 2030 to MY 2038 Change		
	2030 (%)	2038 (%)	2030 (%)	2038 (%)	2030 (%)	2038 (%)	HDPUV4	HDPUV10	HDPUV14
Ford:									
Strong Hybrid (all types)	28	28	28	28	28	28	0	0	0
PHEV (all types)	0	0	0	0	0	4	0	0	+4
BEV (all types)	40	51	40	51	40	51	+11	+11	+11
Advanced Engines	11	2	11	2	12	17	−10	−10	+6
Advanced AERO	100	100	100	100	100	100	0	0	0
Advanced MR	0	0	0	0	0	0	0	0	0
GM:									
Strong Hybrid (all types)	45	16	45	16	45	16	−29	−29	−28
PHEV (all types)	0	29	0	34	0	37	+29	+34	+37
BEV (all types)	5	18	5	18	5	27	+13	+13	+21
Advanced Engines	7	6	7	11	7	20	0	+5	+14
Advanced AERO	100	100	100	100	100	100	0	0	0
Advanced MR	0	0	0	0	0	0	0	0	0
Mercedes-Benz:									
Strong Hybrid (all types)	60	21	60	21	60	21	−40	−40	−40
PHEV (all types)	0	0	0	0	0	0	0	0	0
BEV (all types)	40	79	40	79	40	79	+40	+40	+40
Advanced Engines	0	0	0	0	0	0	0	0	0
Advanced AERO	100	100	100	100	100	100	0	0	0
Advanced MR	0	0	0	0	0	0	0	0	0
Nissan:									
Strong Hybrid (all types)	1	0	1	0	1	0	−1	−1	−1
PHEV (all types)	0	0	0	0	0	0	0	0	0
BEV (all types)	64	70	64	70	64	70	+6	+6	+6
Advanced Engines	5	30	5	30	5	30	+25	+25	+25
Advanced AERO	100	100	100	100	100	100	0	0	0
Advanced MR	0	0	0	0	0	0	0	0	0
Rivian:									
Strong Hybrid (all types)	0	0	0	0	0	0	0	0	0
PHEV (all types)	0	0	0	0	0	0	0	0	0
BEV (all types)	100	100	100	100	100	100	0	0	0
Advanced Engines	0	0	0	0	0	0	0	0	0
Advanced AERO	0	0	0	0	0	0	0	0	0
Advanced MR	0	0	0	0	0	0	0	0	0
Stellantis:									
Strong Hybrid (all types)	0	47	0	47	0	47	+47	+47	+47
PHEV (all types)	0	1	0	1	0	1	+1	+1	+1
BEV (all types)	31	50	31	50	31	50	+19	+19	+19
Advanced Engines	69	1	69	1	69	1	−67	−67	−67
Advanced AERO	100	100	100	100	100	100	0	0	0
Advanced MR	0	0	0	0	0	0	0	0	0

Again, it is clear that a great deal of technology application is expected in response to the baseline, as evidenced by the fact that technology penetration rates for most manufacturers do not change between alternatives. For example, Stellantis is assumed to go from 0 percent strong hybrids in its HDPUV fleet in MY 2030 to 47 percent strong hybrids by MY 2038 under each regulatory alternative, which means that the regulatory alternatives are not influencing that decision—because if they were, we would see technology differences between the alternatives. Of

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[597] All EVs have zero emissions and are asisgned the fuel consumption test group result to a value of zero gallons per 100 miles per 49 CFR 535.6(a)(3)(iii).

the two manufacturers who appear to need to change technology application to meet HDPUV10 and HDPUV14, Ford and GM, we note that the changes for Ford are relatively minor: replacing 4 percent of its ''advanced engine'' vehicles with PHEVs between MYs 2030 and 2038. GM shows more movement, but NHTSA suspects this may be an artifact of our relatively-meager data for the HDPUV fleet. It is very possible that the apparent increase in BEV and advanced engine rates could be due to the fact that technologies in the baseline fleet are based on Phase 1 standards and manufacturers have not started adopting technologies to meet Phase 2 standards. Additionally, NHTSA is allowed to consider banked overcompliance credits for the HDPUV fleet,[598] as well as the full fuel efficiency of AFVs like BEVs and PHEVs.[599] Combined with the fact that BEVs and the electric operation of PHEVs are granted 0 gal/100 miles fuel consumption for compliance purposes, our analysis shows that even with one redesign we see large improvements in the fleet even at low volumes. Based on the information before us, NHTSA cannot conclude that technological feasibility is necessarily a barrier to choosing any of regulatory alternatives considered in this proposal.

The information presented thus far suggests that HDPUV14 would result in the best outcomes for energy conservation, including fuel consumption and fuel expenditure reduced, energy security, climate effects, and most criteria pollutant effects; that it would produce the largest net benefits, and that it is likely achievable with not much more technology than would be applied in the baseline regardless of new HDPUV standards from NHTSA; even if it would not necessarily be the most cost-effective, would result in the highest overall costs, and does not provide the largest consumer net benefits. There is likely a credible case to be made for choosing HDPUV14. For purposes of this proposal, however, NHTSA tentatively concludes that some conservatism may still be appropriate.

There are several reasons for this conservatism. First, NHTSA recognizes that standards have remained stable for this segment for many years, since 2016. While on the one hand, that may mean that the segment has room for improvement, or at least for standards to catch up to where the fleet is, NHTSA is also mindful that the sudden imposition of stringency where there was previously little may require some adjustment time especially with technologies like BEVs and PHEVs that have not been in mass production in the HDPUV space. Second, NHTSA acknowledges that our available data in this segment may be less complete than our data for passenger cars and light trucks. Compared to the CAFE program's robust data submission requirements, manufacturers submit many fewer data elements in the HD program, and the program is newer, so we have many fewer years of historical data. If NHTSA's technology or vehicle make/model assumptions in the baseline lags on road production, then our estimated manufacturer responses to potential new HDPUV standards could lack realism in important ways, particularly given the relatively smaller fleet and fewer numbers of make/models across which manufacturers can spread technology improvements in response to standards. Although NHTSA also relies on manufacturer media publications for announcements of new vehicles and technologies, we are considerate of how those will be produced in large quantities and if they can be considered by other competitors due to intellectual property issues and availability.

Third, again perhaps because of the relatively smaller fleet and fewer numbers of make/models, the sensitivity analysis for HDPUVs strongly suggests that uncertainty in the input assumptions can have significant effects on outcomes. As with any analysis of sufficient complexity, there are a number of critical assumptions here that introduce uncertainty about manufacturer compliance pathways, consumer responses to fuel efficiency improvements and higher vehicle prices, and future valuations of the consequences from higher HDPUV standards. Recognizing that uncertainty, NHTSA also conducted nearly 40 sensitivity analysis runs for the HDPUV fleet analysis. The entire sensitivity analysis is presented in Chapter 9 of the PRIA, demonstrating the effect that different assumptions would have on the costs and benefits associated with the different regulatory alternatives. While NHTSA considers dozens of sensitivity cases to measure the influence of specific parametric assumptions and model relationships, only a small number of them demonstrate meaningful impacts to net benefits under the different alternatives.

The results of the sensitivity analyses for HDPUVs are different from the sensitivity analysis results for passenger cars and light trucks. Generally speaking, for HDPUVs, varying the inputs seems either to make no difference at all, or to make a fairly major difference. As suggested above, NHTSA interprets this as likely resulting from the relatively smaller size and ''blockiness'' of the HDPUV fleet: there are simply fewer vehicles, and fewer models, so variation in input parameters may cause notable moves in tranches of the fleet that are large enough (as a portion of the total HDPUV fleet) to produce meaningful effects on the modeling results. For example, Table V–23 shows estimated per-vehicle costs by HDPUV manufacturer, by regulatory alternative, for the RC (the central analysis) and several selected sensitivity runs with the following effects:

TABLE V–23—EFFECTS OF SELECTED SENSITIVITY RUNS ON PER-VEHICLE COSTS IN MY 2038 (2021$), HDPUV FLEET

Manufacturer	Regulatory alternative	Reference case	Sensitivity runs		
			Battery costs +20%	Tax credit passthrough 75%	AEO 2022 low oil price
Ford	No-Action	2,519	257	−102	−285
	HDPUV4	8	327	261	388
	HDPUV10	17	2,821	2,126	2,322
	HDPUV14	451	4,144	3,084	3,263
GM	No-Action	645	−990	−1,358	−1,395
	HDPUV4	0	0	0	13

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[598] See Manufacturers tab in the CAFE Model Input file market_data_HDPUV_ref.xlsx for HDPUV banked credits.

[599] 49 CFR 535.6(a)(3)(iii).

TABLE V–23—EFFECTS OF SELECTED SENSITIVITY RUNS ON PER-VEHICLE COSTS IN MY 2038 (2021$), HDPUV FLEET—Continued

Manufacturer	Regulatory alternative	Reference case	Sensitivity runs		
			Battery costs +20%	Tax credit passthrough 75%	AEO 2022 low oil price
	HDPUV10	405	2,810	2,382	2,425
	HDPUV14	1,517	4,343	3,570	3,606
Mercedes-Benz	No-Action	2,080	437	854	−381
	HDPUV4	3	−3	−1	−1
	HDPUV10	3	1,303	68	851
	HDPUV14	2	2,474	418	1,652
Nissan	No-Action	5,562	2,229	1,863	1,492
	HDPUV4	−3	1,037	751	1,147
	HDPUV10	−4	3,575	2,725	2,927
	HDPUV14	−3	4,534	3,835	4,207
Rivian	No-Action	0	0	0	0
	HDPUV4	0	0	0	0
	HDPUV10	0	0	0	0
	HDPUV14	0	0	0	0
Stellantis	No-Action	1.095	−1,446	−1,742	−2,055
	HDPUV4	0	0	0	0
	HDPUV10	2	2,200	1,658	1,902
	HDPUV14	2	3,699	2,688	2,891
Industry Average	No-Action	1,520	−477	−781	−970
	HDPUV4	3	138	111	166
	HDPUV10	131	2,483	2,033	2,092
	HDPUV14	633	3,820	3,065	3,062

In this table, ''Battery Costs +20%'' means that direct manufacturing costs for batteries would be 20 percent higher than estimated for the central analysis; ''Tax Credit Passthrough 75%'' means that 75 percent of the value of modeled tax credits would be captured by consumers (meaning that less of the value of modeled tax credits would be available to manufacturers to offset vehicle costs, as compared to the central analysis); and ''AEO 2022 Low Oil Price'' means that the forecasted future price of gasoline would be lower than estimated for the central analysis. Dollar values are incremental to the No-Action alternative and to the RC, and if they are negative, that means that the change in the input assumption causes the model to estimate that costs would decrease with the alternate input. These cases were not chosen for illustration because NHTSA lacks confidence in our assumptions for the central analysis, but simply to show the magnitude of the effect of relatively routine alternate assumptions for important inputs. The proposed standards for HDPUVs will result in a total of 60 percent FE improvement in the rulemaking time frame of only 6 years. With the vehicles in this segment having the same if not longer redesign cycle time, our analysis shows that any change to these inputs could have a dramatic impact on the manufacturers. As shown in Table V–23 above, the industry average incremental cost for HDPUV10 is $131, but that increases to over $2,033 to $2,483 with the change to an input that could be due to any number of global circumstances. These considerations help give NHTSA confidence that HDPUV10 is maximum feasible for the rulemaking time frame.

Specifically, each of these sensitivity runs illustrate that per-vehicle costs for nearly every manufacturer to comply with HDPUV10 and HDPUV14 could be significantly higher under any of these cases. Looking at the industry average results, each of the three sensitivity runs presented here could bring per-vehicle costs over $3,000 per vehicle in MY 2038. Battery costs only 20 percent higher could bring half the manufacturers over $4,000 higher per vehicle. When costs appear to be negative in response to the No-Action alternative, that means that it is more cost-effective to apply technology in the baseline, which means that less technology is available to meet new NHTSA standards (because it has already been applied in the baseline), which means that relatively more expensive technology is what is left to meet more stringent alternatives like HDPUV10 and HDPUV14. For each manufacturer (besides Rivian, a small BEV manufacturer), the jump in cost from HDPUV4 to HDPUV10 is quite large under each sensitivity run shown; the costs for HDPUV14 under each of the sensitivity runs shown would be greater than NHTSA would likely conclude was appropriate for this segment.

Again, that is not to say that NHTSA lacks confidence in its assumptions, but simply that to the extent uncertainty exists, it matters for this segment and the effects that new HDPUV standards would have on the affordability of these vehicles. The nature of this fleet—smaller, with fewer models—and the nature of the technologies that this fleet will be applying leading up to and during the rulemaking time frame, means that the analysis is very sensitive to changes in inputs, and the inputs are admittedly uncertain. If the uncertainty causes NHTSA to set standards higher than they would otherwise have been, and industry is unable to meet the standards, the resources they would have to expend on civil penalties (which can potentially be much higher for HDPUVs than for passenger cars and light truck) would be diverted from their investments in the technological transition, and the estimated benefits would not come to pass anyway. To provide some margin for that uncertainty given the technological transition that this segment is trying to make, NHTSA believes that some conservatism is reasonable and appropriate for this round of standards.

We also note, that because NHTSA does consider BEV technologies in the HDPUV analysis, and because our current regulations assign BEVs a fuel consumption value for compliance purposes of 0 gal/100 miles, this significantly influences our modeling results. This is an artifact of the mathematics of averaging, where including a ''0'' value in the calculation effectively reduces other values by as much as 50 percent (depending on sample size) and is exaggerated when BEV-only manufacturers are considered in industry-average calculations. This effect creates the appearance of overcompliance at the industry level. As for the analysis for passenger cars and light trucks, examining individual manufacturer results can be more informative, and Chapter 8.3 of the PRIA shows that non-BEV-only manufacturers are more challenged by, for example, HDPUV14, although overcompliance is still evident in many MYs. This underscores the effect of BEVs on compliance, particularly when their fuel consumption is counted as 0 even though their energy consumption is non-zero. It also indirectly underscores the effect of the 32902(h) restrictions on NHTSA's decision-making for passenger car and light truck standard stringency, which does not apply in the HDPUV context. We are seeking comment on the assignment of 0 gal/100 miles value for HDPUV BEV compliance. Any change to this value would change the appearance of overcompliance in NHTSA's analysis, and this is another potential reason to be conservative in our proposal.

Based on the information in the record, NHTSA tentatively concludes that HDPUV10 represents the maximum feasible standards for HDPUVs in the MYs 2030 to 2035 time frame. While HDPUV14 could potentially save more fuel and reduce emissions further, it is less cost-effective than HDPUV10 by every metric that NHTSA considered, and the longer redesign cycles in this segment make NHTSA cautious of proposing HDPUV14, even though this segment has plenty of opportunity to improve. Moreover, the effects of uncertainty for our analytical inputs are significant in this analysis, as discussed, and NHTSA believes some conservatism is appropriate for this rulemaking time frame. HDPUV10 will still encourage technology application for some manufacturers while functioning as a backstop for the others, and it remains net beneficial for consumers. For these reasons, NHTSA is proposing HDPUV10 for MYs 2030–2035 HDPUVs. We seek comment on this tentative conclusion, on the feasibility of HDPUV10 in light of the regulatory analysis, and on all aspects of this discussion, including whether and how standards more closely aligned with EPA's standards for these vehicles would be appropriate and maximum feasible for NHTSA to adopt for the model years subject to this rulemaking.

3. Severability

For the reasons described above, NHTSA believes that its authority to propose and implement CAFE and HDPUV standards for the various fleets described is well-supported in law and practice and should be upheld in any legal challenge. NHTSA also believes that its exercise of its authority reflects sound policy.

However, in the event that any portion of the proposed rule is declared invalid, NHTSA intends that the various aspects of the proposal be severable, and specifically, that each proposed standard and each year of each proposed standard is severable, as well as the various compliance proposals discussed in the following section of this preamble. Any of the proposed standards could be implemented independently if any of the other proposed standards were struck down, and NHTSA firmly believes that it would be in the best interests of the nation as a whole for the standards to be applicable in order to support EPCA's overarching purpose of energy conservation. Each proposed standard is justified independently on both legal and policy grounds and could be implemented effectively by NHTSA.

VI. Compliance and Enforcement

NHTSA is proposing changes to its enforcement programs for LDVs in the CAFE program as well for HDPUVs in the Heavy-Duty National Program. These changes include: (1) eliminating AC and off-cycle (OC) fuel consumption improvement values (FCIVs) for BEVs in the LD program, (2) eliminating the 5-cycle and alternative approval pathways for OC FCIVs in the LD program, (3) adding additional deadlines for the alternative approval process for MYs 2025–2026 for the LD program, (4) eliminating OC FCIVs for HDPUVs, (5) making technical amendments to the regulations pertaining to advanced technology credits, and (6) making an assortment of minor technical amendments. To provide context for these proposed changes, this section first provides an overview of NHTSA's enforcement programs. The section then discusses and requests comment on each of the proposed changes. NHTSA is also requesting comment on phasing out FCIVs for CAFE program. Finally, this section concludes with a discussion of one requested change, to create a new program for EJ credits, that NHTSA has decided is not practical to implement at this time.

A. Background

NHTSA has separate enforcement programs for LDVs in the CAFE program and HD vehicles in the Heavy-Duty National program. NHTSA's CAFE enforcement program is largely established by EPCA, as amended by EISA, and is very prescriptive regarding enforcement. EPCA and EISA also clearly specify a number of flexibilities and incentives that are available to manufacturers to help them comply with the CAFE standards. EISA also provides DOT and NHTSA with the authority to regulate HD vehicles, and NHTSA structured the enforcement program for HDPUVs to be similar to its LD enforcement program.

The LD CAFE program includes all vehicles with a Gross Vehicle Weight Rating (GVWR) of 8,500 pounds or less as well as vehicles between 8,501 and 10,000 pounds that are classified as medium-duty passenger vehicles (MDPVs). As prescribed by 49 U.S.C. 32901(a)(19)(B)[600] and defined in 40 CFR 86.1803–01, an MDPV means any HD vehicle with a GVWR of less than 10,000 pounds that is designed primarily for the transportation of persons[601] and subject to requirements that apply for LD trucks.[602] The MDHD Program includes all vehicles 8,501 pounds and up, and the engines that power them, except for MDPVs, that are covered under the LD fuel economy program.

NHTSA's authority to regulate HD vehicles under EISA directs NHTSA to establish fuel efficiency standards for commercial medium- and heavy-duty on-highway vehicles[603] and work trucks.[604] Under this authority, NHTSA

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[600] As prescribed in 49 U.S.C. 32901(a)(19)(B), an MDPV is ''defined in section 86.1803–01 of title 40, Code of Federal Regulations, as in effect on the date of the enactment of the Ten-in-Ten Fuel Economy Act.''

[601] 40 CFR 86.1803 defines an MDPV as ''any vehicle which: (1) Is an ''incomplete truck'' as defined in this subpart; or (2) Has a seating capacity of more than 12 persons; or (3) Is designed for more than 9 persons in seating rearward of the driver's seat; or (4) Is equipped with an open cargo area (for example, a pick-up truck box or bed) of 72.0 inches in interior length or more. A covered box not readily accessible from the passenger compartment will be considered an open cargo area for purposes of this definition.''

[602] See Heavy-duty vehicle definition in 40 CFR 86.1803.

[603] EISA added the following definition to the automobile fuel economy chapter of the U.S. Code: ''commercial medium- and heavy-duty on-highway vehicle'' means an on-highway vehicle with a gross vehicle weight rating of 10,000 pounds or more. 49 U.S.C. 32901(a)(7).

[604] EISA added the following definition to the automobile fuel economy chapter of the U.S. Code:

Continued

has developed standards for three regulatory categories of HD vehicles: combination tractors; HDPUVs; and vocational vehicles. HDPUVs include HD vehicles with a GVWR between 8,501 pounds and 14,000 pounds (known as Class 2b through 3 vehicles) manufactured as complete vehicles by a single or final stage manufacturer or manufactured as incomplete vehicles as designated by a manufacturer.[605] The majority of these HDPUVs are 3/4-ton and 1-ton pickup trucks, 12-and 15-passenger vans, and large work vans that are sold by vehicle manufacturers as complete vehicles, with no secondary manufacturer making substantial modifications prior to registration and use. These vehicles can also be sold as cab-complete vehicles (*i.e.,* incomplete vehicles that include complete or nearly complete cabs that are sold to secondary manufacturers).

B. Overview of Enforcement

This subsection is intended to provide a general overview of NHTSA's enforcement of its fuel economy and fuel efficiency standards in order to provide context for the discussion of the proposed changes to these enforcement programs. At a high-level, NHTSA's fuel efficiency and fuel economy enforcement programs encompass how NHTSA determines whether manufacturers comply with standards for each MY, and how manufacturers may use compliance flexibilities and incentives, or alternatively address noncompliance through paying civil penalties. NHTSA's goal in administering these programs is to balance the energy-saving purposes of the authorizing statutes against the benefits of certain flexibilities and incentives. More detailed explanations of NHTSA's enforcement programs have also been included in recent rulemaking documents.[606] [607]

1. Light Duty CAFE Program

As mentioned above, there are three primary components to NHTSA's compliance program: (1) determining compliance; (2) using flexibilities and incentives; and (3) paying civil penalties for shortfalls. The following table provides an overview of the CAFE program for LDVs and MDPVs.

TABLE V–24—OVERVIEW OF COMPLIANCE FOR CORPORATE AVERAGE FUEL ECONOMY PROGRAM

[Vehicles with a GVWR of 8,500 lbs. or less and MDPVs with a GVWR between 8,501 and 10,000 lbs.]

Component	Applicable regulation (statutory authority)	General description	Proposed changes in NPRM?
Fleet performance requirements			
Fuel Economy Standards	49 CFR 531.5 and 49 CFR 533.5 (49 U.S.C. 32902).	Standards are footprint-based fleet average standards for each of a manufacturer's fleets (*i.e.*, domestic passenger vehicle, import passenger vehicle, and light truck) and expressed in miles per gallon (mpg). NHTSA sets average fuel economy standards that are the maximum feasible for each fleet for each model year. In setting these standards, NHTSA considers technological feasibility, economic practicability, the effect of other motor vehicle standards of the Government on fuel economy, and the need of the U.S. to conserve energy. NHTSA is precluded from considering the fuel economy of vehicles that operate only on alternative fuels, the portion of operation of a dual fueled vehicle powered by alternative fuel, and the trading, transferring, or availability of credits.	Yes: Proposed amendments to 49 CFR 531.5(c)(2) and 49 CFR 533.5(a) to set standards for MY 2027–2032.
Minimum Domestic Passenger Car Standards.	49 CFR 531.5 (49 U.S.C. 32902(b)(4)).	Minimum fleet standards for domestically manufactured passenger vehicles.	Yes: Proposed amendments to 49 CFR 531.5(d) to set standards for MY 2027–2032.
Determining Average Fleet Performance			
2-Cycle Testing	49 CFR 531.6(a) citing 40 CFR part 600 and 49 CFR 533.6 citing 40 CFR part 600 (49 U.S.C. 32904).	Vehicle testing is conducted by EPA using the Federal Test Procedure (Light-duty FTP or "city" test) and Highway Fuel Economy Test (HFET or "highway" test).	No proposed changes.

"work truck" means a vehicle that—(A) is rated at between 8,500 and 10,000 pounds gross vehicle weight; and (B) is not a medium-duty passenger vehicle (as defined in section 86.1803–01 of title 40, Code of Federal Regulations, as in effect on the date of the enactment of [EISA]). 49 U.S.C. 32901(a)(19).

[605] *See* 49 CFR 523.7, 40 CFR 86.1801–12, 40 CFR 86.1819–17, 40 CFR 1037.150.

[606] For more detailed explanations of CAFE enforcement, *see* 77 FR 62649 (October 15, 2012) and 87 FR 26025 (May 2, 2022).

[607] For more detailed explantions of heavy-duty pickup trucks and vans fuel efficiency standards and enforcement, *see* 76 FR 57256 (September 15, 2011) and 81 FR 73478 (October 25, 2016).

TABLE V–24—OVERVIEW OF COMPLIANCE FOR CORPORATE AVERAGE FUEL ECONOMY PROGRAM—Continued

[Vehicles with a GVWR of 8,500 lbs. or less and MDPVs with a GVWR between 8,501 and 10,000 lbs.]

Fleet performance requirements

Component	Applicable regulation (statutory authority)	General description	Proposed changes in NPRM?
AC efficiency FCIV	49 CFR 531.6(b)(1) and 49 CFR 533.6(c)(1) (49 U.S.C. 32904) citing 40 CFR 86.1868–12.	This adjustment to the results from the 2-cycle testing accounts for fuel consumption improvement from technologies that improve AC efficiency that are not accounted for in the 2-cycle testing. The AC efficiency FCIV program began in MY 2017.	Yes: Proposed changes to 49 CFR 531.6 and 533.6 to eliminate AC efficiency FCIVs for BEVs starting in MY 2027.
Off-cycle FCIV	49 CFR 531.6(b)(2) and (3) and 49 CFR 533.6(c)(3) and (4) (49 U.S.C. 32904) citing 40 CFR 86.1869–12.	This adjustment to the results from the 2-cycle testing accounts for fuel consumption improvement from technologies that are not accounted for or not fully accounted for in the 2-cycle testing. The off-cycle FCIV program began in MY 2017.	Yes: Proposing changes to 49 CFR 531.6 and 533.6 to eliminate off-cycle menu FCIVs for BEVs and to eliminate the 5-cycle and alternative approvals starting in MY 2027. PHEVs retain benefits. Proposing a 60-day response deadline for requests for information regarding off-cycle requests for MY 2025–2026.
Advanced full-size pickup trucks FCIV.	49 CFR 533.6(c)(2) citing 40 CFR 86.1870–12 (49 U.S.C. 32904).	This adjustment increases a manufacturer's average fuel economy for hybridized and other performance-based technologies for MY 2017 and 2024.	No proposed changes. The program is set to sunset in MY 2024 and NHTSA is not proposing to extend it.
Dedicated alternative fueled vehicles.	49 CFR 536.10 citing 40 CFR 600.510–12(c) (49 U.S.C. 32905(a) and (c)).	EPA calculates the fuel economy of dedicated alternative fueled vehicles assuming that a gallon of liquid/gaseous alternative fuel is equivalent to 0.15 gallons of gasoline per 49 U.S.C. 32905(a). For BEVs, EPA uses the petroleum equivalency factor as defined by the Department of Energy (see 10 CFR 474.3) (per 49 U.S.C. 32904(a)(2).	No proposed changes.
Dual-fueled vehicles	49 CFR 536.10 citing 40 CFR 600.510–12(c) (49 U.S.C. 32905(b), (d), and (e) and 49 U.S.C. 32906(a)).	EPA calculates the fuel economy of dual-fueled vehicles using a utility factor to account the portion of power energy consumption from the different energy sources. Starting in MY 2019, there is no adjustment to the fuel economy of dual-fueled vehicles other than electric hybrids. For electric hybrids, EPA uses the petroleum equivalency factor for the electric portion of the vehicle's expected energy use (per 49 U.S.C. 32904(a)(2).	No proposed changes.
Earning and Using Credits for Overcompliance and Addressing Shortfalls			
Earning Credits	49 CFR 536.4 (49 U.S.C. 32903(a)).	Manufacturers earn credits for each one tenth of mile by which the average fuel economy vehicles in a particular compliance category in a model year exceeds the applicable fuel economy standard, multiplied by the number of vehicles sold in that compliance category (*i.e.*, fleet).	No proposed changes.
Carry-forward Credits	49 U.S.C. 32903(a)(2).	Manufacturers may carry-forward credits up to 5 model years into the future.	No proposed changes.
Carry-back Credits	49 CFR part 536 (49 U.S.C. 32903(a)(1)).	Manufacturers may carry-back credits up to 3 model years into the past.	No proposed changes.
Credit Transfers	49 CFR part 536 (49 U.S.C. 32903(g)).	Manufacturers may transfer credits between their fleets to increase a fleet's average fuel economy by up to 2 mpg. Manufacturers may not use transferred credits to meet the minimum domestic passenger car standards (see 49 U.S.C. 32903(g)(4) and 49 CFR 536.9).	No proposed changes.

TABLE V–24—OVERVIEW OF COMPLIANCE FOR CORPORATE AVERAGE FUEL ECONOMY PROGRAM—Continued

[Vehicles with a GVWR of 8,500 lbs. or less and MDPVs with a GVWR between 8,501 and 10,000 lbs.]

Fleet performance requirements			
Component	Applicable regulation (statutory authority)	General description	Proposed changes in NPRM?
Credit Trading	49 CFR 536.8 (49 U.S.C. 32903(f)).	Manufacturers may trade an unlimited quantity of credits into fleets of the same compliance category. A manufacturer may then transfer those credits to a different compliance category, but only up to the 2 mpg limit for transfers. Manufacturers may not use traded credits to meet the minimum domestic passenger car standards (see 49 U.S.C. 32903(f)(2) and 49 CFR 536.9).	No proposed changes.
Civil Penalties	49 CFR 578.6(h) (49 U.S.C. 3912.).	Starting in 2023, the civil penalty for CAFE shortfalls is $16 for each tenth of a mpg that a manufacturer's average fuel economy falls short of the standard multiplied by the total number of vehicles in the affected fleet. The civil penalty is adjusted periodically for inflation.	No proposed changes.

a. Determining Compliance

This first component of NHTSA's enforcement program pertains to how NHTSA determines compliance with its fuel economy standards. In general, as prescribed by Congress, NHTSA finalizes footprint-based fleet average standards for LDVs for fuel economy on a mpg basis. In that way, the standard applies to the fleet as a whole and not to a specific vehicle, and manufacturers can balance the performance of their vehicles and technologies in complying with standards. Also, as specified by Congress, LDVs must be is broken down into 3 fleets for compliance purposes: domestic passenger vehicles, import passenger vehicles, and light trucks. Each manufacturer must comply with the fleet average standard derived from the model type target standards. These target standards are taken from a set of curves (mathematical functions) for each fleet. Vehicle testing for the LDV programs is conducted by EPA using the FTP (or ''city'' test) and HFET (or ''highway'' test).[608]

At the end of each MY NHTSA confirms whether a manufacturer's fleet average performance for each of its fleets of LDVs exceeds the applicable target-based fleet standard. NHTSA makes its ultimate determination of a manufacturer's CAFE compliance obligation based on official reported and verified CAFE data received from EPA. Pursuant to 49 U.S.C. 32904(e), EPA is responsible for calculating manufacturers' CAFE values so that NHTSA can determine compliance with its CAFE standards. The EPA-verified data is based on information from NHTSA's testing,[609] its own vehicle testing, and FMY data submitted by manufacturers to EPA pursuant to 40 CFR 600.512–12. A manufacturer's FMY report must be submitted to EPA no later than 90 days after December 31st of the MY including any adjustment for off-cycle credits for the addition of technologies that result in real-world fuel improvements that are not accounted for in the 2-cycle testing as specified in 40 CFR part 600 and 40 CFR part 86. EPA verifies the data submitted by manufacturers and issues final CAFE reports that are sent to manufacturers and to NHTSA electronically between April and October of each year. NHTSA's database system identifies which fleets do not meet the applicable CAFE fleet standards and calculates each manufacturer's credit amounts (credits for vehicles exceeding the standards), credit excesses (credits accrued for a fleet exceeding the standards), and shortfalls (amount by which a fleet fails to meet the standards). A manufacturer meets NHTSA's fuel economy standard if its fleet average performance is greater than or equal to its required standard or its MDPCS (whichever is greater). Congress enacted MDPCSs per 49 U.S.C. 32902. These standards require that domestic passenger car fleets meet a minimum level directed by statute and then projected by the Secretary at the time a standard is promulgated in a rulemaking. In addition, manufacturers are not allowed to use traded or transferred credits to resolve credit shortfalls resulting from failing to exceed the MDPCS.

If a manufacturer's fleet fails to meet a fuel economy standard, NHTSA will provide written notification to the manufacturer that it has not met the standard. The manufacturer will be required to confirm the shortfall and must either submit a plan indicating how to allocate existing credits, or if it does not have sufficient credits available in that fleet, how it will address the shortfall either by earning, transferring and/or acquiring credits or by paying the appropriate civil penalty. The manufacturer must submit a plan or payment within 60 days of receiving agency notification. Credit allocation plans received from the manufacturer will be reviewed and approved by NHTSA. NHTSA will approve a credit allocation plan unless it finds the proposed credits are unavailable or that it is unlikely that the plan will result in the manufacturer earning sufficient credits to offset the shortfall. If a plan is approved, NHTSA will revise the manufacturer's credit account accordingly. If a plan is rejected, NHTSA will notify the manufacturer and request a revised plan or payment of the appropriate fine.

b. Flexibilities

As mentioned above, there are flexibilities manufacturers can use in the CAFE program for compliance purposes. Two general types of flexibilities that exist for the CAFE program include (1) FCIVs that can be used to increase CAFE values; and (2) credit flexibilities. To provide context for the changes NHTSA is proposing, a discussion of two types of FCIVs is provided below. These credits are for

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[608] 40 CFR part 600.

[609] NHTSA conducts vehicle testing under its ''Footprint'' attribute conformity testing to verify track width and wheelbase measurements used by manufactures to derive model type target standards. If NHTSA finds a discrepancy in its testing, manufacturers will need to make changes in their final reports to EPA.

the addition of technologies that improve air/conditioning efficiency (AC FCIVs) and other ''off-cycle'' technologies that reduce fuel consumption that are not accounted for in the 2-cycle testing (OC FCIVs).[610] NHTSA is not proposing any changes to credit flexibilities. A discussion of these flexibilities can be found in previous rulemakings.[611]

As mentioned above, the LD program provides fuel consumption improvement values (FCIVs) for improving the efficiency of AC systems.[612] Improving the efficiency of these systems is important because AC usage places a load on the Internal Combustion (IC) that results in additional fuel consumption, and AC systems are virtually standard automotive accessories, with more than 95 percent of new cars andlight trucks sold in the U.S. equipped with mobile AC systems. Together, this means that AC efficiency can have a signifant impact on total fuel consumption. The AC FCIV program is designed to incentivize the adoption of more efficient systems, thereby reducing energy consumption across the fleet.

Manufacturers can improve the efficiency of AC systems through redesigned and refined AC system components and controls. These improvements, however, are not measurable or recognized using 2-cycle test procedures because the AC is turned off during the CAFE compliance 2-cycle testing. Any AC system efficiency improvements that reduce load on the engine and improve fuel economy, therefore, cannot be accounted for in those tests.

NHTSA adopted EPA's AC efficiency program in the 2017–2025 CAFE final rule.[613] The program provides a technology menu that specifies improvement values for the addition of specific technologies and specifies testing requirements to confirm that the technologies provide emissions reductions when installed as a system on vehicles.[614] A vehicle's total AC efficiency FCIV is calculated by summing the individual values for each efficiency improving technology used on the vehicle, as specified in the AC menu or by the AC17 test result.[615] The total AC efficiency FCIV sum for each vehicle is capped at 5.0 grams/mile for cars and 7.2 grams/mile for trucks.[616] Related to AC efficiency improvements, the off-cycle program, discussed in the next section, contains fuel consumption improvement opportunities for technologies that reduce the thermal loads on a vehicle from environmental conditions (solar loads or parked interior air temperature), that ultimately reduces the total energy required for AC operation. These technologies are listed on a thermal control menu that provides a predefined improvement value for each technology.[617] If a vehicle has more than one thermal load improvement technology, the improvement values are added together, but subject to a cap of 3.0 grams/mile for cars and 4.3 grams/mile for trucks.[618] Manufacturers seeking FCIVs beyond the regulated caps may request the added benefit for AC technology under the off-cycle program.

In additon to allowing improvements for AC efficiency technologies, the CAFE program also provides FCIVs for off-cycle technologies. ''Off-cycle'' technologies are those that reduce vehicle fuel consumption in the real world, but for which the fuel consumption reduction benefits cannot be fully measured under the 2-cycle test procedures used to determine compliance with the fleet average standards. The FTP and HFET cycles are effective in measuring improvements in most fuel efficiency improving technologies; however, they are unable to measure or do not adequately represent certain fuel economy improving technologies because of limitations in the test cycles. For example, off-cycle technologies that improve emissions and fuel efficiency at idle (such as ''stop start'' systems) and those technologies that improve fuel economy to the greatest extent at highway speeds (such as active grille shutters that improve aerodynamics) are not fully accounted for in the 2-cycle tests.

In the 2017–2025 CAFE rulemaking, EPA, in coordination with NHTSA, established regulations extending benefits for off-cycle technologies and created FCIVs for the CAFE program starting with MY 2017.[619] Under its EPCA authority for CAFE, EPA determined that the summation of the all the FCIVs values (for AC, OC, and advanced technology full size pickup trucks) in grams per mile could be converted to equivalent gallons per mile totals for improving CAFE values. More specifically, EPA normalizes the FCIVs values based on the manufacturer's total fleet production and then applies the values in an equation that can increase the manufacturer's CAFE values for each fleet instead of treating them as separate credits as they are in the GHG program.[620]

For determining FCIV benefits, EPA and NHTSA created three compliance pathways for the off-cycle program: (1) menu technologies, (2) 2 to 5-Cycle Testing, and (3) an alternative approval methodology. Manufacturers may generate off-cycle credits or improvements through the EPA and NHTSA approved menu pathway without agency approval. Manufacturers report the inclusion of pre-defined technologies for vehicle configurations that utilize the technologies, from the pre-determined values listed in 40 CFR 1869–12(b), in their PMY and MMY reports to NHTSA and then in their final reports to EPA.

For off-cycle technologies both on and off the pre-defined technology list, EPA allows manufacturers to use 5-cycle testing to demonstrate off-cycle improvements.[621] Starting in MY 2008, EPA developed the ''five-cycle'' test methodology to measure fuel economy for the purpose of improving new car window stickers (labels) and giving consumers better information about the fuel economy they could expect under real-world driving conditions. The ''five-cycle'' methodology was also able to capture real-world fuel consumption improvements that weren't fully reflected on the ''two-cycle'' test and EPA established this methodology as a pathway for a manufacturer to obtain FCIVs. The additional testing allows emission benefits to be demonstrated over some elements of real-world driving not captured by the two-cycle testing, including high speeds, rapid accelerations, hot temperatures, and cold temperatures. Under this pathway, manufacturers submit test data to EPA,

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[610] Manufacturers may also earn FCIVs for full size pickup trucks which have hybrid or electric drivetrains or have advanced technologies as specified in 40 CFR 86.1870–12. NHTSA is not providing an overview of these credits because NHTSA is not proposing any changes for these credits. For an an explanation of these credits see the May 2, 2022 final rule (87 FR 25710, page 26025).

[611] October 15, 2012 (77 FR 63125, starting at page 62649) and May 2, 2022 (87 FR 25710, starting at page 26025).

[612] 40 CFR 1868–12.

[613] October 15, 2012 final rule (77 FR 62624).

[614] *See* 40 CFR 86.1868–12(e) through (g).

[615] *See* 40 CFR 1868–12(g)(2)(iii).

[616] *See* 40 CFR 1868–12(b)(2).

[617] *See* 40 CFR 86.1869–12(b)(1)(viii)(A) through (E).

[618] *See* 40 CFR 86.1869–12(b)(1)(viii).

[619] Off-cycle credits were extened to LDVs under the CAFE program in the October 15, 2012 final rule (77 FR 62624).

[620] FCIV_{AC} and FCIV_{OC} are each deducted as separately calculated credit values from the fleet fuel economy per 40 CFR 600.510 12(c)(1)(ii) and 40 CFR 600.510 12(c)(3)(i) through (ii). AC efficiency credit falls under FCIV_{AC}, while thermal load improvement technology credit falls under FCIV_{OC}.

[621] *See* 40 CFR 86.1869–12(c).

and EPA determines whether there is sufficient technical basis to approve the value of the off-cycle credit or fuel consumption improvement.

The final pathway allowed for manufacturers to earn OC FCIVs is an alternative pathway that requires a manufacturer to seek EPA review and approval.[622] This path allows a manufacturer to submit an application to EPA to request approval of off-cycle benefits using an alternative methodology. The application must describe the off-cycle technology and how it functions to reduce CO_2 emissions under conditions not represented in the 2-cycle testing, as well as provide a complete description of the methodology used to estimate the off-cycle benefit of the technology and all supporting data, including vehicle testing and in-use activity data. A manufacturer may request that EPA, in coordination with NHTSA, informally review their methodology prior to undertaking testing and/or data gathering efforts in support of their application. Once a manufacturer submits an application, EPA publishes a notice of availability in the **Federal Register** notifying the public of a manufacturer's proposed alternative off-cycle benefit calculation methodology.[623] EPA makes a decision whether to approve the methodology after consulting with NHTSA and considering the public comments.

c. Civil Penalties

If a manufacturer does not comply with a CAFE standard and cannot or chooses not to cover the shortfall with credits, EPCA provides for the assessment of civil penalties. The Act specifies a precise formula for determining the amount of civil penalties for such noncompliance. Starting in MY 2023, the penalty, as adjusted for inflation by law, is $16 for each tenth of a mpg that a manufacturer's average fuel economy falls short of the standard multiplied by the total volume of those vehicles in the affected fleet (*i.e.,* import passenger vehicles, domestic passenger vehicles, or light trucks), manufactured for that MY.[624] On November 2, 2015, the Federal Civil Penalties Inflation Adjustment Act Improvements Act (Inflation Adjustment Act or 2015 Act), Pub. L. 114–74, Section 701, was signed into law. The 2015 Act required Federal agencies to promulgate an interim final rule to make an initial ''catch-up'' adjustment to the civil monetary penalties they administer, and then to make subsequent annual adjustments. The amount of the penalty may not be reduced except under the unusual or extreme circumstances specified in the statute,[625] which have never been exercised by NHTSA in the history of the CAFE program.

NHTSA may also assess general civil penalties as prescribed by Congress under 49 U.S.C. 32912(a). A person that violates section 32911(a) of title 49 is liable to the United States Government for a civil penalty of not more than $49,534 for each violation. A separate violation occurs for each day the violation continues. These penalties apply in cases in which NHTSA finds a violation outside of not meeting CAFE standards, such as those that may occur due to violating information request or reporting requirements as specified by Congress or codified in NHTSA's regulations.

2. Heavy-Duty Pickup Trucks and Vans

As with the CAFE enforcement program, there are three primary components to NHTSA's compliance program for HD vehicles: (1) determining compliance; (2) using flexibilities and incentives; and (3) paying civil penalties for shortfalls. The following table provides an overview of the Heavy-Duty Fuel Efficiency Program for HDPUVs.

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[622] 40 CFR 86.1869–12(d).

[623] EPA may waive the notice and comment requirements for technologies for which EPA has previously approved a methodology for determining credits. See 40 CFR 86.1869–12(d)(2)(ii).

[624] *See* 49 U.S.C. 32912(b) and 49 CFR 578.6(h)(2). For MYs before 2019, the penalty is $5.50; for MYs 2019 through 2021, the civil penalty is $14; for MY 2022, the civil penalty is $15.

[625] *See* 49 U.S.C. 32913.

TABLE V–25—OVERVIEW OF COMPLIANCE FOR HEAVY-DUTY FUEL EFFICIENCY PROGRAM FOR PICKUP AND VANS (VEHICLES WITH A GVWR BETWEEN 8,500 AND 14,000 LBS.)

Fleet performance requirements			
Component	Applicable regulation (statutory authority)	General description	Proposed changes in NPRM?
Fuel Efficiency Standards	49 CFR 535.5 (49 U.S.C. 32902(k)).	Standards are attribute-based fleet average standards expressed in gallons per 100 miles. The standards are based on the capability of each model to perform work. A model's work-factor is a measure of its towing and payload capacities and whether equipped with a 4-wheel drive configuration. In setting standards for the Heavy-Duty National Program, NHTSA seeks to implement standards designed to achieve the maximum feasible improvement in fuel efficiency, adopting and implementing test procedures, measurement metrics, fuel economy standards, and compliance and enforcement protocols that are appropriate, cost effective, and technologically feasible.	Yes: Proposed amendments to 49 CFR 535.5(a) to set standards for MY2030 and onward (with increases in the proposed standards between MY 2030 and 2035).
Determining Average Fleet Performance and Certification Flexibilities			
2-Cycle Testing	49 CFR 535.6(a) citing 40 CFR 86.1819–14.	Vehicle testing is conducted by EPA using the Federal Test Procedure and Highway Fuel Economy Test (HFET or ''highway'' test).	No proposed changes.
Exclusion of Vehicles Not Certified as Complete Vehicles.	49 CFR 535.5(a)(5)	The standards for heavy duty pickup trucks do not apply to vehicles that are chassis-certified with respect to EPA's criteria pollutant test procedure in 40 CFR part 86, subpart S. Instead, the vehicles must comply with the vehicle standards in 49 CFR 535.5(b) and the engines used in these vehicles must comply with 49 CFR 535.5(d).	No proposed changes.
Sister Vehicles	49 CFR 535.5(a)(6)	Manufacturers may certify cab-complete vehicles based on a complete sister vehicle for purposes of the fuel consumption standards in 49 CFR 535.5. Manufacturers may also ask to apply the sister vehicle provision to Class 2b and Class 3 incomplete vehicles in unusual circumstances.	No proposed changes.

TABLE V–25—OVERVIEW OF COMPLIANCE FOR HEAVY-DUTY FUEL EFFICIENCY PROGRAM FOR PICKUP AND VANS (VEHICLES WITH A GVWR BETWEEN 8,500 AND 14,000 LBS.)—Continued

Fleet performance requirements			
Component	Applicable regulation (statutory authority)	General description	Proposed changes in NPRM?
Loose Engines	49 CFR 535.5(a)(7)	For MY 2023 and earlier, manufacturers may certify spark-ignition engines with identical hardware compared with engines used in complete pickup trucks as having a fuel consumption target value and test result equal to that of the complete vehicle in the applicable test group with the highest equivalent test weight except that a manufacturer may not generate fuel consumption credits.	No proposed changes. The loose engine program ends after MY 2023.
Optional Certification for Heavier Vehicles	49 CFR 535.5(a)(6)(i)	Manufacturers may certify any complete or cab-complete spark-ignition vehicles above 14,000 pounds GVWR and at or below 26,000 pounds GVWR to the fuel consumption standards for heavy duty pickup trucks and vans in 49 CFR 535.5(a).	No proposed changes.
Alternative Fuel Conversions	49 CFR 535.5(a)(8) citing 40 CFR 85.525.	Alternative fuel vehicle conversions may demonstrate compliance with the standards of this part or other alternative compliance approaches allowed by EPA in 40 CFR 85.525.	No proposed changes.
Earning and Using Credits for Overcompliance and Addressing Shortfalls			
Earning Credits	49 CFR 535.7(a)	Manufacturers earn fuel consumption credits (FCCs) for the weighted value representing the extent to which a vehicle or engine family or fleet within a particular averaging set performs better than the standard.	No proposed changes.
Advanced technology credits	49 CFR 535.7(a)(1)(iii); 49 CFR 535.7(f)(1) citing 40 CFR 86.1819–14 and 86.1865.	Manufacturer may generate credits for vehicle or engine families or subconfigurations containing vehicles with advanced technologies (i.e., hybrids with regenerative braking, vehicles equipped with Rankine-cycle engines, electric and fuel cell vehicles).	No proposed changes.

TABLE V–25—OVERVIEW OF COMPLIANCE FOR HEAVY-DUTY FUEL EFFICIENCY PROGRAM FOR PICKUP AND VANS (VEHICLES WITH A GVWR BETWEEN 8,500 AND 14,000 LBS.)—Continued

Fleet performance requirements			
Component	Applicable regulation (statutory authority)	General description	Proposed changes in NPRM?
Advanced technology credit multiplier	49 CFR 535.5(a)(9) and 535.7(f)(1).	In the 2016 Phase 2 Final Rule, EPA and NHTSA explained that manufacturers may increase advanced technology credits by a 3.5 multiplier for plug-in hybrid electric vehicles, 4.5 for all-electric vehicles, and 5.5 for fuel cell vehicles through My 2027.	Yes: Proposed technical amendments to accurately reflect changes contemplated by 2016 final rule establishing requirements for Phase 2. The multiplier for advanced technology credits ends after MY 2027.
Innovative and off-cycle technology credits	49 CFR 535.7(a)(1)(iv); 49 CFR 535.7(f)(2) citing 49 CFR 86.1819–14(d)(13), 1036.610 and 1037.610.	Manufacturer may generate credits for vehicle or engine families or subconfigurations having fuel consumption reductions resulting from technologies not reflected in the GEM simulation tool or in the FTP chassis dynamometer.	Yes: Proposed changes to eliminate innovative and off-cycle technology credits for heavy-duty pickup trucks and vans.
Banked Surplus Credits	49 CFR 535.7 (a)(3)(i)	Manufacturers may carry-forward credits up to 5 model years into the future.	No proposed changes.
Credit Deficit	49 CFR 535.7(a)(5)	Manufacturers may carry-back credits up to 3 model years into the past.	No proposed changes.
Credit Transfers	49 CFR 535.7	Manufacturers may transfer advanced technology credits across averaging sets.	Yes: Proposed technical amendment to reflect, as intended in the 2016 Phase 2 rule that advanced technology credits may not be transferred across averaging sets for Phase 2 and beyond.[626]
Credit Trading	49 CFR 535.7 (a)(4)	Manufacturers may trade an unlimited quantity of credits to other manufacturers in the same averaging set. Traded credits, other than advanced technology credits, may be used only within the averaging set in which they were generated.	No proposed changes.
Civil Penalties	49 CFR 535.9(b) and 49 CFR 578.6(i) (49 U.S.C. 32912.).	In cases of noncompliance, NHTSA assesses civil penalties based upon consideration of a variety of factors. The maximum civil penalty for a violation of is not more than $48,779 per vehicle or engine. The maximum civil penalty for a related series of violations shall be determined by multiplying $48,779 times the vehicle or engine production volume for the model year in question within the regulatory averaging set.	No proposed changes.

[626] Docket ID NHTSA–2020–0079–0001.

a. Determining Compliance

In general, NHTSA finalizes attribute-based fleet average standards for fuel consumption of HDPUVs on a gal/100-mile basis using a similar compliance strategy as required for light-vehicles in the CAFE program. For these vehicles, the agencies set standards based on attribute factors relative to the capability of each model to perform work, which the agencies defined as ''work factor.'' More specifically, the work-factor of each model is a measure of its towing and payload capacities and whether equipped with a 4-wheel drive configuration. Each manufacturer must comply with the fleet average standard derived from the unique subconfiguration target standards (or groups of subconfigurations approved by EPA in accordance with 40 CFR 86.1819–14(a)(4)) of the model types that make up the manufacturer's fleet in a given MY. Each subconfiguration has a unique attribute-based target standard, defined by each group of vehicles having the same work factor. These target standards are taken from a set of curves (mathematical functions), with separate performance curves for gasoline and diesel vehicles.[627] In general, in calculating HDPUVs, fleets with a mixture of vehicles with increased payloads or greater towing capacity (or utilizing four-wheel drive configurations) will face numerically less stringent standards than fleets consisting of less powerful vehicles. Vehicle testing for both the HD and LDV programs is conducted on chassis dynamometers using the drive cycles from FTP and HFET.[628] While the FTP and the HFET driving patterns are identical to that of the LD test cycles, other test parameters for running them, such as test vehicle loaded weight, are specific to complete HD vehicles.

Due to the variations in designs and construction processes, optional requirements were added to simplify testing and compliance burdens for cab-chassis Class 2b and 3 vehicles. Requirements were added to treat cab-chassis Class 2b and 3 vehicles (vehicles sold as incomplete vehicles with the cab substantially in place but without the primary load-carrying enclosure) equivalent to the complete van or truck product from which they are derived. Manufacturers determine which complete vehicle configurations most closely matches the cab-chassis product leaving its facility and include each of these cab-chassis vehicles in the fleet averaging calculations, as though it were identical to the corresponding complete ''sister'' vehicle. The Phase 1 MDHD program also added a flexibility known as the ''loose engine'' provision. Under the provision, spark-ignition (SI) engines produced by manufacturers of HDPUVs and sold to chassis manufacturers and intended for use in vocational vehicles need not meet the separate SI engine standard, and instead may be averaged with the manufacturer's HDPUVs fleet.[629] This provision was adopted primarily to address small volume sales of engines used in complete vehicles that are also sold to other manufacturers.

And finally, at the end of each MY NHTSA confirms whether a manufacturer's fleet average performance for its fleet of HDPUVs exceeds the applicable target-based fleet standard using the model type work factors. Compliance with the fleet average standards is determined using 2-cycle test procedures. However, manufacturers may also earn credits for the addition of technologies that result in real-world fuel improvements that are not accounted for in the 2-cycle testing. If the fleet average performance exceeds the standard, the manufacturer complies for the MY. If the manufacturer's fleet does not meet the standard, the manufacturer may address the shortfall by using a credit flexibility equal to the credit shortage in the averaging set. The averaging set balance is equal to the balance of earned credits in the account plus any credits that are traded into or out of the averaging set during the MY. If a manufacturer cannot meet the standard using credit flexibilities, NHTSA may assess a civil penalty for any violation of this part under 49 CFR 535.9(b).

b. Flexibilities

Broadly speaking, there are two types of flexibilities available to manufacturers for HDPUVs. Manufacturers may improve fleet averages by (1) earning fuel consumption incentive benefits and by (2) transferring or trading in credits that were earned through overcompliance with the standards. First, as mentioned above, manufacturers may earn credits associated with fuel efficiencies that are not accounted for in the 2-cycle testing.[630] Second, manufacturers may transfer credits into like fleets (*i.e.,* averaging sets) from other manufacturers through trades.[631]

Unlike the LDV program, there is no AC credit program for HDPUVs. Currently, these vehicles may only earn fuel consumption improvement credits through an off-cycle program, which may include earning credits for AC efficiency improvements. In order to receive these credits, manufacturers must submit a request to EPA and NHTSA with data supporting that the technology will result in measurable, demonstrable, and verifiable real-world CO_2 emission reductions and fuel savings. After providing an opportunity for the public to comment on the manufacturer's methodology, the agencies make a decision whether to approve the methodolgy and credits.[632]

In addition to earning additional OC FCIVs, manufacturers have the flexibility to transfer credits into their fleet to meet the standards. Manufacturers may transfer in credits from past (carry-forward credits) MYs of the same averaging set. [633] Manufacturers may also trade in credits earned by another manufacturer, as long as the credits are traded into the same averaging set/fleet type. Manufacturers may not transfer credits between LD CAFE fleets and HD fleets. Likewise, a manufacturer cannot trade in credits from another manufacturer's LD fleet to cover shortfalls in their HD fleets. NHTSA oversees these credit transfer and trades through regulations issued in 49 CFR 535.7, which includes reporting requirements for credit trades and transfers for medium- and HD vehicles.

c. Civil Penalties

The framework established by Congress and codified by NHTSA for civil penalties for the HD program is quite different from the LD program. Congress did not prescribe a specific rate for the fine amount for civil penalties but instead gave NHTSA general authority under EISA, as codified at 49 U.S.C. 32902(k), to establish requirements based upon appropriate measurement metrics, test procedures, standards, and compliance and enforcement protocols for HD vehicles. NHTSA interpreted its

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[627] However, both gasoline and diesel vehicles in this category are included in a single averaging set for generating and using credit flexibilities.

[628] The LD FTP is a vehicle driving cycle that was originally developed for certifying LDVs and subsequently applied to HD chassis testing for criteria pollutants. This contrasts with the Heavy-duty FTP, which refers to the transient engine test cycles used for certifying heavy-duty engines (with separate cycles specified for diesel and spark-ignition engines).

[629] *See* 40 CFR 86.1819–14(k)(8).

[630] Off-cycle benefits were extened to heavy-duty pickup trucks and vans through the–MDHD—Phase 1 program in the September 15, 2011 final rule (76 FR 57106).

[631] *See* 49 CFR 535.7(a)(2)(iii) and 49 CFR 535.7(a)(4).

[632] *See* 49 CFR 535.7(f)(2), 40 CFR 86.1819–14(d)(13), and 40 CFR 86.1869–12(c) through (e).

[633] *See* 49 CFR 535.7(a)(3)(i), 49 CFR 535.7(a)(3)(iv), 49 CFR 535.7(a)(2)(v), and 49 CFR 535.7(a)(5).

authority and developed an enforcement program to include the authority to determine and assess civil penalties for noncompliance that would impose penalties based on the following criteria, as codified in 49 CFR 535.9(b).

In cases of noncompliance, NHTSA assesses civil penalties based upon consideration of the following factors:

- Gravity of the violation.
- Size of the violator's business.
- Violator's history of compliance with applicable fuel consumption standards.
- Actual fuel consumption performance related to the applicable standard.
- Estimated cost to comply with the regulation and applicable standard.
- Quantity of vehicles or engines not complying.
- Civil penalties paid under CAA section 205 (42 U.S.C. 7524) for noncompliance for the same vehicles or engines.

NHTSA considers these factors in determining civil penalties to help ensure, given NHTSA's wide discretion, that penalties would be fair and appropriate, and not duplicative of penalties that could be imposed by EPA. NHTSA goal is to avoid imposing duplicative civil penalties, and both agencies consider civil penalties imposed by the other in the case of non-compliance with GHG and fuel consumption regulations. NHTSA also uses the ''estimated cost to comply with the regulation and applicable standard,'' [634] to ensure that any penalties for non-compliance will not be less than the cost of compliance. It would be contrary to the purpose of the regulation for the penalty scheme to incentivize noncompliance. Further, NHTSA set its maximum civil penalty amount not to exceed the limit that EPA is authorized to impose under the CAA. The agencies agreed that violations under either program should not create greater punitive damage for one program over the other. Therefore, NHTSA's maximum civil penalty for a manufacturer would be calculated as the: Aggregate Maximum Civil Penalty for a Non-Compliant Regulatory Category = (CAA Limit) × (production volume within the regulatory category). This approach applies for all HD vehicles including pickup trucks and vans as well as engines regulated under NHTSA's fuel consumption programs.

C. Proposed Changes

The following sections describe four changes NHTSA is proposing in order to update its enforcement programs for LDVs and for HDPUVs. These changes reflect experience gained in the past few years and are intended to improve to the programs overall.

3. Elimination of OC and AC Efficiency FCIVs for BEVs in the CAFE Program

NHTSA is proposing to remove AC and OC FCIVs for BEVs, which manufacturers can use to comply with CAFE standards, because the FCIVs represent energy savings for vehicles with ICEs. The CAFE program currently provides for credits for vehicles equipped with technologies that improve the efficiency of the vehicles' AC systems and otherwise reduce fuel consumption but are not accounted for in the 2-cycle testing.

Beginning in MY 2027, NHTSA proposes to eliminate eligibility to gain FCIVs for any vehicles that do not have IC engines. Thus, BEVs would no longer be eligible for these credits after MY 2026. NHTSA believes that eliminating AC and OC FCIVs is appropriate because BEVs are currently generating credits in a program designed to provide credits based on reductions in emissions and fuel consumption of IC engine vehicles. In the OC program specifically, we note that the values associated with menu technologies were based on IC engine vehicles with exhaust emissions and fuel consumption. While there may be AC and other technologies that improve BEV energy consumption, the values associated with AC FCIVs and the OC menu FCIVs are based on IC engine vehicles and, therefore, are not appropriate to consider for BEVs. When EPA and NHTSA adopted these flexibilities in the MY 2012 rule, there was little concern about this issue because BEV sales were only a small fraction of total sales, and no upstream net emissions were considered as part of the GHG and fuel economy final standards.[635] [636] Now, however, BEVs are earning FCIVs as part of the fleet compliance that aren't representative of real-world fuel consumption reduction. Therefore, NHTSA is proposing to end off-cycle and AC efficiency FCIVs for LDVs with no IC engine beginning in MY 2027. NHTSA is seeking comments on this proposal.

Relatedly, NHTSA is also seeking comment on three other possible changes for FCIVs. First, NHTSA is seeking comment on whether it should, instead of eliminating FCIVs for BEVs completely, propose new off-cycle and AC values for BEVs that are based on BEV powertrains rather than IC engines, and, if so, how those proposed values should be calculated. Additionally, in light of its proposal to eliminate FCIVs for BEVs, NHTSA is seeking comment on whether it should propose adjusting FCIVs for PHEVs based on utility factor for the portion only operated by IC engine. For CAFE compliance purposes, the fuel economy of dual-fueled vehicles, such as PHEVs, is calculated by EPA using a utility factor to account the portion of power energy consumption from the different energy sources. A utility factor of 0.3, for example, means that the vehicle is estimated to operate as an IC Engine vehicle 70 percent of the vehicle's VMT. NHTSA is requesting comment on whether it should propose reducing FCIVs for PHEVs proportional to the estimated percentage of VMT that the vehicles would be operated as EVs.

NHTSA is also requesting comment on whether it should propose phasing out OC FCIVs for all vehicles before MY 2031. For example, one such approach could be to phase-down the off-cycle menu cap by reducing it to10 g/mi in MY 2027, 8 g/mi in MY 2028, 6 g/mi in MY 2029, and 3 g/mi in MY 2030 before eliminating OC FCIVs in MY 2031. As noted above, FCIVs were added to the CAFE program by the October 15, 2012 final rule and manufacturers were able to start earning OC FCIVs starting in MY 2017.[637] The value of FCIVs for OC technologies listed on the predefined list are derived from estimated emissions reductions associated with the technologies which is then converted into an equivalent improvement in MPG. These values, however, were established based on MY 2008 vehicles and technologies assessed during the 2012 rulemaking and, therefore, the credit levels are potentially becoming less representative of the fuel savings provided by the off-cycle technologies as fuel economy is improved. There is not currently a mechanism to confirm that the off-cycle technologies provide fuel savings commensurate with the level of the credits the menu provides. Further, issues such as the synergistic effects and overlap among off-cycle technologies take on more importance as the FCIVs represent a larger portion of the vehicle fuel economy. Over time NHTSA's standards for CAFE have increased while FCIVs for some menu technologies have remained the same, which may result in the FCIVs being less representative of MPG improvements provided by the off-cycle technologies. Therefore, NHTSA is requesting comment on whether it

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[634] *See* 49 CFR 535.9(b)(4).

[635] *See* 77 FR 62811 (October 15, 2012).

[636] 2022 EPA Automotive Trends Report at Table 4.1 on page 74.

[637] 77 FR 62624.

should phase out FCIVs for off-cycle technologies for ICE vehicles. Alternatively, NHTSA is requesting comment on whether it should propose new values for off-cycle technologies that are more representative of the real-world fuel savings provided by these technologies, and if so, how NHTSA should calculate the appropriate values for these technologies.

To help NHTSA understand the potential impacts of some of these additional changes for FCIVs, we conducted sensitivity analyses on removing FCIVs for BEVs, and also for phasing out all FCIVs. These sensitivities are discussed in Chapter 9 of the accompanying PRIA. NHTSA is requesting comment on these analyses as well as whether there may be a more appropriate approach to modeling the impacts of these potential changes.

4. Elimination of the 5-Cycle and Alternative Approval Pathways for CAFE

NHTSA is proposing to eliminate both the 5-cycle pathway and the alternative pathway for off-cycle FCIVs for LDVs starting in MY 2027. NHTSA is proposing this change because we do not believe that the benefit to manufacturers is significant enough to justify that the programs require a significant amount of time and resources to be committed to reviewing and approving requests. Further, based on the general degree of robustness of data provided by manufacturers to EPA and NHTSA for approval consideration, the analysis is often delayed and/or ultimately unproductive, causing undesirable and often unnecessary delays to final compliance processing.

NHTSA does not believe that the 5-cycle pathway is beneficial to manufacturers or to NHTSA, as the pathway is used infrequently, provides minimal benefits, and requires a significant amount of time for review. Historically, only a few technologies have been approved for FCIVs through 5-cycle testing. The 5-cycle demonstrations are less frequent than the alternate pathway due to the complexity and cost of demonstrating real-world emissions reductions for technologies not listed on the menu. Therefore, NHTSA proposes to eliminate the 5-cycle pathway, starting in MY 2027 for earning off-cycle fuel economy improvements. NHTSA is seeking comments on this proposal.

NHTSA is also proposing to eliminate the alternative approval process for off-cycle FCIVs starting in MY 2027. Manufacturers currently seek EPA review, in consultation with NHTSA, through a notice and comment process, to use an alternative methodology other than the menu or 5-cycle methodology. Manufacturers must provide supporting data on a case-by-case basis demonstrating the benefits of the off-cycle technology on their vehicle models. Manufacturers may also use the alternative approval pathway to apply for FCIVs for menu technologies where the manufacturer is able to demonstrate FCIVs greater than those provided by the menu.

NHTSA is proposing to eliminate the alternative approval process for off-cycle credits starting in MY 2027. The alternative approval process was used successfully by several manufacturers for high efficiency alternators, resulting in EPA adding them to the off-cycle menu beginning in MY 2021.[638] The program has resulted in a number of concepts for potential off-cycle technologies over the years, but few have been implemented, at least partly due to the difficulty in demonstrating the quantifiable real-world fuel consumption reductions associated with using the technology. Many FCIVs sought by manufacturers have been relatively small (less than 1 g/mile). Manufacturers have commented several times that the process takes too long, but the length of time is often associated with the need for additional data and information or issues regarding whether a technology is eligible for FCIVs. NHTSA has been significantly impacted in conducting its final compliance processes due to the untimeliness of OC approvals. Therefore, NHTSA proposes to eliminate the alternative approval process for earning off-cycle fuel economy improvements starting in MY 2027. NHTSA is seeking comments on this proposal.

5. Elimination of OC FCIVs for Heavy-Duty Pickup Trucks and Vans Starting in MY 2030

NHTSA is proposing to eliminate OC FCIVs for HDPUVs for the same reasons discussed above for proposing to eliminate the 5-cycle and alternative pathways for OC FCIVs starting in MY 2030. Currently, manufacturers of HDPUVs may only earn FCIVs through an off-cycle program that involves requesting public comment and case-by-case review and approval. Since its inception, the program has involved lengthy and resource-intensive processes that have not resulted in significant benefits to the HDPUV fleet. At this time, NHTSA does not believe the benefit provided by these credits justifies NHTSA's time and resources. Accordingly, NHTSA is proposing to end the off-cycle program for HDPUVs starting in MY 2030. NHTSA is requesting comment on this proposal.

NHTSA is also requesting comment on eliminating OC FCIVs for BEVs if NHTSA does not eliminate OC FCIVs for all HDPUVs. In the current regulation, we are considering all BEVs and PHEVs to have no fuel usage in that they consume zero g/mile for compliance. Accordingly, these vehicles would go to negative compliance values if we allowed OC FCIVs to be applied.

6. Requirement To Respond to Requests for Information Regarding Off-Cycle Requests Within 60 Days for LDVs for MYs 2025 and 2026

For MY 2025 and MY 2026, NHTSA is proposing to create a time limit to respond to requests for information regarding request for OC petitions for LDVs. This proposal is intended to allow for the timelier processing of OC petitions. In the last rule, NHTSA added provisions clarifying and outlining the deadlines for manufacturers to submit off-cycle requests.[639] Since laying out those new requirements, NHTSA has identified another point in the OC request process that is delaying the timely processing of the requests. When considering OC petitions, NHTSA and EPA frequently need to request additional information from the manufacturer, and NHTSA observes that it has sometimes taken OEMs an extended amount of time to respond to these requests.

NHTSA proposes to create a deadline of 60 days for responding to requests for additional information regarding OC petitions. If the manufacturer does not respond within the 60-day limit with the requested information, NHTSA may deny the petition for the petitioned MY. NHTSA may grant an extension for responding if the manufacturer responds within 60 days with a reasonable timeframe for when the requested information can be provided to the agencies. If an OEM does not respond to NHTSA/EPA's call for additional data regarding the request within a timely manner, the request will be denied. The request will no longer be considered for the MY in question, but the OEM may still request consideration of the credits for the following year. A manufacturer may request consideration for later MYs by responding to NHTSA/EPA's data request and expressing such interest.

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[638] See 85 FR 25236 (April 30, 2020).

[639] See 49 CFR 531.6(b)(3)(i) and 49 CFR 533.6(c)(4)(i).

7. Technical Amendments for Advanced Technology Credits

NHTSA is proposing to make technical amendments to the current regulations pertaining to advanced technology credits. In the Phase 2 rule for the Heavy-Duty National Program, NHTSA and EPA jointly explained that we were adopting advanced technology credit multipliers for three types of advanced technologies. As described in the final rule, there would be a 3.5 multiplier for advanced technology credits for plug-in hybrid vehicles, a 4.5 multiplier for advanced technology credits for all-electric vehicles, and a 5.5 multiplier for advanced technology credits for fuel cell vehicles. The agencies stated that their intention in adopting these multipliers was to create a meaningful incentive to manufacturers considering adopting these technologies in their vehicles. The agencies further noted that the adoption rates for these advanced technologies in heavy vehicles was essentially non-existent at the time the final rule was issued and seemed unlikely to grow significantly within the next decade without additional incentives. Because of their large size, the agencies decided to adopt them as an interim program that would continue through MY 2027. These changes, however, were not accurately reflected in the regulatory changes made by the final rule. NHTSA is now correcting the regulations to clarify that for Phase 2, advanced technology credits may be increased by the corresponding multiplier through MY 2027.

Additionally, the final rule also explained that because of the adoption of the large multipliers, the agencies were discontinuing the allowance to use advanced technology credits across averaging sets. This change was also not accurately reflected in the regulatory changes. NHTSA is also proposing to make the technical correction to reflect the intended change.

In the interim and until the proposed technical amendment is implemented, there is no multiplier for advanced technology credits for Phase 2. However, NHTSA will permit manufacturers to use the larger multipliers with the condition that if they choose to do so, they will not be permitted to transfer the increased advanced technology credits across averaging sets.

8. Additional Technical Amendments

In addition to the proposed changes discussed above, NHTSA is also proposing to make minor technical amendments to 49 CFR parts 531, 533, 535, and 537. These amendments are largely to update statutory citations and to update cross-references. Specifically, NHTSA is proposing to make the following technical amendments:

a. Change references to section 502 of the Motor Vehicle Informaiton and Cost Savings Act to the appropriate codified provision (*i.e.,* 49 U.S.C. 32901 or 32902) in 49 CFR 531.1, 531.4, 533.1, 533.4, 535.4, 537.3, and 537.4.

b. Amend § 531.4 to include a definition for ''domestically manufactured passenger autobile'' which references 49 U.S.C. 32904(b)(3) and 40 CFR 600.511–08.

c. Amend § 531.5 to correct a cross reference to the provision containing NHTSA's standards for low-volume motor vehicles (found in 49 CFR 531.5(e)) and to include references to the provision as appropriate.

d. Amend § 535.4 to correct a typographical error to change ''Alterers'' to ''Alterer.''

e. Amend § 535.7(b)(2) to correct a cross-reference to the EPA provision's provision regarding fuel consumption values for advanced technologies.

f. Amend § 537.2 to correct a typographical error.

g. Amend § 537.3 to end the reporting requirements in (c)(7)(iii) end after MY 2027 to coincide with the sunset date for FCIVs for advanced full-size pickup trucks.

D. Decision Not To Propose Non-Fuel Saving Credits or Flexibilities

In a comment to the August 16, 2022 EIS scoping notice for MY 2027 and beyond CAFE standards,[640] Hyundai requested that NHTSA consider ''developing an optional program that provides additional credits or flexibilities to manufacturers who target higher fuel economy vehicle distribution in communities of color, tribal communities, and other historically underserved communities.'' [641] Hyundai stated that ''[t]he NEPA process, and specifically the EIS, is an appropriate and, indeed, critical opportunity for NHTSA to consider EJ and effects of its proposed action on EJ communities—*i.e.,* communities of color, tribal communities, and other disadvantaged, underserved, or historically marginalized communities that often absorb negative environmental effects.''

Hyundai stated that ''in evaluating the range of alternatives for establishing new CAFE standards, Hyundai encourages NHTSA to consider alternatives that have lower impact on, and in fact benefit, EJ communities.'' Hyundai stated that more specifically, NHTSA should consider ''developing and evaluating an optional program that would allow a manufacturer to earn some type of value or flexibility—whether that includes an additional type of credit or a higher flexibility cap—for vehicles that benefit EJ communities.'' Hyundai said that NHTSA is well-suited to explore this concept, given NHTSA's precedent for such additional types of optional credits or flexibilities, ''such as AC credits and off-cycle credits as part of the CAFE program.'' Hyundai proposed that ''[t]he optional credits could be based on the placement of certain vehicle types in programs intended to provide verifiable benefits to EJ communities and could be equivalent to a corresponding EPA program that generates GHG credits. Similar to the off-cycle program, these credits could be converted/adjusted to apply to a manufacturer's fuel economy fleet performance.''

Hyundai encouraged NHTSA to ''consider such alternatives that will allow manufacturers the option to earn additional credits for focusing on vehicle development and deployment programs that benefit EJ communities . . . Proposed additional ''EJ credits'' could apply to EVs, PHEV, HEVs, and better-performing combustion engines, such as super-ultra low emission vehicles (''SULEVs'') providing verifiable benefits to EJ communities.'' Hyundai stated that in addition to NHTSA evaluating alternatives that ''create an incentive for high-performing fuel economy and advanced technology vehicles that benefit EJ communities, such as the optional programs described above,'' NHTSA should ''analyze the impacts on these communities of programs that do not create such an incentive.'' Hyundai stated that they would provide more specific suggestions for implementation of such alternatives as part of the comment process for this proposal.

Because creation of any such program would be a part of NHTSA's CAFE Compliance and Enforcement program, we respond to this comment here rather than in the Draft EIS.

NHTSA has been examining EJ considerations of CAFE standards since the earliest CAFE EISs in the 2000s.[642] Since that time, we have received feedback from States, non-government organizations, Native American Tribes, faith groups, and individuals on how

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[640] Notice of Intent To Prepare an Environmental Impact Statement for MYs 2027 and Beyond Corporate Average Fuel Economy Standards and MYs 2029 and Beyond Heavy-Duty Pickup Trucks and Vans Vehicle Fuel Efficiency Improvement Program Standards (87 FR 50386).

[641] Docket ID NHTSA–2022–0075–0011.

[642] See Draft Environmental Impact Statement Corporate Average Fuel Economy Standards, Passenger Cars and Light Trucks, MYs 2012–2016 (September 2009).

NHTSA can better consider EJ when setting CAFE standards. It is an important milestone that automakers now want to begin engaging in this conversation, as including communities with EJ concerns in their product planning can provide verifiable benefits to those communities, as Hyundai recognized.

While NHTSA shares Hyundai's desire for underserved and EJ communities to have greater access to higher fuel economy vehicles—and welcomes any further suggestions from Hyundai or other stakeholders about how NHTSA could, consistent with its statutory authority, work with the automotive industry to structure the CAFE program to better benefit communities with EJ concerns—NHTSA did not propose an EJ credit program as part of this document. The following section discusses the factors that NHTSA considered in response to Hyundai's comment. We believe framing these considerations will be instructive for any more specific suggestions for implementations of EJ credits from Hyundai or other stakeholders as part of the comment process for this proposal.

In addition to NEPA and its implementing regulations,[643] relevant E.O.s,[644] and DOT Order 5610.2C, U.S. Department of Transportation Actions to Address Environmental Justice in Minority Populations and Low-Income Populations,[645] NHTSA considers EJ as it sets vehicle fuel economy standards pursuant to EPCA/EISA. Without repeating extensively the purpose of EPCA, which is described above, ''Congress created mandatory vehicle fuel economy standards, intended to be technology forcing, with the recognition that ''market forces . . . may not be strong enough to bring about the necessary fuel conservation which a national energy policy demands.'' ''[646] Congress provided one explicit statutory flexibility for vehicle manufacturers in EPCA: when a vehicle manufacturer's fleet achieves a higher CAFE value than its CAFE standard, the fleet earns overcompliance credits that can be carried backwards and forwards and traded between fleets, or to other manufacturers.[647] However, Congress recognized that one credit is not necessarily equal to another,[648] and ensured this flexibility would conserve energy by commanding NHTSA to administer the credit program in such a way that that total oil savings associated with the original overcompliance would be preserved.[649]

NHTSA has created some additional flexibilities by regulation consistent with its EPCA authority (not expressly included or prohibited by EPCA) to harmonize better with some of EPA's programmatic decisions under the CAA's more flexible regulatory structure. However, neither flexibilities for AC efficiency and off-cycle technology fuel consumption improvement values,[650] nor the incentive for pickup truck performance and hybridization,[651] seem to provide the precedent that Hyundai suggests. These flexibilities are intended to promote greater fuel economy by recognizing technologies that reduce gasoline consumption, and in particular in vehicle classes that previously struggled to adopt fuel saving technology while maintaining utility requirements. NHTSA has declined to provide credits for vehicle technologies that do not provide fuel savings connected to a specific technology's adoption.[652] Hyundai's proposal for EJ credits would not promote greater fuel economy. Instead, the proposal would grant credit for technologies that are already present on vehicles.

This is not the first time that manufacturers have requested credits for technologies that are already present on a vehicle that contribute to the vehicle's increased fuel economy or decreased CO_2 emissions values.[653] In the 2012 rule for MYs 2017 and beyond, EPA and NHTSA declined to grant off-cycle credits and FCIVs for technologies that are integral or inherent to the basic vehicle design like the vehicle's engine or transmission. The agencies appropriately stated then that ''there are fundamental issues as to whether these technologies would ever warrant off-cycle credits. Being integral, there is no need to provide an incentive for their use, and (more important), these technologies would be incorporated regardless. Granting credits would be a windfall.''[654] The powertrain technologies that Hyundai proposes to be eligible for EJ credits include all of the same technologies that are integral to basic vehicle designs required by

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[643] 42 U.S.C. 4321 et seq; 40 CFR parts 1500 through 1508.

[644] E.O. 12898 on Federal Actions To Address Environmental Justice in Minority Populations and Low-Income Populations; E.O. 14008 on Tackling the Climate Crisis at Home and Abroad; E.O. 13990 on Protecting Public Health and the Environment and Restoring Science to Tackle the Climate Crises; E.O. 13985 on Advancing Racial Equity and Support for Underserved Communities Through the Federal Government.

[645] DOT Order 5610.2C, U.S. Department of Transportation Actions to Address Environmental Justice in Minority Populations and Low-Income Populations (May 16, 2021). DOT's Order defines ''environmental justice'' as the fair treatment and meaningful involvement of all people, regardless of race, ethnicity, income, national origin, or educational level, with respect to the development, implementation and enforcement of environmental laws, regulations and policies. For the purpose of DOT's Environmental Justice Strategy, fair treatment means that no population, due to policy or economic disempowerment, is forced to bear a disproportionate burden of the negative human health and environmental impacts, including social and economic effects, resulting from transportation decisions, programs and policies made, implemented and enforced at the Federal, State, local or tribal level.

[646] *Ctr. for Auto Safe'y* v. *Nat'l Highway Traffic Safety Admin.,* 793 F.2d 1322, 1339 (D.C. Cir. 1986) (citing S.REP. NO. 179, 94th Cong., 1st Sess. 2 (1975), U.S. Code Cong. & Admin.News 1975, p. 1762).

[647] 49 U.S.C. 32903.

[648] For example, the fuel savings lost if the average fuel economy of a manufacturer falls one-tenth of a mpg below the level of a relatively low standard are greater than the fuel savings gained by raising the average fuel economy of a manufacturer one-tenth of a mpg above the level of a relatively high CAFE standard. See also 73 FR 24462 (May 2, 2008), Table IX–I.—Comparison of Fuel Savings at Different Fuel Economy Baselines.

[649] 49 U.S.C. 32903(f).

[650] Vehicle manufacturers have the option to generate ''credits'' for off-cycle technologies and improved AC systems under the EPA's CO_2 program; however, under NHTSA's CAFE program, manufacturers receive a fuel consumption improvement value (FCIV) equal to the value of the technology benefit not captured on the 2-cycle test. The FCIV is not a ''credit'' in the NHTSA CAFE program—unlike, for example, the statutory overcompliance credits described above—but FCIVs directly increase the reported fuel economy of a manufacturer's fleet, which is used to determine compliance. FCIVs are only a ''credit'' to the extent that a manufacturer using these specific technologies on a vehicle increases their fleet fuel economy level above and beyond their CAFE standard. NHTSA provides for these FCIVs because there is a direct link between these technologies improving the fuel economy of a vehicle in real-world operation above and beyond the vehicle's rated fuel economy value on the two-cycle test.

[651] *See* 49 © 553.6(c). Like AC and off-cycle FCIVs, the performance and hybrid pickup truck incentive in NHTSA's program is an adjustment to the fuel economy value of a vehicle, per EPA's EPCA measurement and testing authority, and not a ''credit.'' EPA and NHTSA ensured that these credits would not dilute potential increases in fleet fuel economy or decreases in GHG emissions by only providing the credit if a manufacturer includes the technology on significant increasing quantities of its full-sized pickup trucks. For example, in MY 2021 a manufacturer could only receive the credit if at least 80% of its full-size pickup trucks met the incentive's requirements. Note also that to date, no manufacturer has claimed the hybrid and performance pickup truck credit.

[652] 77 FR 62732–3 (Oct. 15, 2012) (''The agencies believe that there is a very significant distinction between technologies providing direct and reliably quantifiable improvements to fuel economy and GHG emission reductions, and technologies which provide those improvements by indirect means, where the improvement is not reliably quantifiable, and may be speculative (or in many instances, non-existent), or may provide benefit to other vehicles on the road more than for themselves. As the agencies have reiterated, and many commenters have likewise maintained, credits should be available only for technologies providing real-world improvements, the improvements must be verifiable, and the process by which credits are granted and implemented must be transparent.'').

[653] 77 FR 62732 (Oct. 15, 2012).

[654] *Id.*

more stringent standards under EPCA and the CAA.

It is not at all clear that EPCA would allow such a program, but NHTSA also believes that any new incentive program for vehicle manufacturers would need to (1) provide verifiable benefits for EJ communities, and (2) support EPCA's overarching purpose of energy conservation. Accordingly, we have identified some initial substantive issues and questions that we believe would be helpful for Hyundai or any other stakeholder to address before moving forward submitting a proposal to NHTSA for EJ or other similar credits.

CAFE standards have the potential to benefit communities with environmental justice concerns. Hyundai appears to imply in their comment letter that CAFE regulatory alternatives that do not include an EJ credit would not benefit EJ communities.[655] There are a few reasons why we do not believe this is the case.

Evidence suggests that the CAFE program produces fuel savings benefits for purchasers of vehicles, and that these benefits may be particularly important to households that spend a disproportionate share of their income on fuel, like lower income households. While it is true that lower income households are more likely to purchase used vehicles, and NHTSA's authority to regulate vehicle fuel economy applies to new vehicles that a manufacturer produces for sale in each MY,[656] research suggests that all income groups will benefit from improvements in fuel efficiency. The 2015 NAS report found that CAFE standards made both new and used cars more affordable due to the value of added fuel savings realized over the lifetime of the vehicle.[657] Additionally, the net benefits extended to consumers from the standards were estimated to be greater for low-income households.[658]

More recent data affirms that fuel spending constitutes a higher percentage of earnings in low-income households: U.S. households earning less than $25,000 spend 50 percent of their income on vehicle ownership and operation annually, or about $7,400.[659] Research has shown that CAFE standards provide distributed benefits across household income ranges, with low-income households in the lower 80 percent of the U.S. income distribution receiving annual net savings on vehicles and fuel estimated between 0.5 and 2.0 percent of their average annual income from 1980 to 2014.[660]

Separately, this proposal incorporates the use of a proposed PEF value that better reflects EV fuel efficiency and also a less stringent rate of CAFE increase for passenger cars than light trucks. This should allow manufacturers to increase their fleet fuel economy so that fuel economy improvements are not concentrated in either the vehicles that were traditionally the smallest and least expensive (and would then become more expensive from the addition of fuel-economy-improving technology), or in the most expensive vehicles (which would have more fuel economy improvements but would not be targeted towards EJ communities). This will also benefit buyers in the used car market (who, again, are more likely to be low-income buyers), as they will have more options for fuel efficient vehicles. The new standards should, in theory, incentivize manufacturers to increase the fuel economy of their entire fleet, and the entire range of income groups would receive distributed benefits accordingly.

CAFE standards also have the potential to benefit EJ communities because increasing fleet fuel economy produces important environmental and health-related benefits, including reductions in GHGs as well as reductions in harmful air pollutants that are emitted from upstream sources of gasoline production and from vehicle exhaust systems.

As noted in the Draft EIS, a body of scientific literature signals disproportionate exposure of low-income and minority populations to poor air quality and proximity of minority and low-income populations to industrial, manufacturing, and hazardous waste facilities like oil production and refining facilities. Similarly, research shows that minority and low-income populations are disproportionately located in proximity to electric power plants and are thus exposed to pollutants associated with power generation. Research also shows that communities that live near heavily trafficked roadways—disproportionately low income and communities of color—are disproportionately exposed to vehicle exhaust pollutants. Finally, research demonstrates that EJ communities are more likely to suffer the consequences of climate change including more ozone pollution and more exposure to potentially deadly heatwaves, among other impacts. Health-related sensitivities in low-income and minority populations additionally increase the risk of damaging impacts from poor air quality under climate change, underscoring the potential benefits of improving air quality for communities overburdened by poor environmental quality.

The combined CAFE and HDPUV standards contribute to a reduction in fuel use, meaning that to the extent that minority and low-income populations live closer to upstream sources of vehicle-related emissions, like oil extraction, distribution, and refining facilities or are more susceptible to their impacts (*e.g.,* health and other impacts relating to emissions, vibration, or noise from the oil extraction, distribution, and refining process), they are more likely to experience reduced impacts resulting from a reduction in these activities. In addition, negative impacts from electric power plant emissions may be mitigated to the extent that the electrical grid becomes cleaner and draws more from renewable energy generation, which is projected to occur. The EIA's AEO 2023 projects that renewable sources of energy will displace fossil fuels in the electric power sector due to declining renewable technology costs and rising subsidies for renewable power. Finally, emissions of most vehicle-based criteria pollutant and air toxic emissions are also anticipated to decrease across all alternatives analyzed in the Draft EIS compared to the No-Action Alternative, even considering an increase in vehicle miles traveled due to vehicles becoming more efficient (*i.e.,* the rebound effect). When the power sector emission projections are updated in the analysis that will accompany the final standards, these emission reductions are likely to be greater and universal across different pollutant types.

Relatedly, adverse health impacts from criteria pollutant emissions are

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[655] Hyundai, at 4. (''At this early scoping stage, we encourage NHTSA to consider and evaluate such alternatives that create an incentive for high-performing fuel economy and advanced technology vehicles that benefit EJ communities, such as the optional programs described above. For comprehensive analysis, we also recommend that NHTSA analyze the impacts on these communities of programs that do not create such an incentive.'').

[656] NHTSA does consider the impact of CAFE regulatory costs on new vehicles when setting standards, and in particular for this proposal, concluded that the increases in regulatory costs are more than offset by the fuel savings that consumers will experience. However, some factors related to vehicle affordability—specifically manufacturer and dealer pricing strategies—are beyond NHTSA's control.

[657] 2015 NAS report, at 331.

[658] *Id.* The NAS report estimated that some low-income households spent almost 50 percent more on fuel than on vehicles in 2011. The study estimated that the standards assessed in 2015 would increase vehicle prices by about 6 percent but reduce fuel consumption by one-third relative to the 2016 standards.

[659] Bauer, Gordon & Hsu, Chih-Wei & Lutsey, Nicholas. (2021). When might lower-income drivers benefit from electric vehicles? Quantifying the economic equity implications of electric vehicle adoption. (citing U.S. Bureau of Labor Statistics, 2020).

[660] Greene & Welch, 2018, Energy Policy, 122: 528–541.

projected to decrease nationwide under each of the action alternatives compared to the No-Action Alternative. To the extent that EJ communities are disproportionately located closer to sources of upstream and downstream pollution that decrease as a result of increased CAFE standards, those communities could see health benefits due to decreasing emissions.

Finally, all action alternatives are projected to result in small but incrementally important decreases in global mean surface temperature, atmospheric CO_2 concentrations, sea level rise, and increases in ocean pH. The reduction of air pollutants and GHGs could result in improvements in air quality, decreases in total health effects, and a reduction in the number and severity of outbreaks of vector-borne illnesses related to climate change for minority and low-income communities. Fleetwide improvements in fuel economy, in other words, have the potential to benefit EJ communities by reducing disproportionate environmental impacts on those overburdened communities.

Ensuring the incentive benefits environmental justice communities by not ''*double counting*'' *across regulatory programs.* Hyundai stated that ''[p]roposed additional ''EJ credits'' could apply to EVs, PHEV, HEVs, and better-performing combustion engines, such as [SULEVs] providing verifiable benefits to EJ communities.'' However, Congress has already provided an explicit incentive in EPCA for manufacturers to produce better-performing combustion engines; manufacturers earn overcompliance credits when their fleet of vehicles performs at a level more than the ''maximum feasible'' level that NHTSA determines can be achieve in a MY.[661] Relatedly, Congress also provided an incentive in EPCA to encourage the production of alternative fueled vehicles.[662] Similarly, Congress requires manufacturers to sell better-forming combustion engines such as SULEVs under the CAA. In fact, under EPA's Tier 3 emissions standards and California's Low Emission Vehicle (LEV III) standards, vehicle exhaust emissions are required to decrease significantly by MY 2025.[663]

It is not clear how giving manufacturers a credit for doing something they are already required to do would benefit communities with EJ concerns without simply providing a credit windfall for manufacturers, which would itself reduce the air pollution reduction co-benefits which directly benefit these communities.

Ensuring continued increases in overall fleet fuel economy in accordance with EPCA. While the CAFE standards proposed will ensure that manufacturers improve the fuel economy level of vehicles across their entire fleets, NHTSA is concerned that EJ credits may actually create a perverse incentive by allowing fuel economy increases in a manufacturer's fleet to stagnate. EJ credits may allow manufacturers to produce a few highly fuel-efficient vehicles that allow several other low-efficiency vehicles to be sold. Credits (overcompliance, proposed EJ, or otherwise) allow manufacturers to meet their CAFE standard without applying additional technology to vehicles. And, as Congress recognized in EPCA through its mandate to NHTSA to preserve total oil savings in credit exchanges, a gallon of fuel saved by technology application is worth more than a credit applied so that a manufacturer does not have to improve its fleet fuel economy through technology application. NHTSA is interested in comments from Hyundai or other stakeholders about how EJ credits would ensure continued increases in a manufacturer's fleet fuel economy level. Would a minimum production threshold, like with the full-size pickup truck incentives, be appropriate in a proposed EJ credit program?

Separate from Hyundai's request, NHTSA remains mindful of its obligations to consider the effects of its rules on EJ communities, in accordance with NEPA, all relevant EOs, including President Biden's E.O. 14008, and the DOT's EJ strategies. The Draft EIS and this preamble both discuss NHTSA's considerations about the effects of this proposal on EJ communities. In addition, Section V of this preamble discusses NHTSA's considerations on the additional cost of technology required to meet the proposal's preferred level of CAFE standards.

VII. Public Participation

NHTSA requests comments on all aspects of this NPRM. This section describes how you can participation in this process.

How do I prepare and submit comments?

Your comments must be written and in English.[664] To ensure that your comments are correctly filed in the docket, please include the docket number NHTSA–2023–0022 in your comments. Your comments must not be more than 15 pages long.[665] NHTSA established this limit to encourage you to write your primary comments in a concise fashion. However, you may attach necessary additional documents to your comments, and there is no limit on the length of the attachments If you are submitting comments electronically as a PDF (Adobe) file, we ask that the documents please be scanned using the Optical Character Recognition (OCR) process, thus allowing NHTSA to search and copy certain portions of your submissions.[666] Please note that pursuant to the Data Quality Act, in order for substantive data to be relied upon and used by NHTSA, it must meet the information quality standards set forth in the OMB and DOT Data Quality Act guidelines. Accordingly, we encourage you to consult the guidelines in preparing your comments. OMB's guidelines may be accessed at *https://www.gpo.gov/fdsys/pkg/FR-2002-02-22/pdf/R2-59.pdf.* DOT's guidelines may be accessed at *https://www.transportation.gov/dot-information-dissemination-quality-guidelines.*

Tips for Preparing Your Comments

When submitting comments, please remember to:

- Identify the rulemaking by docket number and other identifying information (subject heading, **Federal Register** date, and page number).
- Explain why you agree or disagree, suggest alternatives, and substitute language for your requested changes.
- Describe any assumptions and provide any technical information and/or data that you used.
- If you estimate potential costs or burdens, explain how you arrived at your estimate in sufficient detail to allow for it to be reproduced.
- Provide specific examples to illustrate your concerns and suggest alternatives.

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[661] 49 U.S.C. 32903.

[662] See 87 FR 25995–6 (May 2, 2022) (''NHTSA agrees that the intent of 32902(h), when combined with the other statutory incentives in EPCA such as those at 49 U.S.C. 32905 and 32906, was to encourage production of alternative fueled vehicles. NHTSA disagrees that the approach taken [in regulations setting CAFE standards] to modeling the current existence of alternative fueled vehicles (AFVs) and their possible application in MYs beyond those for which we are setting standards in any way disincentivizes their application or conflicts with EPA or Administration electrification goals.'').

[663] 79 FR 23414 (April 28, 2014); U.S. EPA Green Vehicle Guide, Smog Rating (last updated April 4, 2023), *https://www.epa.gov/greenvehicles/smog-rating;* 13 CCR 1961.2.

[664] 49 CFR 553.21.

[665] *Id.*

[666] OCR is the process of converting an image of text, such as a scanned paper document or electronic fax file, into computer-editable text.

- Explain your views as clearly as possible, avoiding the use of profanity or personal threats.
- Make sure to submit your comments by the comment period deadline identified in the **DATES** section above.

How can I be sure that my comments were received?

If you submit your comments to NHTSA's docket by mail and wish DOT Docket Management to notify you upon receipt of your comments, please enclose a self-addressed, stamped postcard in the envelope containing your comments. Upon receiving your comments, Docket Management will return the postcard by mail.

How do I submit confidential business information?

If you wish to submit any information under a claim of confidentiality, you should submit your complete submission, including the information you claim to be CBI, to NHTSA's Office of the Chief Counsel. When you send a comment containing CBI, you should include a cover letter setting forth the information specified in our CBI regulation.[667] In addition, you should submit a copy from which you have deleted the claimed CBI to the docket by one of the methods set forth above.

NHTSA is currently treating electronic submission as an acceptable method for submitting CBI to NHTSA under 49 CFR part 512. Any CBI submissions sent via email should be sent to an attorney in the Office of the Chief Counsel at the address given above under **FOR FURTHER INFORMATION CONTACT**. Likewise, for CBI submissions via a secure file transfer application, an attorney in the Office of the Chief Counsel must be set to receive a notification when files are submitted and have access to retrieve the submitted files. At this time, regulated entities should not send a duplicate hardcopy of their electronic CBI submissions to DOT headquarters. If you have any questions about CBI or the procedures for claiming CBI, please consult the person identified in the **FOR FURTHER INFORMATION CONTACT** section.

Will NHTSA consider late comments?

NHTSA will consider all comments received before the close of business on the comment closing date indicated above under **DATES**. To the extent practicable, we will also consider comments received after that date. If interested persons believe that any information that NHTSA places in the docket after the issuance of the NPRM affects their comments, they may submit comments after the closing date concerning how NHTSA should consider that information for the final rule. However, NHTSA's ability to consider any such late comments in this rulemaking will be limited due to the time frame for issuing a final rule.

If a comment is received too late for us to practicably consider in developing a final rule, we will consider that comment as an informal suggestion for future rulemaking action.

How can I read the comments submitted by other people?

You may read the materials placed in the dockets for this document (*e.g.,* the comments submitted in response to this document by other interested persons) at any time by going to *https://www.regulations.gov.* Follow the online instructions for accessing the dockets. You may also read the materials at the DOT Docket Management Facility by going to the street address given above under **ADDRESSES**.

How do I participate in the public hearings?

NHTSA will hold one virtual public hearing during the public comment period. NHTSA will announce the specific date and web address for the hearing in a supplemental **Federal Register** notification. NHTSA will accept oral and written comments to the rulemaking documents and will also accept comments to the Draft EIS at this hearing. The hearing will start at 9 a.m. Eastern time and will continue until everyone has had a chance to speak.

NHTSA will conduct the hearing informally, and technical rules of evidence will not apply. We will arrange for a written transcript of each hearing to be posted in the dockets as soon as it is available and keep the official record of the hearing open for 30 days following the hearing to allow you to submit supplementary information.

How do I comment on the Draft Environmental Impact Statement?

The Draft EIS associated with this proposal has a unique public docket number and is available Docket No. NHTSA–2022–0075. Comments on the Draft EIS can be submitted electronically at *https://www.regulations.gov,* at this docket number. You may also mail or hand deliver comments to Docket Management, U.S. Department of Transportation, 1200 New Jersey Avenue SE, Room W12–140, Washington, DC 20590 (referencing Docket No. NHTSA–2022–0075), between 9 a.m. and 5 p.m., Monday through Friday, except on Federal holidays. To be sure that someone is there to help you, please call (202) 366–9322 before coming. All comments and materials received, including the names and addresses of the commenters who submit them, will become part of the administrative record and will be posted on the internet without change at *https://www.regulations.gov.*

VIII. Regulatory Notices and Analyses

A. Executive Order 12866, Executive Order 13563

E.O. 12866, ''Regulatory Planning and Review'' (58 FR 51735, Oct. 4, 1993), as amended by E.O. 13563, ''Improving Regulation and Regulatory Review'' (76 FR 3821, Jan. 21, 2011) and E.O. 14094, ''Modernizing Regulatory Review'' (88 FR 21879), provide for making determinations whether a regulatory action is ''significant'' and therefore subject to the Office of Management and Budget (OMB) review process and to the requirements of the E.O. Under these E.O.s, this action is an ''significant regulatory action'' under section 3(f)(1) of Executive Order 12866 because it is likely to have an annual effect on the economy of $200 million or more. Accordingly, NHTSA submitted this action to OMB for review and any changes made in response to interagency feedback submitted via the OMB review process have been documented in the docket for this action. The estimated benefits and costs of this proposal are described above and in the PRIA, which is located in the docket and on NHTSA's website.

B. DOT Regulatory Policies and Procedures

This proposal is also significant within the meaning of the DOT's Regulatory Policies and Procedures. The estimated benefits and costs of the proposal are described above and in the PRIA, which is located in the docket and on NHTSA's website.

C. Executive Order 13990

E.O. 14037, ''Strengthening American Leadership in Clean Cars and Trucks'' (86 FR 43583, Aug. 10, 2021), directs the Secretary of Transportation (by delegation, NHTSA) to consider beginning work on a rulemaking under EISA to establish new fuel economy standards for passenger cars and LD trucks beginning with MY 2027 and extending through and including at least MY 2030, and to consider beginning work on a rulemaking under EISA to establish new fuel efficiency standards for HDPUVs beginning with MY 2028

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[667] *See* 49 CFR part 512.

and extending through and including at least MY 2030.[668] The E.O. directs the Secretary to consider issuing any final rule no later than July 2024;[669] to coordinate with the EPA and the Secretaries of Commerce, Labor, and Energy;[670] and to coordinate this work, ''as appropriate and consistent with applicable law, with the State of California as well as other States that are leading the way in reducing vehicle emissions, including by adopting California's standards.''[671] The Secretary is also directed to ''seek input from a diverse range of stakeholders, including representatives from labor unions, States, industry, EJ organizations, and public health experts.''[672]

This proposal seeks to follow the directions of this E.O. It is proposed under NHTSA's statutory authorities as set forth in EISA. It proposes new CAFE standards for passenger cars and light trucks beginning in MY 2027, and new fuel efficiency standards for HDPUVs beginning in MY 2030 due to statutory lead time and stability requirements. NHTSA coordinated with both EPA and with the State of California in developing this proposal, and the proposal also accounts for the views provided by labor unions, States, industry, and EJ organizations.

D. Environmental Considerations

1. National Environmental Policy Act (NEPA)

Concurrently with this NPRM, NHTSA is releasing a Draft EIS, pursuant to the National Environmental Policy Act, 42 U.S.C. 4321 through 4347, and implementing regulations issued by the Council on Environmental Quality (CEQ), 40 CFR part 1500, and NHTSA, 49 CFR part 520. NHTSA prepared the Draft EIS to analyze and disclose the potential environmental impacts of the proposed CAFE and HDPUV FE standards and a range of alternatives. The Draft EIS analyzes direct, indirect, and cumulative impacts and analyzes impacts in proportion to their significance. It describes potential environmental impacts to a variety of resources, including fuel and energy use, air quality, climate, land use and development, hazardous materials and regulated wastes, historical and cultural resources, and EJ. The Draft EIS also describes how climate change resulting from global carbon dioxide emissions (including CO_2 emissions attributable to the U.S. LD and HDPUV transportation sectors under the alternatives considered) could affect certain key natural and human resources. Resource areas are assessed qualitatively and quantitatively, as appropriate, in the Draft EIS.

NHTSA has considered the information contained in the Draft EIS as part of developing this proposal. The Draft EIS is available for public comment; instructions for the submission of comments are included inside the document. NHTSA will simultaneously issue the Final Environmental Impact Statement and Record of Decision, pursuant to 49 U.S.C. 304a(b), unless it is determined that statutory criteria or practicability considerations preclude simultaneous issuance. For additional information on NHTSA's NEPA analysis, please see the Draft EIS.

2. Clean Air Act (CAA) as Applied to NHTSA's Proposal

The CAA (42 U.S.C. 7401 *et seq.*) is the primary Federal legislation that addresses air quality. Under the authority of the CAA and subsequent amendments, EPA has established National Ambient Air Quality Standards (NAAQS) for six criteria pollutants, which are relatively commonplace pollutants that can accumulate in the atmosphere as a result of human activity. EPA is required to review NAAQS every five years and to revise those standards as may be appropriate considering new scientific information.

The air quality of a geographic region is usually assessed by comparing the levels of criteria air pollutants found in the ambient air to the levels established by the NAAQS (taking into account, as well, the other elements of a NAAQS: averaging time, form, and indicator). Concentrations of criteria pollutants within the air mass of a region are measured in parts of a pollutant per million parts (ppm) of air or in micrograms of a pollutant per cubic meter (μg/m3) of air present in repeated air samples taken at designated monitoring locations using specified types of monitors. These ambient concentrations of each criteria pollutant are compared to the levels, averaging time, and form specified by the NAAQS in order to assess whether the region's air quality is in attainment with the NAAQS.

When the measured concentrations of a criteria pollutant within a geographic region are below those permitted by the NAAQS, EPA designates the region as an attainment area for that pollutant, while regions where concentrations of criteria pollutants exceed Federal standards are called nonattainment areas. Former nonattainment areas that are now in compliance with the NAAQS are designated as maintenance areas. Each State with a nonattainment area is required to develop and implement a State Implementation Plan (SIP) documenting how the region will reach attainment levels within time periods specified in the CAA. For maintenance areas, the SIP must document how the State intends to maintain compliance with the NAAQS. EPA develops a Federal Implementation Plan (FIP) if a State fails to submit an approvable plan for attaining and maintaining the NAAQS. When EPA revises a NAAQS, each State must revise its SIP to address how it plans to attain the new standard.

No Federal agency may ''engage in, support in any way or provide financial assistance for, license or permit, or approve'' any activity that does not ''conform'' to a SIP or FIP after EPA has approved or promulgated it.[673] Further, no Federal agency may ''approve, accept or fund'' any transportation plan, program, or project developed pursuant to Title 23 or Chapter 53 of Title 49, U.S.C., unless the plan, program, or project has been found to ''conform'' to any applicable implementation plan in effect.[674] The purpose of these conformity requirements is to ensure that Federally sponsored or conducted activities do not interfere with meeting the emissions targets in SIPs or FIPs, do not cause or contribute to new violations of the NAAQS, and do not impede the ability of a State to attain or maintain the NAAQS or delay any interim milestones. EPA has issued two sets of regulations to implement the conformity requirements:

(1) The Transportation Conformity Rule[675] applies to transportation plans, programs, and projects that are developed, funded, or approved under 23 U.S.C. (Highways) or 49 U.S.C. Chapter 53 (Public Transportation)

(2) The General Conformity Rule[676] applies to all other Federal actions not covered under transportation conformity. The General Conformity Rule establishes emissions thresholds, or *de minimis* levels, for use in evaluating the conformity of an action that results in emissions increases.[677] If the net increases of direct and indirect emissions exceed any of these thresholds, and the action is not otherwise exempt, then a conformity

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[668] 86 FR 43583 (Aug. 10, 2021), Sec. 2(b) and (c).

[669] *Id.,* Sec. 5(b).

[670] *Id.,* Sec. 6(a) and (b).

[671] ©., Sec. 6(c).

[672] *Id.,* Sec. 6(d).

[673] 42 U.S.C. 7506(c)(1).

[674] 42 U.S.C. 7506(c)(2).

[675] 40 CFR part 51, subpart T, and part 93, subpart A.

[676] 40 CFR part 51, subpart W, and part 93, subpart B.

[677] 40 CFR 93.153(b).

determination is required. The conformity determination can entail air quality modeling studies, consultation with EPA and state air quality agencies, and commitments to revise the SIP or to implement measures to mitigate air quality impacts.

The proposed CAFE and HDPUV FE standards and associated program activities are not developed, funded, or approved under 23 U.S.C. or 49 U.S.C. Chapter 53. Accordingly, this proposed action and associated program activities would not be subject to transportation conformity. Under the General Conformity Rule, a conformity determination is required where a Federal action would result in total direct and indirect emissions of a criteria pollutant or precursor originating in nonattainment or maintenance areas equaling or exceeding the rates specified in 40 CFR 93.153(b)(1) and (2). As explained below, NHTSA's action would result in neither direct nor indirect emissions as defined in 40 CFR 93.152.

The General Conformity Rule defines direct emissions as ''those emissions of a criteria pollutant or its precursors that are caused or initiated by the Federal action and originate in a nonattainment or maintenance area and occur at the same time and place as the action and are reasonably foreseeable.'' [678] NHTSA's action would set fuel economy standards for passenger cars and light trucks and fuel efficiency standards for HDPUVs. It therefore would not cause or initiate direct emissions consistent with the meaning of the General Conformity Rule.[679] Indeed, the proposal in aggregate reduces emissions, and to the degree the model predicts small (and time-limited) increases, these increases are based on a theoretical response by individuals to fuel prices and savings, which are at best indirect.

Indirect emissions under the General Conformity Rule are ''those emissions of a criteria pollutant or its precursors (1) that are caused or initiated by the federal action and originate in the same nonattainment or maintenance area but occur at a different time or place as the action; (2) that are reasonably foreseeable; (3) that the agency can practically control; and (4) for which the agency has continuing program responsibility.'' [680] Each element of the definition must be met to qualify as indirect emissions. NHTSA has determined that, for purposes of general conformity, emissions (if any) that may result from the proposed fuel economy and fuel efficiency standards would not be caused by the agency's action, but rather would occur because of subsequent activities the agency cannot practically control. ''[E]ven if a Federal licensing, rulemaking or other approving action is a required initial step for a subsequent activity that causes emissions, such initial steps do not mean that a Federal agency can practically control any resulting emissions.'' [681]

As the CAFE and HDPUV FE programs use performance-based standards, NHTSA cannot control the technologies vehicle manufacturers use to improve the fuel economy of passenger cars and light trucks and fuel efficiency of HDPUVs. Furthermore, NHTSA cannot control consumer purchasing (which affects average achieved fleetwide fuel economy and fuel efficiency) and driving behavior (*i.e.,* operation of motor vehicles, as measured by VMT). It is the combination of fuel economy and fuel efficiency technologies, consumer purchasing, and driving behavior that results in criteria pollutant or precursor emissions. For purposes of analyzing the environmental impacts of the alternatives considered under NEPA, NHTSA has made assumptions regarding all of these factors. NHTSA's Draft EIS projects that increases in air toxics and criteria pollutants would occur in some nonattainment areas under certain alternatives in the near term, although over the longer term, all action alternatives see improvements. However, the proposed standards and alternatives do not mandate specific manufacturer decisions, consumer purchasing, or driver behavior, and NHTSA cannot practically control any of them.[682]

In addition, NHTSA does not have the statutory authority or practical ability to control the actual VMT by drivers. As the extent of emissions is directly dependent on the operation of motor vehicles, changes in any emissions that would result from NHTSA's proposed CAFE and HDPUV FE standards are not changes NHTSA can practically control or for which NHTSA has continuing program responsibility. Therefore, the proposed CAFE and HDPUV FE standards and alternative standards considered by NHTSA would not cause indirect emissions under the General Conformity Rule, and a general conformity determination is not required.

3. National Historic Preservation Act (NHPA)

The NHPA (54 U.S.C. 300101 *et seq.*) sets forth government policy and procedures regarding ''historic properties''—that is, districts, sites, buildings, structures, and objects included on or eligible for the National Register of Historic Places. Section 106 of the NHPA requires Federal agencies to ''take into account'' the effects of their actions on historic properties.[683] NHTSA concludes that the NHPA is not applicable to this proposal because the promulgation of CAFE standards for passenger cars and light trucks and HDPUV FE standards for HDPUVs is not the type of activity that has the potential to cause effects on historic properties. However, NHTSA includes a brief, qualitative discussion of the impacts of the action alternatives on historical and cultural resources in the Draft EIS.

4. Fish and Wildlife Conservation Act (FWCA)

The FWCA (16 U.S.C. 2901 *et seq.*) provides financial and technical assistance to States for the development, revision, and implementation of conservation plans and programs for nongame fish and wildlife. In addition, FWCA encourages all Federal departments and agencies to utilize their statutory and administrative authorities to conserve and to promote conservation of nongame fish and wildlife and their habitats. NHTSA concludes that the FWCA does not apply to this proposal because it does not involve the conservation of nongame fish and wildlife and their habitats. However, NHTSA conducted a qualitative review in its Draft EIS of the related direct, indirect, and cumulative impacts, positive or negative, of the Proposed Action and alternatives on potentially affected resources, including nongame fish and wildlife and their habitats.

5. Coastal Zone Management Act (CZMA)

The CZMA (16 U.S.C. 1451 *et seq.*) provides for the preservation, protection, development, and (where

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[678] 40 CFR 93.152.

[679] *Dep't of Transp.* v. *Pub. Citizen,* 541 U.S.752 at 772 (''[T]he emissions from the Mexican trucks are not 'direct' because they will not occur at the same time or at the same place as the promulgation of the regulations.''). NHTSA's action is to establish fuel economy standards for MY 2021–2026 passenger car and light trucks; any emissions increases would occur in a different place and well after promulgation of the final rule.

[680] 40 CFR 93.152.

[681] 40 CFR 93.152.

[682] *See, e.g., Dep't of Transp.* v. *Pub. Citizen,* 541 U.S. 752, 772–73 (2004); *S. Coast Air Quality Mgmt. Dist.* v. *Fed. Energy Regulatory Comm'n,* 621 F.3d 1085, 1101 (9th Cir. 2010).

[683] Section 106 is now codified at 54 U.S.C. 306108. Implementing regulations for the section 106 process are located at 36 CFR part 800.

possible) restoration and enhancement of the Nation's coastal zone resources. Under the statute, States are provided with funds and technical assistance in developing coastal zone management programs. Each participating State must submit its program to the Secretary of Commerce for approval. Once the program has been approved, any activity of a Federal agency, either within or outside of the coastal zone, that affects any land or water use or natural resource of the coastal zone must be carried out in a manner that is consistent, to the maximum extent practicable, with the enforceable policies of the State's program.[684]

NHTSA concludes that the CZMA does not apply to this proposal because it does not involve an activity within, or outside of, the nation's coastal zones that affects any land or water use or natural resource of the coastal zone. NHTSA has, however, conducted a qualitative review in the Draft EIS of the related direct, indirect, and cumulative impacts, positive or negative, of the action alternatives on potentially affected resources, including coastal zones.

6. Endangered Species Act (ESA)

Under section 7(a)(2) of the ESA, Federal agencies must ensure that actions they authorize, fund, or carry out are ''not likely to jeopardize the continued existence'' of any Federally listed threatened or endangered species (collectively, ''listed species'') or result in the destruction or adverse modification of the designated critical habitat of these species.[685] If a Federal agency determines that an agency action may affect a listed species or designated critical habitat, it must initiate consultation with the appropriate Service—the U.S. Fish and Wildlife Service (FWS) of the Department of the Interior (DOI) or the National Oceanic and Atmospheric Administration's National Marine Fisheries Service of the Department of Commerce (together, ''the Services'') or both, depending on the species involved—in order to ensure that the action is not likely to jeopardize the species or destroy or adversely modify designated critical habitat.[686] Under this standard, the Federal agency taking action evaluates the possible effects of its action and determines whether to initiate consultation.[687]

The section 7(a)(2) implementing regulations require consultation if a Federal agency determines its action ''may affect'' listed species or critical habitat.[688] The regulations define ''effects of the action'' as ''all consequences to listed species or critical habitat that are caused by the proposed action, including the consequences of other activities that are caused by the proposed action. A consequence is caused by the proposed action if it would not occur *but for* the proposed action and it is *reasonably certain to occur.*''[689] The definition makes explicit a ''but for'' test and the concept of ''reasonably certain to occur'' for all effects.[690] The Services have defined ''but for'' causation to mean ''that the consequence in question would not occur if the proposed action did not go forward. In other words, if the agency fails to take the proposed action and the activity would still occur, there is no 'but for' causation. In that event, the activity would not be considered an effect of the action under consultation.''[691]

The ESA regulations also provide a framework for determining whether consequences are caused by a proposed action and are therefore ''effects'' that may trigger consultation. The regulations provide in part:

> To be considered an effect of a proposed action, a consequence must be caused by the proposed action (*i.e.,* the consequence would not occur but for the proposed action and is reasonably certain to occur). A conclusion of reasonably certain to occur must be based on clear and substantial information, using the best scientific and commercial data available. Considerations for determining that a consequence to the species or critical habitat is not caused by the proposed action include, but are not limited to:
>
> (1) The consequence is so remote in time from the action under consultation that it is not reasonably certain to occur; or
>
> (2) The consequence is so geographically remote from the immediate area involved in the action that it is not reasonably certain to occur; or
>
> (3) The consequence is only reached through a lengthy causal chain that involves so many steps as to make the consequence not reasonably certain to occur.[692]

The regulations go on to make clear that the action agency must factor these considerations into its assessments of potential effects.[693]

The Services have previously provided legal and technical guidance about whether CO_2 emissions associated with a specific proposed Federal action trigger ESA section 7(a)(2) consultation. NHTSA analyzed the Services' history of actions, analysis, and guidance in Appendix G of the MY 2012–2016 CAFE standards EIS and now incorporate by reference that appendix here.[694] In that appendix, NHTSA looked at the history of the Polar Bear Special Rule and several guidance memoranda provided by FWS and the U.S. Geological Survey. Ultimately, DOI concluded that a causal link could not be made between CO_2 emissions associated with a proposed Federal action and specific effects on listed species; therefore, no section 7(a)(2) consultation would be required.

Subsequent to the publication of that appendix, a court vacated the Polar Bear Special Rule on NEPA grounds, though it upheld the ESA analysis as having a rational basis.[695] FWS then issued a revised Final Special Rule for the Polar Bear.[696] In that final rule, FWS provided

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[684] 16 U.S.C. 1456(c)(1)(A).

[685] 16 U.S.C. 1536(a)(2).

[686] *See* 50 CFR 402.14.

[687] *See* 50 CFR 402.14(a) (''Each Federal agency shall review its actions at the earliest possible time to determine whether any action may affect listed species or critical habitat.'').

[688] 50 CFR 402.14(a). The recently issued final rule revising the regulations governing the ESA section 7 consultation process was published at 84 FR 44976 (Aug. 27, 2019). The effective date of the new regulations was subsequently delayed to October 28, 2019. 84 FR 50333 (Sept. 25, 2019). As discussed in the text that follows, NHTSA believes that the conclusion would be the same under both the current and prior regulations.

[689] 50 CFR 402.02 (emphasis added), as amended by 84 FR 44976, 45016 (Aug. 27, 2019).

[690] The Services' prior regulations defined ''effects of the action'' in relevant part as ''the direct and indirect effects of an action on the species or critical habitat, together with the effects of other activities that are interrelated or interdependent with that action, that will be added to the environmental baseline.'' 50 CFR 402.02 (as in effect prior to Oct. 28, 2019). Indirect effects were defined as ''those that are caused by the proposed action and are later in time, but still are reasonably certain to occur.'' *Id.*

[691] 84 FR 44977 (Aug. 27, 2019) (''As discussed in the proposed rule, the Services have applied the 'but for' test to determine causation for decades. That is, we have looked at the consequences of an action and used the causation standard of 'but for' plus an element of foreseeability (*i.e.,* reasonably certain to occur) to determine whether the consequence was caused by the action under consultation.''). We note that as the Services do not consider this to be a change in their longstanding application of the ESA, this interpretation applies equally under the prior regulations (which were effective through October 28, 2019), and the current regulations.

[692] 50 CFR 402.17(b).

[693] 50 CFR 402.17(c) (''*Required consideration.* The provisions in paragraphs (a) and (b) of this section must be considered by the action agency and the Services.'').

[694] Available on NHTSA's Corporate Average Fuel Economy website at *https://static.nhtsa.gov/nhtsa/downloads/CAFE/2012-2016%20Docs-PCLT/2012-2016%20Final%20Environmental%20Impact%20Statement/Appendix_G_Endangered_Species_Act_Consideration.pdf.*

[695] *In re: Polar Bear Endangered Species Act Listing and Section 4(D) Rule Litigation,* 818 F.Supp.2d 214 (DDC Oct. 17, 2011).

[696] 78 FR 11766 (Feb. 20, 2013).

that for ESA section 7, the determination of whether consultation is triggered is narrow and focused on the discrete effect of the proposed agency action. FWS wrote, ''[T]he consultation requirement is triggered only if there is a causal connection between the proposed action and a discernible effect to the species or critical habitat that is reasonably certain to occur. One must be able to 'connect the dots' between an effect of a proposed action and an impact to the species and there must be a reasonable certainty that the effect will occur.''[697] The statement in the revised Final Special Rule is consistent with the prior guidance published by FWS and remains valid today.[698] Likewise, the current regulations identify remoteness in time, geography, and the causal chain as factors to be considered in assessing whether a consequence is ''reasonably certain to occur.'' If the consequence is not reasonably certain to occur, it is not an ''effect of a proposed action'' and does not trigger the consultation requirement.

In this NPRM, NHTSA states that pursuant to section 7(a)(2) of the ESA, NHTSA considered the effects of the proposed standards and reviewed applicable ESA regulations, case law, and guidance to determine what, if any, impact there might be to listed species or designated critical habitat. NHTSA has considered issues related to emissions of CO_2 and other GHGs, and issues related to non-GHG emissions. Based on this assessment, NHTSA determines that the action of setting CAFE and HDPUV FE standards does not require consultation under section 7(a)(2) of the ESA. Accordingly, NHTSA has concluded its review of this action under section 7 of the ESA.

7. Floodplain Management (Executive Order 11988 and DOT Order 5650.2)

These Orders require Federal agencies to avoid the long- and short-term adverse impacts associated with the occupancy and modification of floodplains, and to restore and preserve the natural and beneficial values served by floodplains. E.O. 11988, ''Floodplain management'' (May 24, 1977), also directs agencies to minimize the impacts of floods on human safety, health and welfare, and to restore and preserve the natural and beneficial values served by floodplains through evaluating the potential effects of any actions the agency may take in a floodplain and ensuring that its program planning and budget requests reflect consideration of flood hazards and floodplain management. DOT Order 5650.2, ''Floodplain Management and Protection'' (April 23, 1979), sets forth DOT policies and procedures for implementing E.O. 11988. The DOT Order requires that the agency determine if a proposed action is within the limits of a base floodplain, meaning it is encroaching on the floodplain, and whether this encroachment is significant. If significant, the agency is required to conduct further analysis of the proposed action and any practicable alternatives. If a practicable alternative avoids floodplain encroachment, then the agency is required to implement it.

In this proposal, NHTSA is not occupying, modifying, and/or encroaching on floodplains. NHTSA therefore concludes that the Orders do not apply to this proposal. NHTSA has, however, conducted a review of the alternatives on potentially affected resources, including floodplains, in its Draft EIS.

8. Preservation of the Nation's Wetlands (Executive Order 11990 and DOT Order 5660.1a)

These Orders require Federal agencies to avoid, to the extent possible, undertaking or providing assistance for new construction located in wetlands unless the agency head finds that there is no practicable alternative to such construction and that the proposed action includes all practicable measures to minimize harms to wetlands that may result from such use. E.O. 11990, ''Protection of Wetlands'' (May 24, 1977), also directs agencies to take action to minimize the destruction, loss, or degradation of wetlands in ''conducting Federal activities and programs affecting land use, including but not limited to water and related land resources planning, regulating, and licensing activities.'' DOT Order 5660.1a, ''Preservation of the Nation's Wetlands'' (August 24, 1978), sets forth DOT policy for interpreting E.O. 11990 and requires that transportation projects ''located in or having an impact on wetlands'' should be conducted to assure protection of the Nation's wetlands. If a project does have a significant impact on wetlands, an EIS must be prepared.

NHTSA is not undertaking or providing assistance for new construction located in wetlands. NHTSA therefore concludes that these Orders do not apply to this NPRM. NHTSA has, however, conducted a review of the alternatives on potentially affected resources, including wetlands, in its Draft EIS.

9. Migratory Bird Treaty Act (MBTA), Bald and Golden Eagle Protection Act (BGEPA), Executive Order 13186

The MBTA (16 U.S.C. 703–712) provides for the protection of certain migratory birds by making it illegal for anyone to ''pursue, hunt, take, capture, kill, attempt to take, capture, or kill, possess, offer for sale, sell, offer to barter, barter, offer to purchase, purchase, deliver for shipment, ship, export, import, cause to be shipped, exported, or imported, deliver for transportation, transport or cause to be transported, carry or cause to be carried, or receive for shipment, transportation, carriage, or export'' any migratory bird covered under the statute.[699]

The BGEPA (16 U.S.C. 668–668d) makes it illegal to ''take, possess, sell, purchase, barter, offer to sell, purchase or barter, transport, export or import'' any bald or golden eagles.[700] E.O. 13186, ''Responsibilities of Federal Agencies to Protect Migratory Birds,'' helps to further the purposes of the MBTA by requiring a Federal agency to develop an MOU with FWS when it is taking an action that has (or is likely to have) a measurable negative impact on migratory bird populations.

NHTSA concludes that the MBTA, BGEPA, and E.O. 13186 do not apply to this NPRM because there is no disturbance, take, measurable negative impact, or other covered activity involving migratory birds or bald or golden eagles involved in this rulemaking.

10. Department of Transportation Act (Section 4(f))

Section 4(f) of the Department of Transportation Act of 1966 (49 U.S.C. 303), as amended, is designed to preserve publicly owned park and recreation lands, waterfowl and wildlife refuges, and historic sites. Specifically, section 4(f) provides that DOT agencies cannot approve a transportation program or project that requires the use of any publicly owned land from a public park, recreation area, or wildlife or waterfowl refuge of national, State, or local significance, unless a determination is made that:

(1) There is no feasible and prudent alternative to the use of land, and

(2) The program or project includes all possible planning to minimize harm to the property resulting from the use.

These requirements may be satisfied if the transportation use of a section 4(f)

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[697] 78 FR 11784–11785 (Feb. 20, 2013).

[698] See DOI Solicitor's Opinion No. M–37017, ''Guidance on the Applicability of the Endangered Species Act Consultation Requirements to Proposed Actions Involving the Emissions of Greenhouse Gases'' (Oct. 3, 2008).

[699] 16 U.S.C. 703(a).

[700] 16 U.S.C. 668(a).

property results in a de minimis impact on the area.

NHTSA concludes that section 4(f) does not apply to this NPRM because this rulemaking is not an approval of a transportation program nor project that requires the use of any publicly owned land.

11. Department of Transportation Act (Section 4(f))

E.O. 12898, ''Federal Actions to Address EJ in Minority Populations and Low-Income Populations'' (Feb. 16, 1994), directs Federal agencies to promote nondiscrimination in federal programs substantially affecting human health and the environment, and provide minority and low-income communities access to public information on, and an opportunity for public participation in, matters relating to human health or the environment. E.O. 12898 also directs agencies to identify and consider any disproportionately high and adverse human health or environmental effects that their actions might have on minority and low-income communities and provide opportunities for community input in the NEPA process. CEQ has provided agencies with general guidance on how to meet the requirements of the E.O. as it relates to NEPA. E.O. 14096, ''*Revitalizing Our Nation's Commitment to Environmental Justice for All,*'' (April 21, 2023), builds on and supplements E.O. 12898, and further directs Federal agencies to prioritize EJ initiatives in their core missions.

Additionally, the 2021 DOT Order 5610.2C, ''U.S. Department of Transportation Actions to Address Environmental Justice in Minority Populations and Low-Income Populations'' (May 16, 2021), describes the process for DOT agencies to incorporate EJ principles in programs, policies, and activities. The DOT's EJ Strategy specifies that EJ and fair treatment of all people means that no population be forced to bear a disproportionate burden due to transportation decisions, programs, and policies. It also defines the terms *minority* and *low-income* in the context of DOT's EJ analyses. *Minority* is defined as a person who is Black, Hispanic or Latino, Asian American, American Indian or Alaskan Native, or Native Hawaiian or other Pacific Islander. *Low-income* is defined as a person whose household income is at or below the Department of Health and Human Services poverty guidelines. Low-income and minority populations may live in geographic proximity or be geographically dispersed/transient. In 2021, DOT reviewed and updated its EJ strategy to ensure that it continues to reflect its commitment to EJ principles and integrate those principles into DOT programs, policies, and activities.

Section VI and the Draft EIS discuss NHTSA's consideration of EJ issues associated with this proposal.

12. Executive Order 13045

This action is subject to E.O. 13045 (62 FR 19885, Apr. 23, 1997) because it is an economically significant regulatory action as defined by E.O. 12866, and NHTSA has reason to believe that the environmental health and safety risks related to this action, although small, may have a disproportionate effect on children. Specifically, children are more vulnerable to adverse health effects related to mobile source emissions, as well as to the potential long-term impacts of climate change. Pursuant to E.O. 13045, NHTSA must prepare an evaluation of the environmental health or safety effects of the planned action on children and an explanation of why the planned action is preferable to other potentially effective and reasonably feasible alternatives considered by NHTSA. Further, this analysis may be included as part of any other required analysis.

All of the action alternatives would reduce CO_2 emissions relative to the baseline and thus have positive effects on mitigating global climate change, and thus environmental and health effects associated with climate change. While environmental and health effects associated with criteria pollutant and toxic air pollutant emissions vary over time and across alternatives, negative effects, when estimated, are extremely small. This preamble and the Draft EIS discuss air quality, climate change, and their related environmental and health effects. In addition, Section V of this preamble explains why NHTSA believes that the proposed standards are preferable to other alternatives considered. Together, this preamble and Draft EIS satisfy NHTSA's responsibilities under E.O. 13045.

E. Regulatory Flexibility Act

Pursuant to the Regulatory Flexibility Act (5 U.S.C. 601 *et seq.,* as amended by the Small Business Regulatory Enforcement Fairness Act (SBREFA) of 1996), whenever an agency is required to publish an NPRM or final rule, it must prepare and make available for public comment a regulatory flexibility analysis that describes the effect of the rule on small entities (*i.e.,* small businesses, small organizations, and small governmental jurisdictions). No regulatory flexibility analysis is required if the head of an agency certifies the rule will not have a significant economic impact on a substantial number of small entities. SBREFA amended the Regulatory Flexibility Act to require Federal agencies to provide a statement of the factual basis for certifying that a rule will not have a significant economic impact on a substantial number of small entities.

NHTSA has considered the impacts of this proposed rule under the Regulatory Flexibility Act and the head of NHTSA certifies that this proposed rule will not have a significant economic impact on a substantial number of small entities. The following is NHTSA's statement providing the factual basis for this certification pursuant to 5 U.S.C. 605(b).

Small businesses are defined based on the North American Industry Classification System (NAICS) code.[701] One of the criteria for determining size is the number of employees in the firm. For establishments primarily engaged in manufacturing or assembling automobiles, including HDPUVs, the firm must have less than 1,500 employees to be classified as a small business. This rulemaking would affect motor vehicle manufacturers. As shown in Table VII–1, NHTSA has identified fourteen small manufacturers that produce passenger cars, light trucks, SUVs, HD pickup trucks, and vans of electric, hybrid, and ICEs. NHTSA acknowledges that some very new manufacturers may potentially not be listed. However, those new manufacturers tend to have transportation products that are not part of the LD and HDPUV vehicle fleet and have yet to start production of relevant vehicles. Moreover, NHTSA does not believe that there are a ''substantial number'' of these companies.[702]

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[701] Classified in NAICS under Subsector 336—Transportation Equipment Manufacturing for Automobile and Light Duty Motor Vehicle Manufacturing (336110) and Heavy Duty Truck Manufacturing (336120). Available at: *https://www.sba.gov/document/support-table-size-standards. (Accessed: May 31, 2023).*

[702] 5 U.S.C. 605(b).

TABLE VII–1—SMALL DOMESTIC MANUFACTURERS

Manufacturers	Founded	Employees [703]	Estimated annual Production [704]
BXR Motors	2007	< 20	< 100
Canoo (HDPUV)	2018	812	0
Falcon Motorsports	2009	< 10	< 100
Faraday Future (HDPUV)	2014	600	0
Fisker (HDPUV)	2016	455	< 500
Lordstown (HDPUV)	2018	260	< 100
Lucra Cars	2005	< 10	< 100
Lyons Motor Car	2012	12	< 100
Panoz	1988	< 50	< 100
Rezvani Motors	2014	10	< 100
Rossion Automotive	2007	< 20	< 100
Saleen	1984	81	< 100
Shelby American	1962	< 200	< 100
Workhorse Group (HDPUV)	2007	331	< 100

NHTSA believes that the proposed rulemaking would not have a significant economic impact on small vehicle manufacturers, because under 49 CFR part 525 passenger car manufacturers building less than 10,000 vehicles per year can petition NHTSA to have alternative standards determined for them. Listed manufacturers producing ICE vehicles do not currently meet the standard and must already petition NHTSA for relief. If the standard is raised, it has no meaningful impact on these manufacturers—they still must go through the same process and petition for relief. Given there already is a mechanism for relieving burden on small businesses, a regulatory flexibility analysis was not prepared.

All HDPUV manufacturers listed in Table VII–1 build BEVs which far exceed the fuel economy standards. NHTSA has researched the HDPUV manufacturing industry and found no small manufacturers of ICE vehicles that would be impacted by the proposed rulemaking. NHTSA welcomes comment on any information regarding small business HDPUV manufacturers that have may been omitted.

Further, small manufacturers of EVs would not face a significant economic impact. The method for earning credits applies equally across manufacturers and does not place small entities at a significant competitive disadvantage. In any event, even if the rulemaking had a ‘‘significant economic impact’’ on these small EV manufacturers, the number of these companies is not ‘‘a substantial number.’’ [705] For these reasons, their existence does not alter NHTSA's analysis of the applicability of the Regulatory Flexibility Act.

F. Executive Order 13132 (Federalism)

E.O. 13132 requires Federal agencies to develop an accountable process to ensure ‘‘meaningful and timely input by State and local officials in the development of regulatory policies that have federalism implications.’’ The order defines the term ‘‘[p]olicies that have federalism implications’’ to include regulations that have ‘‘substantial direct effects on the States, on the relationship between the national government and the States, or on the distribution of power and responsibilities among the various levels of government.’’ Under the order, agencies may not issue a regulation that has federalism implications, that imposes substantial direct compliance costs, unless the Federal Government provides the funds necessary to pay the direct compliance costs incurred by the State and local governments, or the agencies consult with State and local officials early in the process of developing the proposed regulation.

Similar to the CAFE preemption final rule,[706] NHTSA does not believe that this proposal implicates E.O. 13132, because it neither imposes substantial direct compliance costs on State, local, or Tribal governments, nor does it preempt State law. Thus, this proposal does not implicate the consultation procedures that E.O. 13132 imposes on agency regulations that would either preempt State law or impose substantial direct compliance costs on State, local, or Tribal governments, because the only entities subject to this proposal are vehicle manufacturers. Nevertheless, NHTSA has complied with the Order's requirements and consulted directly with the CARB in developing a number of elements of this proposal.

G. Executive Order 12988 (Civil Justice Reform)

Pursuant to E.O. 12988, ‘‘Civil Justice Reform’’ (61 FR 4729, Feb. 7, 1996), NHTSA has considered whether this proposal would have any retroactive effect. This proposal does not have any retroactive effect.

H. Executive Order 13175 (Consultation and Coordination With Indian Tribal Governments)

This proposal does not have tribal implications, as specified in E.O. 13175 (65 FR 67249, Nov. 9, 2000). This proposal would be implemented at the Federal level and would impose compliance costs only on vehicle manufacturers. Thus, E.O. 13175, which requires consultation with Tribal officials when agencies are developing policies that have ‘‘substantial direct effects’’ on Tribes and Tribal interests, does not apply to this proposal.

I. Unfunded Mandates Reform Act

Section 202 of the Unfunded Mandates Reform Act of 1995 (UMRA) requires Federal agencies to prepare a written assessment of the costs, benefits, and other effects of a proposed or final rule that includes a Federal mandate likely to result in the expenditure by State, local, or Tribal governments, in the aggregate, or by the private sector, of more than $100 million in any one year (adjusted for inflation with base year of 1995). Adjusting this amount by the implicit gross domestic product price deflator for 2021 results in $166 million (118.895/71.823 = 1.66).[707] Before

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[703] Estimated number of employees as of December 2022, source: linkedin.com, zoominfo.com, rocketreach.co, and datanyze.com.

[704] Rough estimate of LDV production for MY 2022.

[705] 5 U.S.C. 605.

[706] *See* 86 FR 74236, 74365 (Dec. 29, 2021).

[707] BEA. 2023. National Income and Product Accounts, Table 1.1.9: Implicit Price Deflators for Gross Domestic Product. Available at: *https://*

Continued

promulgating a rule for which a written statement is needed, section 205 of UMRA generally requires NHTSA to identify and consider a reasonable number of regulatory alternatives and adopt the least costly, most cost-effective, or least burdensome alternative that achieves the objective of the rule. The provisions of section 205 do not apply when they are inconsistent with applicable law. Moreover, section 205 allows NHTSA to adopt an alternative other than the least costly, most cost-effective, or least burdensome alternative if NHTSA publishes with the rule an explanation of why that alternative was not adopted.

This rulemaking will not result in the expenditure by State, local, or Tribal governments, in the aggregate, of more than $166 million annually, but it will result in the expenditure of that magnitude by vehicle manufacturers and/or their suppliers. In developing this proposed rule, we considered a range of alternative fuel economy and fuel efficiency standards. As explained in detail in Section V of the preamble above, NHTSA tentatively concludes that our selected alternatives are the maximum feasible alternatives that achieve the objectives of this rulemaking, as required by EPCA/EISA.

J. Regulation Identifier Number

The DOT assigns a regulation identifier number (RIN) to each regulatory action listed in the Unified Agenda of Federal Regulations. The Regulatory Information Service Center publishes the Unified Agenda in April and October of each year. The RIN contained in the heading at the beginning of this document may be used to find this action in the Unified Agenda.

K. National Technology Transfer and Advancement Act

Section 12(d) of the National Technology Transfer and Advancement Act (NTTAA) requires NHTSA evaluate and use existing voluntary consensus standards in its regulatory activities unless doing so would be inconsistent with applicable law (*e.g.,* the statutory provisions regarding NHTSA's vehicle safety authority) or otherwise impractical.[708]

Voluntary consensus standards are technical standards developed or adopted by voluntary consensus standards bodies. Technical standards are defined by the NTTAA as ''performance-based or design-specific technical specification and related management systems practices.'' They pertain to ''products and processes, such as size, strength, or technical performance of a product, process or material.''

Examples of organizations generally regarded as voluntary consensus standards bodies include the American Society for Testing and Materials, International, the SAE, and the American National Standards Institute (ANSI). If NHTSA does not use available and potentially applicable voluntary consensus standards, it is required by the Act to provide Congress, through OMB an explanation of reasons for not using such standards. There are currently no consensus standards that NHTSA administers relevant to these proposed CAFE standards.

L. Department of Energy Review

In accordance with 49 U.S.C. 32902(j)(2), NHTSA submitted this proposal to the DOE for review. That agency did not make any comments that NHTSA did not address.

M. Paperwork Reduction Act

Under the procedures established by the Paperwork Reduction Act of 1995 (PRA) (44 U.S.C. 3501, et. seq.), Federal agencies must obtain approval from the OMB for each collection of information they conduct, sponsor, or require through regulations. A person is not required to respond to a collection of information by a Federal Agency unless the collection displays a valid OMB control number. This NPRM proposes changes that relate to an information collection that is subject to the PRA, but the changes are not expected to increase the burden associated with the information collection. Additional details about NHTSA's information collection for its Corporate Average Fuel Economy (CAFE) program (OMB control number 2127–0019) and how NHTSA estimated burden for this collection are available in the supporting statements for the currently approved collection.[709]

N. Privacy Act

In accordance with 5 U.S.C. 553(c), NHTSA is soliciting comments from the public to inform the rulemaking process better. These comments will post, without edit, to *https://www.regulations.gov,* as described in DOT's systems of records notice, DOT/ALL–14 FDMS, accessible through *https://www.transportation.gov/individuals/privacy/privacy-act-system-records-notices.* In order to facilitate comment tracking and response, NHTSA encourages commenters to provide their names or the names of their organizations; however, submission of names is completely optional.

IX. Regulatory Text

List of Subjects in 49 CFR Parts 531, 533, 535, and 537

Fuel economy, Reporting and recordkeeping requirements.

For the reasons discussed in the preamble, NHTSA proposes to amend 49 CFR parts 531, 533, 535, and 537 as follows:

PART 531—PASSENGER AUTOMOBILE AVERAGE FUEL ECONOMY STANDARDS

■ 1. The authority citation for Part 531 continues to read as follows:

Authority: 49 U.S.C. 32902; delegation of authority at 49 CFR 1.95.

■ 2. Revise § 531.1 to read as follows:

§ 531.1 Scope.

This part establishes average fuel economy standards pursuant to 49 U.S.C. 32902 for passenger automobiles.

■ 3. Revise § 531.4 to read as follows:

§ 531.4 Definitions.

(a) *Statutory terms.* (1) The terms *average fuel economy, manufacture, manufacturer,* and *model year* are used as defined in 49 U.S.C. 32901.

(2) The terms *automobile* and *passenger automobile* are used as defined in 49 U.S.C. 32901 and in accordance with the determination in part 523 of this chapter.

(b) *Other terms.* As used in this part, unless otherwise required by the context—

(1) The term *domestically manufactured passenger automobile* means the vehicle is deemed to be manufactured domestically under 49 U.S.C. 32904(b)(3) and 40 CFR 600.511–08.

(2) [Reserved]

■ 4. Amend § 531.5 by revising paragraphs (a) through (d) to read as follows:

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categories=survey. (Accessed: May 31, 2023).

[708] 15 U.S.C. 272.

[709] Office of Information and Regulatory Affairs. 2022. Supporting Statements: Part A, Corporate Average Fuel Economy Reporting. OMB 2127–0019. Available at: *https://www.reginfo.gov/public/do/PRAViewDocument?ref_nbr=202210-2127-003.* (Accessed: May 31, 2023).

§ 531.5 Fuel economy standards.

(a) Except as provided in paragraph (e) of this section, each manufacturer of passenger automobiles shall comply with the fleet average fuel economy standards in table 1 to this paragraph (a), expressed in miles per gallon, in the model year specified as applicable:

TABLE 1 TO PARAGRAPH (a)

Model year	Average fuel economy standard (miles per gallon)
1978	18.0
1979	19.0
1980	20.0
1981	22.0
1982	24.0
1983	26.0
1984	27.0
1985	27.5
1986	26.0
1987	26.0
1988	26.0
1989	26.5
1990–2010	27.5

(b) Except as provided in paragraph (e) of this section, for model year 2011, a manufacturer's passenger automobile fleet shall comply with the fleet average fuel economy level calculated for that model year according to figure 1 and the appropriate values in table 2 to this paragraph (b).

Figure 1 to paragraph (b)

$$Required\_Fuel\_Economy\_Level = \frac{N}{\sum_i \frac{N_i}{T_i}}$$

Where:

N is the total number (sum) of passenger automobiles produced by a manufacturer;

N_i is the number (sum) of the *ith* passenger automobile model produced by the manufacturer; and

T_i is the fuel economy target of the *ith* model passenger automobile, which is determined according to the following formula, rounded to the nearest hundredth:

$$\frac{1}{\frac{1}{a} + \left(\frac{1}{b} - \frac{1}{a}\right)\frac{e^{(x-c)d}}{1 + e^{(x-c)d}}}$$

Where:

Parameters *a, b, c,* and *d* are defined in table 2 to this paragraph (b);

e = 2.718; and

x = footprint (in square feet, rounded to the nearest tenth) of the vehicle model.

TABLE 2 TO PARAGRAPH (b)—PARAMETERS FOR THE PASSENGER AUTOMOBILE FUEL ECONOMY TARGETS

Model year	Parameters			
	a (mpg)	*b* (mpg)	*c* (gal/mi/ft²)	*d* (gal/mi)
2011	31.20	24.00	51.41	1.91

(c) Except as provided in paragraph (e) of this section, for model years 2012–2032, a manufacturer's passenger automobile fleet shall comply with the fleet average fuel economy level calculated for that model year according to this figure 2 and the appropriate values in this table 3 to this paragraph (c).

Figure 2 to paragraph (c)

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

Where:

$CAFE_{required}$ is the fleet average fuel economy standard for a given fleet (domestic passenger automobiles or import passenger automobiles);

Subscript i is a designation of multiple groups of automobiles, where each group's designation, *i.e.,* i = 1, 2, 3, etc., represents automobiles that share a unique model type and footprint within the applicable fleet, either domestic passenger automobiles or import passenger automobiles;

$Production_i$ is the number of passenger automobiles produced for sale in the United States within each *ith* designation, *i.e.,* which share the same model type and footprint;

$TARGET_i$ is the fuel economy target in miles per gallon (mpg) applicable to the footprint of passenger automobiles within each *ith* designation, *i.e.,* which share the same model type and footprint, calculated according to Figure 3 and rounded to the nearest hundredth of a mpg, *i.e.,* 35.455 = 35.46 mpg, and the summations in the numerator and denominator are both performed over all models in the fleet in question.

Figure 3 to Paragraph (c)

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

Where:

TARGET is the fuel economy target (in mpg) applicable to vehicles of a given footprint (*FOOTPRINT*, in square feet);

Parameters *a, b, c,* and *d* are defined in table 3 to this paragraph (c); and

The *MIN* and *MAX* functions take the minimum and maximum, respectively, of the included values.

TABLE 3 TO PARAGRAPH (c)—PARAMETERS FOR THE PASSENGER AUTOMOBILE FUEL ECONOMY TARGETS

[MYs 2012–2032]

Model year	Parameters			
	a (mpg)	*b* (mpg)	*c* (gal/mi/ft²)	*d* (gal/mi)
2012	35.95	27.95	0.0005308	0.006057
2013	36.80	28.46	0.0005308	0.005410
2014	37.75	29.03	0.0005308	0.004725
2015	39.24	29.90	0.0005308	0.003719
2016	41.09	30.96	0.0005308	0.002573
2017	43.61	32.65	0.0005131	0.001896
2018	45.21	33.84	0.0004954	0.001811
2019	46.87	35.07	0.0004783	0.001729
2020	48.74	36.47	0.0004603	0.001643
2021	49.48	37.02	0.000453	0.00162
2022	50.24	37.59	0.000447	0.00159
2023	51.00	38.16	0.000440	0.00157
2024	55.44	41.48	0.000405	0.00144
2025	60.26	45.08	0.000372	0.00133
2026	66.95	50.09	0.000335	0.00120
2027	68.32	51.12	0.00033	0.00117
2028	69.71	52.16	0.00032	0.00115
2029	71.14	53.22	0.00032	0.00113
2030	72.59	54.31	0.00031	0.00110
2031	74.07	55.42	0.00030	0.00108
2032	75.58	56.55	0.00030	0.00106

(d) In addition to the requirements of paragraphs (b) and (c) of this section, each manufacturer, other than manufacturers subject to standards in paragraph (e) of this section, shall also meet the minimum fleet standard for domestically manufactured passenger automobiles expressed in table 4 to this paragraph (d):

TABLE 4 TO PARAGRAPH (d)—MINIMUM FUEL ECONOMY STANDARDS FOR DOMESTICALLY MANUFACTURED PASSENGER AUTOMOBILES

[MYs 2011–2032]

Model year	Minimum standard
2011	27.8
2012	30.7
2013	31.4
2014	32.1
2015	33.3
2016	34.7
2017	36.7
2018	38.0
2019	39.4
2020	40.9
2021	39.9
2022	40.6
2023	41.1
2024	44.3
2025	48.1
2026	53.5
2027	54.1
2028	55.3
2029	56.4
2030	57.5
2031	58.7
2032	59.9

* * * * *

■ 4. Amend § 531.6 by revising paragraph (b) to read as follows:

§ 531.6 Measurement and calculation procedures.

* * * * *

(b) For model years 2017 and later, a manufacturer is eligible to increase the fuel economy performance of passenger cars in accordance with procedures established by the Environmental

Protection Agency (EPA) set forth in 40 CFR part 600, subpart F, including adjustments to fuel economy for fuel consumption improvements related to air conditioning (AC) efficiency and off-cycle technologies. Manufacturers must provide reporting on these technologies as specified in § 537.7 of this chapter by the required deadlines.

(1) *Efficient AC technologies.* A manufacturer may increase its fleet average fuel economy performance through the use of technologies that improve the efficiency of AC systems pursuant to the requirements in 40 CFR 86.1868–12. Fuel consumption improvement values resulting from the use of those AC systems must be determined in accordance with 40 CFR 600.510–12(c)(3)(i). Starting in MY 2027, fuel consumption improvement values may only increase the fuel economy of vehicles propelled by internal combustion engines (ICEs) and, therefore, will be calculated based only on the number of vehicles with internal combustion vehicles that are equipped with the technologies.

(2) *Off-cycle technologies on EPA's predefined list.* A manufacturer may increase its fleet average fuel economy performance through the use of off-cycle technologies pursuant to the requirements in 40 CFR 86.1869–12for predefined off-cycle technologies in accordance with 40 CFR 86.1869–12(b). The fuel consumption improvement is determined in accordance with 40 CFR 600.510–12(c)(3)(ii). Starting in MY 2027, fuel consumption improvement values may only increase the fuel economy of vehicles propelled by ICEs and, therefore, will be calculated based only on the number of vehicles with internal combustion vehicles that are equipped with the technologies.

(3) *Off-cycle technologies using 5-cycle testing.* Through MY 2027, a manufacturer may increase its fleet average fuel economy performance through the use of off-cycle technologies tested using the EPA's 5-cycle methodology in accordance with 40 CFR 86.1869–12(c). The fuel consumption improvement is determined in accordance with 40 CFR 600.510–12(c)(3)(ii).

(4) *Off-cycle technologies using the alternative EPA-approved methodology.* Through MY 2027, a manufacturer may seek to increase its fuel economy performance through use of an off-cycle technology requiring an application request made to the EPA in accordance with 40 CFR 86.1869–12(d).

(i) *Eligibility under the Corporate Average Fuel Economy (CAFE) program requires compliance with paragraphs (b)(4)(i)(A) through (C) of this section.* Paragraphs (b)(4)(i)(A), (B) and (D) of this section apply starting in model year 2024. Paragraph (b)(4)(i)(E) of this section applies starting in MY 2025.

(A) A manufacturer seeking to increase its fuel economy performance using the alternative methodology for an off-cycle technology, should submit a detailed analytical plan to EPA prior to the applicable model year. The detailed analytical plan may include information, such as planned test procedure and model types for demonstration. The plan will be approved or denied in accordance with 40 CFR 86.1869.12(d).

(B) A manufacturer seeking to increase its CAFE program fuel economy performance using the alternative methodology for an off-cycle technology must submit an official credit application to EPA and obtain approval in accordance with 40 CFR 86.1869.12(e) prior to September of the given model year.

(C) A manufacturer's plans, applications and requests approved by the EPA must be made in consultation with NHTSA. To expedite NHTSA's consultation with the EPA, a manufacturer must concurrently submit its application to NHTSA if the manufacturer is seeking off-cycle fuel economy improvement values under the CAFE program for those technologies. For off-cycle technologies that are covered under 40 CFR 86.1869–12(d), NHTSA will consult with the EPA regarding NHTSA's evaluation of the specific off-cycle technology to ensure its impact on fuel economy and the suitability of using the off-cycle technology to adjust the fuel economy performance.

(D) A manufacturer may request an extension from NHTSA for more time to obtain an EPA approval. Manufacturers should submit their requests 30 days before the deadlines in paragraphs (b)(4)(i)(A) through (C) of this section. Requests should be submitted to NHTSA's Director of the Office of Vehicle Safety Compliance at *cafe@dot.gov.*

(E) For MYs 2025 and 2026, a manufacturer must respond within 60-days to any requests from EPA or NHTSA for additional information or clarifications to submissions provided pursuant to paragraphs (b)(4)(i)(A) and (B) of this section. Failure to respond within 60 days may result in denial of the manufacturer's request to increase its fuel economy performance through use of an off-cycle technology requests made to the EPA in accordance with 40 CFR 86.1869–12(d).

(ii) *Review and approval process.* NHTSA will provide its views on the suitability of the technology for that purpose to the EPA. NHTSA's evaluation and review will consider:

(A) Whether the technology has a direct impact upon improving fuel economy performance;

(B) Whether the technology is related to crash-avoidance technologies, safety critical systems or systems affecting safety-critical functions, or technologies designed for the purpose of reducing the frequency of vehicle crashes;

(C) Information from any assessments conducted by the EPA related to the application, the technology and/or related technologies; and

(D) Any other relevant factors.

(iii) *Safety.* (A) Technologies found to be defective or non-compliant, subject to recall pursuant to part 573 of this chapter, Defect and Noncompliance Responsibility and Reports, due to a risk to motor vehicle safety, will have the values of approved off-cycle credits removed from the manufacturer's credit balance or adjusted to the population of vehicles the manufacturer remedies as required by 49 U.S.C. chapter 301. NHTSA will consult with the manufacturer to determine the amount of the adjustment.

(B) Approval granted for innovative and off-cycle technology credits under NHTSA's fuel efficiency program does not affect or relieve the obligation to comply with the Vehicle Safety Act (49 U.S.C. chapter 301), including the ''make inoperative'' prohibition (49 U.S.C. 30122), and all applicable Federal motor vehicle safety standards (FMVSSs) issued thereunder (part 571 of this chapter). In order to generate off-cycle or innovative technology credits manufacturers must state—

(*1*) That each vehicle equipped with the technology for which they are seeking credits will comply with all applicable FMVSS(s); and

(*2*) Whether or not the technology has a fail-safe provision. If no fail-safe provision exists, the manufacturer must explain why not and whether a failure of the innovative technology would affect the safety of the vehicle.

PART 533—LIGHT TRUCK FUEL ECONOMY STANDARDS

■ 5. The authority citation for part 533 continues to read as follows:

Authority: 49 U.S.C. 32902; delegation of authority at 49 CFR 1.95.

■ 6. Revise § 533.1 to read as follows:

§ 533.1 Scope.

This part establishes average fuel economy standards pursuant to 49 U.S.C. 32902 for light trucks.

■ 7. Revise § 533.4 to read as follows:

§ 533.4 Definitions.

(a) *Statutory terms.* (1) The terms *average fuel economy, average fuel economy standard, fuel economy, import, manufacture, manufacturer,* and *model year* are used as defined in 49 U.S.C. 32901.

(2) The term *automobile* is used as defined in 49 U.S.C. 32901 and in accordance with the determinations in part 523 of this chapter.

(b) *Other terms.* As used in this part, unless otherwise required by the context—

(1) *Light truck* is used in accordance with the determinations in part 523 of this chapter.

(2) *Captive import* means with respect to a light truck, one which is not domestically manufactured, as defined in section 502(b)(2)(E) of the Motor Vehicle Information and Cost Savings Act, but which is imported in the 1980 model year or thereafter by a manufacturer whose principal place of business is in the United States.

(3) *4-wheel drive, general utility vehicle* means a 4-wheel drive, general purpose automobile capable of off-highway operation that has a wheelbase of not more than 280 centimeters, and that has a body shape similar to 1977 Jeep CJ–5 or CJ–7, or the 1977 Toyota Land Cruiser.

(4) *Basic engine* means a unique combination of manufacturer, engine displacement, number of cylinders, fuel system (as distinguished by number of carburetor barrels or use of fuel injection), and catalyst usage.

(5) *Limited product line light truck* means a light truck manufactured by a manufacturer whose light truck fleet is powered exclusively by basic engines which are not also used in passenger automobiles.

■ 8. Amend § 533.5 by revising table 7 to paragraph (a) and paragraph (j) to read as follows:

§ 533.5 Requirements.

(a) * * *

TABLE 7 TO PARAGRAPH (a)—PARAMETERS FOR THE LIGHT TRUCK FUEL ECONOMY TARGETS FOR MYS

[2017–2032]

Model year	Parameters							
	a (mpg)	*b* (mpg)	*c* (gal/mi/ft²)	*d* (gal/mi)	*e* (mpg)	*f* (mpg)	*g* (gal/mi/ft²)	*h* (gal/mi)
2017	36.26	25.09	0.0005484	0.005097	35.10	25.09	0.0004546	0.009851
2018	37.36	25.20	0.0005358	0.004797	35.31	25.20	0.0004546	0.009682
2019	38.16	25.25	0.0005265	0.004623	35.41	25.25	0.0004546	0.009603
2020	39.11	25.25	0.0005140	0.004494	35.41	25.25	0.0004546	0.009603
2021	39.71	25.63	0.000506	0.00443	NA	NA	NA	NA
2022	40.31	26.02	0.000499	0.00436	NA	NA	NA	NA
2023	40.93	26.42	0.000491	0.00429	NA	NA	NA	NA
2024	44.48	26.74	0.000452	0.00395	NA	NA	NA	NA
2025	48.35	29.07	0.000416	0.00364	NA	NA	NA	NA
2026	53.73	32.30	0.000374	0.00327	NA	NA	NA	NA
2027	55.96	33.64	0.00036	0.00314	NA	NA	NA	NA
2028	58.30	35.05	0.00034	0.00302	NA	NA	NA	NA
2029	60.73	36.51	0.00033	0.00289	NA	NA	NA	NA
2030	63.26	38.03	0.00032	0.00278	NA	NA	NA	NA
2031	65.89	39.61	0.00031	0.00267	NA	NA	NA	NA
2032	68.64	41.26	0.00029	0.00256	NA	NA	NA	NA

* * * * *

(j) For model years 2017–2032, a manufacturer's light truck fleet shall comply with the fleet average fuel economy standard calculated for that model year according to figures 2 and 4 to paragraph (a) of this section and the appropriate values in table 7 to paragraph (a) of this section.

■ 9. Amend § 533.6 by:

■ a. Revising paragraphs (c) introductory text, (c)(1) and (3);

■ b. Redesignating paragraph (c)(4) as (c)(5);

■ c. Adding a new paragraph (c)(4); and

■ d. Revising newly redesignated paragraph (c)(5).

The revisions and addition read as follows:

§ 533.6 Measurement and calculation procedures.

* * * * *

(c) For model years 2017 and later, a manufacturer is eligible to increase the fuel economy performance of light trucks in accordance with procedures established by the Environmental Protection Agency (EPA) set forth in 40 CFR part 600, subpart F, including adjustments to fuel economy for fuel consumption improvements related to air conditioning (AC) efficiency, off-cycle technologies, and hybridization and other performance-based technologies for full-size pickup trucks that meet the requirements specified in 40 CFR 86.1803. Manufacturers must provide reporting on these technologies as specified in § 537.7 of this chapter by the required deadlines.

(1) *Efficient AC technologies.* A manufacturer may seek to increase its fleet average fuel economy performance through the use of technologies that improve the efficiency of AC systems pursuant to the requirements in 40 CFR 86.1868–12. Fuel consumption improvement values resulting from the use of those AC systems must be determined in accordance with 40 CFR 600.510–12(c)(3)(i). Starting in MY 2027, fuel consumption improvement values may only increase the fuel economy of vehicles propelled by internal combustion engines (ICEs) and, therefore, will be calculated based only on the number of vehicles with internal combustion vehicles that are equipped with the technologies.

* * * * *

(3) *Off-cycle technologies on EPA's predefined list.* A manufacturer may seek to increase its fleet average fuel economy performance through the use of off-cycle technologies pursuant to the requirements in 40 CFR 86.1869–12 for predefined off-cycle technologies in accordance with 40 CFR 86.1869–12(b). The fuel consumption improvement is determined in accordance with 40 CFR 600.510–12(c)(3)(ii). Starting in MY 2027, fuel consumption improvement values may only increase the fuel economy of vehicles propelled by ICEs and, therefore, will be calculated based

only on the number of vehicles with internal combustion vehicles that are equipped with the technologies.

(4) *Off-cycle technologies using 5-cycle testing.* Through MY 2027, a manufacturer may increase its fleet average fuel economy performance through the use of off-cycle technologies tested using the EPA's 5-cycle methodology in accordance with 40 CFR 86.1869–12(c). The fuel consumption improvement is determined in accordance with 40 CFR 600.510–12(c)(3)(ii).

(5) *Off-cycle Technologies using the alternative EPA-approved methodology.* Through MY 2027, a manufacturer may seek to increase its fuel economy performance through use of an off-cycle technology requiring an application request made to the EPA in accordance with 40 CFR 86.1869–12(d).

(i) *Eligibility under the Corporate Average Fuel Economy (CAFE) program requires compliance with paragraphs (c)(5)(i)(A) through (C) of this section.* Paragraphs (c)(5)(i)(A), (B) and (D) of this section apply starting in model year 2024. Paragraph (b)(5)(i)(E) of this section applies starting in MY 2025.

(A) A manufacturer seeking to increase its fuel economy performance using the alternative methodology for an off-cycle technology, should submit a detailed analytical plan to EPA prior to the applicable model year. The detailed analytical plan may include information such as, planned test procedure and model types for demonstration. The plan will be approved or denied in accordance with 40 CFR 86.1869.12(d).

(B) A manufacturer seeking to increase its fuel economy performance using the alternative methodology for an off-cycle technology must submit an official credit application to EPA and obtain approval in accordance with 40 CFR 86.1869.12(e) prior to September of the given model year.

(C) A manufacturer's plans, applications and requests approved by the EPA must be made in consultation with NHTSA. To expedite NHTSA's consultation with the EPA, a manufacturer must concurrently submit its application to NHTSA if the manufacturer is seeking off-cycle fuel economy improvement values under the CAFE program for those technologies. For off-cycle technologies that are covered under 40 CFR 86.1869–12(d), NHTSA will consult with the EPA regarding NHTSA's evaluation of the specific off-cycle technology to ensure its impact on fuel economy and the suitability of using the off-cycle technology to adjust the fuel economy performance.

(D) A manufacturer may request an extension from NHTSA for more time to obtain an EPA approval. Manufacturers should submit their requests 30 days before the deadlines above. Requests should be submitted to NHTSA's Director of the Office of Vehicle Safety Compliance at *cafe@dot.gov.*

(E) For MYs 2025 and 2026, a manufacturer must respond within 60-days to any requests from EPA or NHTSA for additional information or clarifications to submissions provided pursuant to paragraphs (b)(4)(i)(A) and (B) of this section. Failure to respond within 60 days may result in denial of the manufacturer's request to increase its fuel economy performance through use of an off-cycle technology requests made to the EPA in accordance with 40 CFR 86.1869–12(d).

(ii) *Review and approval process.* NHTSA will provide its views on the suitability of the technology for that purpose to the EPA. NHTSA's evaluation and review will consider:

(A) Whether the technology has a direct impact upon improving fuel economy performance;

(B) Whether the technology is related to crash-avoidance technologies, safety critical systems or systems affecting safety-critical functions, or technologies designed for the purpose of reducing the frequency of vehicle crashes;

(C) Information from any assessments conducted by the EPA related to the application, the technology and/or related technologies; and

(D) Any other relevant factors.

(E) NHTSA will collaborate to host annual meetings with EPA at least once by July 30th before the model year begins to provide general guidance to the industry on past off-cycle approvals.

(iii) *Safety.* (A) Technologies found to be defective or non-compliant, subject to recall pursuant to part 573 of this chapter, Defect and Noncompliance Responsibility and Reports, due to a risk to motor vehicle safety, will have the values of approved off-cycle credits removed from the manufacturer's credit balance or adjusted to the population of vehicles the manufacturer remedies as required by 49 U.S.C. chapter 301. NHTSA will consult with the manufacturer to determine the amount of the adjustment.

(B) Approval granted for innovative and off-cycle technology credits under NHTSA's fuel efficiency program does not affect or relieve the obligation to comply with the Vehicle Safety Act (49 U.S.C. chapter 301), including the "make inoperative" prohibition (49 U.S.C. 30122), and all applicable Federal motor vehicle safety standards issued thereunder (FMVSSs) (part 571 of this chapter). In order to generate off-cycle or innovative technology credits manufacturers must state—

(*1*) That each vehicle equipped with the technology for which they are seeking credits will comply with all applicable FMVSS(s); and

(*2*) Whether or not the technology has a fail-safe provision. If no fail-safe provision exists, the manufacturer must explain why not and whether a failure of the innovative technology would affect the safety of the vehicle.

PART 535—MEDIUM- AND HEAVY-DUTY VEHICLE FUEL EFFICIENCY PROGRAM

■ 10. The authority citation for part 535 continues to read as follows:

Authority: 49 U.S.C. 32902 and 30101; delegation of authority at 49 CFR 1.95.

■ 11. Amend § 535.4 by revising the introductory text, removing the definition for "Alterers", and adding the definition for "Alterer", in alphabetical order, to read as follows:

§ 535.4 Definitions.

The terms manufacture, manufacturer, commercial medium-duty on highway vehicle, commercial heavy-duty on highway vehicle, fuel, and work truck are used as defined in 49 U.S.C. 32901. See 49 CFR 523.2 for general definitions related to NHTSA's fuel efficiency programs.

* * * * *

Alterer means a manufacturer that modifies an altered vehicle as defined in 49 CFR 567.3

* * * * *

■ 12. Amend § 535.5 by revising paragraphs (a) introductory text, (a)(1), (2) and (9) to read as follows:

§ 535.5 Standards.

(a) *Heavy-duty pickup trucks and vans.* Each manufacturer's fleet of heavy-duty pickup trucks and vans (HDPUVs) shall comply with the fuel consumption standards in this paragraph (a) expressed in gallons per 100 miles. Each vehicle must be manufactured to comply for its full useful life. For the Phase 1 program, if the manufacturer's fleet includes conventional vehicles (gasoline, diesel and alternative fueled vehicles) and advanced technology vehicles (hybrids with powertrain designs that include energy storage systems, vehicles with waste heat recovery, EVs and fuel cell vehicles), it may divide its fleet into two separate fleets each with its own separate fleet average fuel consumption standard which the manufacturer must comply with the requirements of this paragraph (a). For Phase 2 and later, manufacturers may calculate their fleet average fuel consumption standard for a conventional fleet and multiple advanced technology vehicle fleets. Advanced technology vehicle fleets should be separated into plug-in hybrid electric vehicles, electric vehicles and fuel cell vehicles. NHTSA standards correspond to the same requirements for the Environmental Protection Agency (EPA) as specified in 40 CFR 86.1819–14.

(1) *Mandatory standards.* For model years 2016 and later, each manufacturer must comply with the fleet average standard derived from the unique subconfiguration target standards (or groups of subconfigurations approved by EPA in accordance with 40 CFR 86.1819) of the model types that make up the manufacturer's fleet in a given model year. Each subconfiguration has a unique attribute-based target standard, defined by each group of vehicles having the same payload, towing capacity and whether the vehicles are equipped with a 2-wheel or 4-wheel drive configuration. Phase 1 target standards apply for model years 2016 through 2020. Phase 2 target standards apply for model year 2021 through 2029. NHTSA's Phase 3 HDPUVs apply for model year 2030 and later.

(2) *Subconfiguration target standards.* (i) Two alternatives exist for determining the subconfiguration target standards for Phase 1. For each alternative, separate standards exist for compression-ignition and spark-ignition vehicles:

(A) The first alternative allows manufacturers to determine a fixed fuel consumption standard that is constant over the model years; and

(B) The second alternative allows manufacturers to determine standards that are phased-in gradually each year.

(ii) Calculate the subconfiguration target standards as specified in this paragraph (a)(2)(ii), using the appropriate coefficients from table 1 to paragraph (a)(2)(ii), choosing between the alternatives in paragraph (a)(2)(i) of this section. For electric or fuel cell heavy-duty vehicles, use compression-ignition vehicle coefficients ''c'' and ''d'' and for hybrid (including plug-in hybrid), dedicated and dual-fueled vehicles, use coefficients ''c'' and ''d'' appropriate for the engine type used. Round each standard to the nearest 0.001 gallons per 100 miles and specify all weights in pounds rounded to the nearest pound. Calculate the subconfiguration target standards using the following equation:

Subconfiguration Target Standard (gallons per 100 miles) = [c × (WF)] + d

Where:

WF = Work Factor = [0.75 × (Payload Capacity + Xwd)] + [0.25 × Towing Capacity]

Xwd = 4wd Adjustment = 500 lbs. if the vehicle group is equipped with 4wd and all-wheel drive, otherwise equals 0 lbs. for 2wd.

Payload Capacity = GVWR (lbs.)—Curb Weight (lbs.) (for each vehicle group) Towing Capacity = GCWR (lbs.)—GVWR (lbs.) (for each vehicle group)

TABLE 1 TO PARAGRAPH (a)(2)(ii)—COEFFICIENTS FOR MANDATORY SUBCONFIGURATION TARGET STANDARDS

Phase 1 Alternative 1—Fixed Target Standards		
Compression Ignition (CI) Vehicle Coefficients		
Model Year(s)	c	d
2016 to 2018	0.0004322	3.330
2019 to 2020	0.0004086	3.143
SI Vehicle Coefficients		
2016 to 2017	0.0005131	3.961
2018 to 2020	0.0004086	3.143
Phase 1 Alternative 2—Phased-in Target Standards		
CI Vehicle Coefficients		
2016	0.0004519	3.477
2017	0.0004371	3.369
2018 to 2020	0.0004086	3.143
SI Vehicle Coefficients		
2016	0.0005277	4.073
2017	0.0005176	3.983
2018 to 2020	0.0004951	3.815
Phase 2—Fixed Target Standards		
CI Vehicle Coefficients		
2021	0.0003988	3.065
2022	0.0003880	2.986
2023	0.0003792	2.917
2024	0.0003694	2.839
2025	0.0003605	2.770
2026	0.0003507	2.701
2027 to 2029	0.0003418	2.633
2030	0.0003076	2.370
2031	0.0002769	2.133
2032	0.0002492	1.919
2033	0.0002243	1.728
2034	0.0002018	1.555
2035	0.0001816	1.399
SI Vehicle Coefficients		
2021	0.0004827	3.725
2022	0.0004703	3.623
2023	0.0004591	3.533
2024	0.0004478	3.443
2025	0.0004366	3.364
2026	0.0004253	3.274
2027 to 2029	0.0004152	3.196
2030	0.0003737	2.876
2031	0.0003363	2.589
2032	0.0003027	2.330
2033	0.0002724	2.097
2034	0.0002452	1.887
2035	0.0002207	1.698

* * * * *

(9) *Advanced, innovative and off-cycle technologies.* For vehicles subject to Phase 1 standards, manufacturers may generate separate credit allowances for advanced and innovative technologies as specified in § 535.7(f)(1) and (2). For vehicles subject to Phase 2 standards, manufacturers may generate separate credits allowance for off-cycle technologies in accordance with § 535.7(f)(2). Separate credit allowances for advanced technology vehicles cannot be generated; instead, manufacturers may use the credit m specified in § 535.7(f)(1)(ii) through model year 2026.

* * * * *

■ 13. Amend § 535.6 by revising paragraph (a)(1) to read as follows:

§ 535.6 Measurement and calculation procedures.

* * * * *

(a) * * *

(1) For the Phase 1 program, if the manufacturer's fleet includes conventional vehicles (gasoline, diesel and alternative fueled vehicles) and advanced technology vehicles (hybrids with powertrain designs that include energy storage systems, vehicles with waste heat recovery, electric vehicles and fuel cell vehicles), it may divide its fleet into two separate fleets each with its own separate fleet average fuel consumption performance rate. For Phase 2 and later, manufacturers may calculate their fleet average fuel consumption rates for a conventional fleet and separate advanced technology vehicle fleets. Advanced technology vehicle fleets should be separated into plug-in hybrid electric vehicles, electric vehicles and fuel cell vehicles.

* * * * *

■ 14. Amend § 535.7 by revising paragraphs (a)(1)(iii) and (iv), (a)(2)(iii), (a)(4)(i) and (ii), (b)(2), (f)(1)(ii), (f)(2) introductory text, (f)(2)(ii), and (f)(2)(vi)(B) to read as follows:

§ 535.7 Averaging, banking, and trading (ABT) credit program.

(a) * * *

(1) * * *

(iii) *Advanced technology credits.* Credits generated by vehicle or engine families or subconfigurations containing vehicles with advanced technologies (*i.e.,* hybrids with regenerative braking, vehicles equipped with Rankine-cycle engines, electric and fuel cell vehicles).

(iv) *Innovative and off-cycle technology credits.* Credits can be generated by vehicle or engine families or subconfigurations having fuel consumption reductions resulting from technologies not reflected in the GEM simulation tool or in the Federal Test Procedure (FTP) chassis dynamometer and that were not in common use with heavy-duty vehicles or engines before model year 2010 that are not reflected in the specified test procedure. Manufacturers should prove that these technologies were not in common use in heavy-duty vehicles or engines before model year 2010 by demonstrating factors such as the penetration rates of the technology in the market. NHTSA will not approve any request if it determines that these technologies do not qualify. The approach for determining innovative and off-cycle technology credits under this fuel consumption program is described in paragraph (f)(2) of this section and by the Environmental Protection Agency (EPA) under 40 CFR 86.1819–14(d)(13), 1036.610, and 1037.610. Starting in model year 2030, manufacturers certifying vehicles under § 535.5(a) may not earn off-cycle technology credits under 40 CFR 86.1819–14(d)(13).

(2) * * *

(iii) Positive credits, other than advanced technology credits in Phase 1, generated and calculated within an averaging set may only be used to offset negative credits within the same averaging set.

* * * * *

(4) * * *

(i) Manufacturers may only trade banked credits to other manufacturers to use for compliance with fuel consumption standards. Traded FCCs, other than advanced technology credits earned in Phase 1, may be used only within the averaging set in which they were generated. Manufacturers may only trade credits to other entities for the purpose of expiring credits.

(ii) Advanced technology credits earned in Phase 1 can be traded across different averaging sets.

* * * * *

(b) * * *

(2) Adjust the fuel consumption performance of subconfigurations with advanced technology for determining the fleet average actual fuel consumption value as specified in paragraph (f)(1) of this section and 40 CFR 86.1819–14(d)(6)(iii). Advanced technology vehicles can be separated in a different fleet for the purpose of applying credit incentives as described in paragraph (f)(1) of this section.

* * * * *

(f) * * *

(1) * * *

(ii) There are no separate credit allowances for advanced technology vehicles in the Phase 2 program. Instead, vehicle families containing plug-in battery electric hybrids, all-electric, and fuel cell vehicles certifying to Phase 2 standards may multiply credits by a multiplier of:

(A) 3.5 times for plug-in hybrid electric vehicles;

(B) 4.5 times for all-electric vehicles; and

(C) 5.5 times for fuel cell vehicles.

* * * * *

(2) *Innovative and off-cycle technology credits.* This provision allows fuel saving innovative and off-cycle engine and vehicle technologies to generate fuel consumption credits (FCCs) comparable to CO_2 emission credits consistent with the provisions of 40 CFR 86.1819–14(d)(13) (for heavy-duty pickup trucks and vans), 40 CFR 1036.610 (for engines), and 40 CFR 1037.610 (for vocational vehicles and tractors) through MY 2029.

* * * * *

(ii) For model years 2021 through 2029, manufacturers may generate off-cycle technology credits for introducing technologies that are not reflected in the EPA specified test procedures. Upon identification and joint approval with EPA, NHTSA will allow equivalent FCCs into its program to those allowed by EPA for manufacturers seeking to obtain innovative technology credits in a given model year. Such credits must remain within the same regulatory subcategory in which the credits were generated. NHTSA will adopt FCCs depending upon whether—

(A) The technology meets paragraphs (f)(2)(i)(A) and (B) of this section.

(B) For heavy-duty pickup trucks and vans, manufacturers using the 5-cycle test to quantify the benefit of a technology are not required to obtain approval from the agencies to generate results.

* * * * *

(vi) * * *

(B) For model years 2021 through 2029, manufacturers may not rely on an approval for model years before 2021. Manufacturers must separately request the agencies' approval before applying an improvement factor or credit under this section for 2021 through 2029 engines and vehicle, even if the agencies approve the improvement factor or credit for similar engine and vehicle models before model year 2021.

* * * * *

PART 537—AUTOMOTIVE FUEL ECONOMY REPORTS

■ 15. The authority citation for part 537 continues to read as follows:

Authority: 49 U.S.C. 32907; delegation of authority at 49 CFR 1.95.

■ 16. Revise § 537.2 to read as follows:

§ 537.2 Purpose.

The purpose of this part is to obtain information to aid the National Highway Traffic Safety Administration in evaluating automobile manufacturers' plans for complying with average fuel economy standards and in preparing an annual review of the average fuel economy standards.

■ 17. Revise § 537.3 to read as follows:

§ 537.3 Applicability.

This part applies to automobile manufacturers, except for manufacturers subject to an alternate fuel economy standard under 49 U.S.C. 32902(d).

■ 18. Revise § 537.4 to read as follows:

§ 537.4 Definitions.

(a) *Statutory terms.* (1) The terms *average fuel economy standard, fuel, manufacture,* and *model year* are used as defined in 49 U.S.C. 32901.

(2) The term *manufacturer* is used as defined in 49 U.S.C. 32901and in accordance with part 529 of this chapter.

(3) The terms *average fuel economy, fuel economy,* and *model type* are used as defined in subpart A of 40 CFR part 600.

(4) The terms *automobile, automobile capable of off-highway operation,* and *passenger automobile* are used as defined in 49 U.S.C. 32901 and in accordance with the determinations in part 523 of this chapter.

(b) *Other terms.* (1) The term *loaded vehicle weight* is used as defined in subpart A of 40 CFR part 86.

(2) The terms *axle ratio, base level, body style, car line, combined fuel economy, engine code, equivalent test weight, gross vehicle weight, inertia weight, transmission class,* and *vehicle configuration* are used as defined in subpart A of 40 CFR part 600.

(3) The term *light truck* is used as defined in part 523 of this chapter and in accordance with determinations in that part.

(4) The terms *approach angle, axle clearance, brakeover angle, cargo carrying volume, departure angle, passenger carrying volume, running clearance,* and *temporary living quarters* are used as defined in part 523 of this chapter.

(5) The term *incomplete automobile manufacturer* is used as defined in part 529 of this chapter.

(6) As used in this part, unless otherwise required by the context:

(i) *Administrator* means the Administrator of the National Highway Traffic Safety Administration or the Administrator's delegate.

(ii) *Current model year* means:

(A) In the case of a pre-model year report, the full model year immediately following the period during which that report is required by § 537.5(b) to be submitted.

(B) In the case of a mid-model year report, the model year during which that report is required by § 537.5(b) to be submitted.

(iii) *Average* means a production-weighted harmonic average.

(iv) *Total drive ratio* means the ratio of an automobile's engine rotational speed (in revolutions per minute) to the automobile's forward speed (in miles per hour).

■ 19. Amend § 537.7 by revising paragraphs (c)(7)(i) through (iii) to read as follows:

§ 537.7 Pre-model year and mid-model year reports.

* * * * *

(c) * * *

(7) * * *

(i) Provide a list of each air conditioning (AC) efficiency improvement technology utilized in your fleet(s) of vehicles for each model year for which the manufacturer qualifies for fuel consumption improvement values under 49 CFR 531.6 or 533.6. For each technology identify vehicles by make and model types that have the technology, which compliance category those vehicles belong to and the number of vehicles for each model equipped with the technology. For each compliance category (domestic passenger car, import passenger car, and light truck), report the AC fuel consumption improvement value in gallons/mile in accordance with the equation specified in 40 CFI00.510–12(c)(3)(i).

(ii) Manufacturers must provide a list of off-cycle efficiency improvement technologies utilized in its fleet(s) of vehicles for each model year that is pending or approved by the Environmental Protection Agency (EPA) for which the manufacturer qualifies for fuel consumption improvement values under 49 CFR 531.6 or 533.6. For each technology, manufacturers must identify vehicles by make and model types that have the technology, which compliance category those vehicles belong to, the number of vehicles for each model equipped with the technology, and the associated off-cycle credits (grams/mile) available for each technology. For each compliance category (domestic passenger car, import passenger car, and light truck), manufacturers must calculate the fleet off-cycle fuel consumption improvement value in gallons/mile in accordance with the equation specified in 40 CFR 600.510–12(c)(3)(ii).

(iii) For model years up to 2024, manufacturers must provide a list of full-size pickup trucks in its fleet that meet the mild and strong hybrid vehicle definitions. For each mild and strong hybrid type, manufacturers must identify vehicles by make and model types that have the technology, the number of vehicles produced for each model equipped with the technology, the total number of full-size pickup trucks produced with and without the technology, the calculated percentage of hybrid vehicles relative to the total number of vehicles produced, and the associated full-size pickup truck credits (grams/mile) available for each technology. For the light truck compliance category, manufacturers must calculate the fleet pickup truck fuel consumption improvement value in gallons/mile in accordance with the equation specified in 40 CFR 600.510–12(c)(3)(iii).

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Ann Carlson,

Acting Administrator.

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