DEPARTMENT OF TRANSPORTATION

National Highway Traffic Safety Administration

49 CFR Parts 523, 531, 533, 536, and 537

[NHTSA–2025–0491]

RIN 2127–AM76

The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule III for Model Years 2022 to 2031 Passenger Cars and Light Trucks

AGENCY: National Highway Traffic Safety Administration (NHTSA).

ACTION: Notice of proposed rulemaking (NPRM).

SUMMARY: NHTSA, on behalf of the Department of Transportation (DOT), proposes to substantially recalibrate the Corporate Average Fuel Economy (CAFE) program to realign this program with Congressional intent. That recalibration includes proposing to amend DOT's fuel economy standards for light-duty vehicles for model years (MYs) 2022–2026 and MYs 2027–2031. Consistent with statutory requirements, the fuel economy standards proposed in this rule are founded on light-duty vehicles powered by gasoline and diesel fuels, a category that includes non-plug-in hybrid vehicles. In formulating the proposed standards, NHTSA has not considered, consistent with law, the imputed fuel-economy performance of battery-powered electric vehicles (EVs) or the electric operation of vehicles that use plug-in hybrid electric powertrains, nor compliance credits or adjustments to the two-cycle fuel economy test procedures to account for air conditioning and off-cycle technologies. NHTSA also is proposing to eliminate the inter-manufacturer credit trading system and to amend the light-duty vehicle fleet classification system to allocate vehicles into passenger and non-passenger automobile fleets appropriately, based on their attributes and capabilities, starting in MY 2028. Elimination of unlawful considerations, combined with several of the proposed changes, would significantly improve the capabilities of manufacturers to meet fuel economy standards, better align the program with Congressional intent, and reduce manufacturer incentives to design vehicles and add features that are not desired by American consumers and that have questionable real-world fuel economy benefits. NHTSA is therefore proposing to set fuel economy standards that increase from newly proposed MY 2022 standards at a rate of 0.5 percent per year through MY 2026, followed by 0.25 percent per year through MY 2031, with MY 2027 stringency established as a bridge between the two sets of standards. The reduced stringency increases in later years, coupled with a reevaluation of the coefficients that define the functions governing fuel economy standards, are intended to establish maximum feasible standards in a manner that gains real-world fuel-economy-benefits, while enabling the industry to adapt to the proposed substantial recalibration of the CAFE program. NHTSA projects that the amended standards would correspond to the industry fleetwide average for all light-duty vehicles of roughly 34.5 miles per gallon (mpg) in MY 2031.

DATES:

Comments: Comments are requested on or before January 20, 2026. See the **SUPPLEMENTARY INFORMATION** section on ''Public Participation,'' below, for more information about written comments. In compliance with the Paperwork Reduction Act, NHTSA is also seeking comments on a modification of an existing information collection. For additional information, see the Paperwork Reduction Act section under Section VIII below. All comments relating to the information collection requirements should be submitted to NHTSA and to the Office of Management and Budget (OMB) at the address listed in the **ADDRESSES** section on or before 45 days from date of publication.

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 Supplemental Environmental Impact Statement (Draft SEIS) 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: For access to the dockets or to read background documents or comments received, please visit *https://www.regulations.gov,* 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.

Comments on the proposed information collection requirements should be submitted to: Office of Management and Budget at *www.reginfo.gov/public/do/PRAMain.* To find this information collection, select ''Currently under Review—Open for Public Comment'' or use the search function. It is requested that comments sent to the OMB also be sent to the NHTSA rulemaking docket identified in the heading of this document.

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: *CAFE_Mbox@dot.gov.* For legal issues, Hannah Fish, NHTSA Office of Chief Counsel, National Highway Traffic Safety Administration, 1200 New Jersey Avenue SE, Washington, DC 20590; email: *CAFE_Mbox@dot.gov.*

SUPPLEMENTARY INFORMATION:

TABLE OF ACRONYMS AND ABBREVIATIONS

Abbreviation	Term
4WD	Four Wheel Drive.
AC	Air conditioning.
ACME	Adaptive Cylinder Management Engine.
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.
AEB	Automatic Emergency Braking.
AEO	Annual Energy Outlook.

TABLE OF ACRONYMS AND ABBREVIATIONS—Continued

Abbreviation	Term
AER	All-Electric Range.
AERO	Aerodynamic Drag Technology.
AERO0	Base Level Aerodynamic Drag Technology.
AERO5	Aerodynamic Drag, 5% Drag Coefficient Reduction.
AERO10	Aerodynamic Drag, 10% Drag Coefficient Reduction.
AERO15	Aerodynamic Drag, 15% Drag Coefficient Reduction.
AERO20	Aerodynamic Drag, 20% Drag Coefficient Reduction.
AFV	Alternative Fuel Vehicle.
AHSS	Advanced High Strength Steel.
AIS	Abbreviated Injury Scale.
AMFA	Alternative Motor Fuels Act of 1988.
AMPC	Advanced Manufacturing Production Tax Credit.
AMTL	Advanced Mobility Technology Laboratory.
Argonne	Argonne National Laboratory.
ANSI	American National Standards Institute.
APA	Administrative Procedure Act.
AT	Automatic Transmission.
AWD	All-Wheel Drive.
BEV	Battery Electric Vehicle.
BGEPA	Bald and Golden Eagle Protection Act.
BISG	Belt Integrated Starter Generator.
BLS	Bureau of Labor Statistics.
BMEP	Brake Mean Effective Pressure.
BSD	Blind Spot Detection.
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.
CFR	Code of Federal Regulations.
CH_4	Methane.
CNG	Compressed Natural Gas.
CO_2	Carbon Dioxide.
COVID–19	Coronavirus disease of 2019.
CPM	Cost Per Mile.
CR	Compression Ratio.
CVC	Clean Vehicle Credits.
CVT	Continuously Variable Transmission.
CW	Curb Weight.
CY	Calendar Year.
CZMA	Coastal Zone Management Act.
DCT	Dual-Clutch Transmission.
DEAC	Dynamic Cylinder Deactivation.
DMC	Direct Manufacturing Costs.
DOE	U.S. Department of Energy.
DOI	U.S. Department of the Interior.
DOHC	Dual-Overhead Camshaft.
DOT	U.S. Department of Transportation.
DSLI	Advanced Diesel Engine With Improvements.
eCVT	Electronic Continuously Variable Transmissions.
EGR	Exhaust Gas Recirculation.
EIA	U.S. Energy Information Administration.
EISA	Energy Independence and Security Act of 2007
E.O.	Executive Order.
EPA	U.S. Environmental Protection Agency.
EPCA	Energy Policy and Conservation Act of 1975.
ESA	Endangered Species Act.
ETDS	Electric Traction Drive System.
EV	Electric Vehicle.
FCEV	Fuel Cell Electric Vehicle.
FCIV	Fuel Consumption Improvement Value.
FCW	Forward Collision Warning.
FEOC	Foreign entity of concern.
FHWA	Federal Highway Administration.
FIP	Federal Implementation Plan.
FRIA	Final Regulatory Impact Analysis.
FTP	Federal Test Procedure.
FWD	Front-wheel Drive.
FWS	U.S. Fish and Wildlife Service.
GCWR	Gross Combined Weight Rating.

TABLE OF ACRONYMS AND ABBREVIATIONS—Continued

Abbreviation	Term
GDP	Gross Domestic Product.
GES	General Estimates System.
GM	General Motors.
GREET	Greenhouse gases, Regulated Emissions, and Energy use in Transportation.
GVWR	Gross Vehicle Weight Rating.
HCR	High Compression Ratio.
HCRD	High Compression Ratio Engine with Cylinder Deactivation.
HCRE	High Compression Ratio Engine with Cooled Exhaust Gas Recirculation.
HEG	High Efficiency Gearbox.
HEV	Hybrid Electric Vehicle.
HFET	Highway Fuel Economy Test.
HP	Horsepower.
HVAC	Heating, Ventilation, and Air Conditioning.
IAV	Ingenieurgesellschaft Auto und Verkehr.
ICCT	International Council on Clean Transportation.
ICE	Internal Combustion Engine.
ICR	Information Collection Request.
IIHS	Insurance Institute for Highway Safety.
IRA	Inflation Reduction Act.
LCA	Lane Change Assist.
LD	Light-Duty.
LDW	Lane Departure Warning.
LDWF	Light-Duty Work Factor.
LFP	Lithium Iron Phosphate.
LIVC	Late Intake Valve Closing.
LKA	Lane Keep Assist.
MAD	Minimum Absolute Deviation.
MAGICC	Model for the Assessment of Greenhouse Gas Induced Climate Change.
MBTA	Migratory Bird Treaty Act.
MDPCS	Minimum Domestic Passenger Car Standard.
MDPV	Medium-Duty Passenger Vehicle.
MOVES	Motor Vehicle Emission Simulator.
mpg	Miles Per Gallon.
mph	Miles Per Hour.
MR	Mass Reduction.
MR0	Base Level Mass Reduction Technology.
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.
NCE	Non-Criteria Emission.
NEMS	National Energy Modeling System.
NEPA	National Environmental Policy Act.
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.
NTTAA	National Technology Transfer and Advancement Act.
NVO	Negative Valve Overlaps.
gpm	gallons per mile.
OC	Off-Cycle.
OCR	Optical Character Recognition.
OEM	Original Equipment Manufacturer.
OHV	Overhead Valve.
OLS	Ordinary Least Square.
OMB	Office of Management and Budget.
OPEC	Organization of the Petroleum Exporting Countries.
ORNL	Oak Ridge National Laboratory.
PAEB	Pedestrian Automatic Emergency Braking.
PC	Passenger Car.
PEF	Petroleum Equivalency Factor.
PHEV	Plug-in Hybrid Electric Vehicle.
$PM_{2.5}$	Particulate matter 2.5 microns or less in diameter.
PPC	Passive Prechamber Combustion.
ppm	parts per million.
PRA	Paperwork Reduction Act of 1995.
PRIA	Preliminary Regulatory Impact Analysis.
ROLL	Tire Rolling Resistance.

TABLE OF ACRONYMS AND ABBREVIATIONS—Continued

Abbreviation	Term
ROLL0	Base Level Tire Rolling Resistance.
ROLL10	Tire Rolling Resistance, 10% Improvement.
ROLL20	Tire Rolling Resistance, 20% Improvement.
ROLL30	Tire Rolling Resistance, 30% Improvement.
RPE	Retail Price Equivalent.
RPM	Revolutions Per Minute.
RRC	Rolling Resistance Coefficient.
RWD	Rear-Wheel Drive.
SAE	Society of Automotive Engineers.
SEC	Securities and Exchange Commission.
SEIS	Supplemental Environmental Impact Statement.
SGDI	Stoichiometric Gasoline Direct Injection.
SHEV	Strong Hybrid Electric Vehicle.
SHEVPS	Power-Split Strong Hybrid Electric Vehicle.
SI	Spark Ignition.
SIP	State Implementation Plan.
SKIP	Refers to skip input in Market Data Input File.
SOC	State of Charge.
SOHC	Single Overhead Camshaft.
SO_X	Sulfur Oxide.
SS12V	12V Micro Hybrid Start-Stop System.
SUV	Sport Utility Vehicle.
SwRI	Southwest Research Institute.
TAR	Technical Assessment Report.
TS&D	Fuel Transportation, Storage, and Distribution.
TSD	Technical Support Document.
TURBO0	Reference baseline turbocharged downsized technology.
TURBO1	Turbocharged downsized technology.
TURBO2	Advanced turbocharged downsized technology.
TURBOAD	Turbocharged engine with advanced cylinder deactivation.
TURBOD	Turbocharged engine with cylinder deactivation.
TURBOE	Turbocharged engine with cooled exhausted recirculation.
UMRA	Unfunded Mandates Reform Act.
U.S.	United States.
U.S.C	Unites States Code.
VCR	Variable Compression Ratio.
Volpe or Volpe Center	Volpe National Transportation Systems Center.
VMT	Vehicle Miles Traveled.
VSL	Value of a Statistical Life.
VTG	Variable Turbo Geometry.
VTGE	Variable Turbo Geometry (Electric).
VVL	Variable Valve Lift.
VVT	Variable Valve Timing.
VWA	Volkswagen Group of America.
ZEV	Zero Emission Vehicle.

Does this action apply to me?

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

[1] *See* 49 CFR part 523.

Category	NAICS Codes[A]	Examples of Potentially Regulated Entities
Industry	336110 336310 336350	Motor Vehicle & Parts Manufacturers.
Industry	811111 811112 811198 423110	Commercial Importers of Vehicles and Vehicle Components.
Industry	335312 336312 336399 811198	Alternative Fuel Vehicle (AFV) Converters.

[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

The relationship between the light-duty vehicle market and the CAFE program has gone through several cycles over its almost 50-year history. First created to require conservation of petroleum in response to price shocks caused by the Arab oil embargoes of the 1970s, the CAFE program has led not only to the desired improvements in fuel economy but also created unintended responses from vehicle manufacturers—often to the detriment of consumers.

Over the CAFE program's history, separate standards for the passenger car and light truck fleets (referred to by law as passenger automobiles and non-passenger automobiles) have led manufacturers to reshape the market in unanticipated ways—such as by almost eliminating the production of station wagons (passenger cars that generally have more robust cargo capacity, adding mass and reducing fuel economy) in favor of vehicles like minivans and crossover utility vehicles (considered light trucks, and subject to less stringent standards).

Strict mile-per-gallon-based standards in the program's early years also led manufacturers to seek significant reductions in vehicle size and mass, leading to increased injury or fatality risk for occupants of smaller vehicles involved in a crash.[2] NHTSA sought to mitigate these responses by creating attribute-based standards that relate the ''footprint'' size of vehicles to fuel economy, to some positive effect.

Meanwhile, the U.S. Environmental Protection Agency (EPA) started providing special fuel economy adjustments for technologies that had potential for fuel economy improvements but were not measurable using the laboratory test procedures (*i.e.,* the ''two-cycle'' tests) for vehicle fuel economy. This included accommodating adjustments to efficiency values if manufacturers implemented preferred air conditioning (AC) technologies, and if manufacturers installed special technologies with purported fuel-saving benefits that could not be captured on the aforementioned two-cycle tests, accordingly known as ''off-cycle'' (OC) technologies (*e.g.,* vehicle stop/start functions that shut off the engine when the vehicle has stopped). These regulatory adjustments have led to widespread adoption of technologies with uncertain real-world benefits, added costs, and, in many cases, consumer backlash.

The creation of a system for inter-manufacturer credit trading—intended to improve the cost-effectiveness of the CAFE program by allowing manufacturers that could improve the fuel economy of their fleets more cost-effectively to earn credits for exceeding fuel economy standards and sell those credits to manufacturers that would need to incur higher costs to meet fuel economy standards—has also resulted in a windfall for EV-exclusive manufacturers that sell credits to other non-EV manufacturers, which in turn pay for those credits with capital that could be invested toward improving the fuel economy performance or other desirable attributes of their traditional fleets. The enormous fuel economy values assigned to EVs have, heretofore, been included in the baseline fleet fuel economy for subsequent CAFE rulemakings upon which stringency increases are applied—thereby significantly increasing the fuel economy requirements for traditional gasoline- or diesel-fueled fleets.[3]

At the same time, the classification system that has long divided the fleet between passenger cars (intended to

[2] Transportation Research Board and National Research Council, Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, National Academies Press: Washington, DC (2002), available at: *https://nap.nationalacademies.org/catalog/10172/effectiveness-and-impact-of-corporate-average-fuel-economy-cafe-standards* (accessed: Feb. 7, 2024). This report describes at length and quantifies the potential safety problem with average fuel economy standards that specify a single numerical requirement for the entire industry, noting that smaller and lighter vehicles incentivized by those standards could be less safe for their occupants.

[3] In a hypothetical and simplified example, if the baseline passenger car fleet of vehicles with an identical footprint consisted of nine gasoline-powered vehicles achieving 30 mpg and one EV achieving 150 mpg, the baseline fleet to which stringency increases would apply would be measured at 42 mpg. When CAFE standards are set unlawfully considering EV fuel economy, manufacturers of gasoline-powered vehicles would face a challenge in catching up to the overall fleet fuel economy, requiring disproportionate investment in fuel-saving technologies, and incentivizing the purchase of regulatory credits from the EV manufacturer.

move passengers) and light trucks (intended to move cargo or operate off road) no longer lives up to its anticipated use. Indeed, while 68 percent of the light-duty fleet meets the current light truck regulatory definition, the majority of these vehicles (*e.g.,* all-wheel drive (AWD) crossover utility vehicles, vehicles with three or more rows of seating, and vehicles that do not have an approach angle high enough to handle an off-highway obstacle) cannot realistically operate off road and have little value moving cargo. Instead, most of these vehicles are designed and intended primarily to move passengers but have additional features solely to meet regulatory definitions [4]—resulting in little added functionality, reduced fuel economy performance, added cost, and a fairly homogenous design language lacking in creativity.

While the CAFE program was intended to push manufacturers to improve fuel economy while preserving their ability to design and produce vehicles that meet market demands, the system has spun off its axis and requires recalibration. Instead of allowing manufacturers to design and produce vehicles they believe their customers will want and need, while spreading real-world fuel economy improvements across their fleets, the system has increasingly led manufacturers to try to fit square vehicle pegs in round classification holes to force the adoption of technologies that do not meet the demands of American families simply to obtain on-paper fuel economy improvements that may have little basis in reality. All of this adds inefficiency and cost—pushing even more consumers out of an already unaffordable new car market.

By delegation of authority from the Secretary of Transportation (the Secretary), NHTSA is proposing to amend the previously promulgated CAFE standards applicable to passenger and non-passenger automobiles (colloquially referred to as passenger cars and light trucks, and together known as light-duty vehicles) produced for MYs 2022–2026 and MYs 2027–2031. Proposing amended standards beginning with MY 2022 is consistent with the Secretary's direction in the January 28, 2025, memorandum titled ''Fixing the CAFE Program'' and is also the earliest model year for which NHTSA has not concluded CAFE compliance proceedings; additional discussion regarding NHTSA's proposal to amend standards beginning in MY 2022 can be found in Section V.

Consistent with the terms of the CAFE program mandated in the Energy Policy and Conservation Act (EPCA), as amended by the Energy Independence and Security Act (EISA) and other laws (codified in chapter 329 of title 49, United States Code), the fuel economy standards proposed herein are founded on light-duty vehicles powered by gasoline and diesel fuels, a category that includes non-plug-in hybrid vehicles.[5] In formulating the proposed standards, NHTSA has not considered the imputed fuel-economy performance of EVs or the electric operation of plug-in hybrid electric vehicles (PHEVs). This approach marks a change from previous rulemakings, as described above, but brings the CAFE program into compliance with statutory restrictions.

This proposed rule fulfills NHTSA's statutory obligation to set CAFE standards at the maximum feasible level that the agency determines vehicle manufacturers can achieve in each model year, balancing four key factors: technological feasibility, economic practicability, the need of the Nation to conserve energy, and the effect of other Federal regulations on fuel economy.[6] This balancing must take into account current and projected circumstances and cannot consider the availability of alternative fuel technologies (*e.g.,* EVs or PHEV electric operation), or compliance credits.[7] This action is also consistent with Executive Order (E.O.) 14148, ''Initial Rescissions of Harmful Executive Orders and Actions,'' [8] and E.O. 14154, ''Unleashing American Energy,'' [9] as well as the Secretarial memorandum titled ''Fixing the CAFE Program.'' [10]

The standards presented in this proposal significantly differ from those finalized in the 2020, 2022, and 2024 rules because, in formulating those prior standards, NHTSA considered both the fuel economy of EVs and PHEVs and compliance credits that could be earned when a manufacturer over-complied with an applicable fuel economy standard impermissibly. As a result, the fuel economy standards previously established by NHTSA for passenger cars and light trucks for MYs 2022–2031 failed to satisfy substantive statutory requirements. NHTSA is proposing in this NPRM the ''maximum feasible'' amended fuel economy requirements for the model years in question that best reflect and balance the various practical considerations and limitations mandated for the CAFE program.

This rulemaking is intended to establish maximum feasible fuel economy standards while restoring the functionality intended by Congress. It marks a significant reset. As an initial matter, NHTSA proposes to remove consideration of prohibited technologies and credits from every aspect of the standards development process to bring the program back within its statutory constraints. NHTSA discussed extensively its prior unlawful consideration of prohibited technologies and credits in the standards development process in the final rule, *Resetting the Corporate Average Fuel Economy Program,*[11] and includes a more detailed discussion in Section V, below.

NHTSA is proposing to remove consideration of AC efficiency and OC fuel consumption improvement values (FCIVs) from its standard-setting analysis starting with MY 2028, which is the first year in which a removal of FCIVs could go into effect.[12] This change will ensure that NHTSA's CAFE standards are achievable without the implementation of technologies not demanded by consumers and with questionable fuel economy benefits.

The agency also proposes to eliminate the inter-manufacturer credit trading program (which is authorized, but not required, by 49 U.S.C. 32903(f)) beginning with MY 2028. This change in the program is long overdue. While NHTSA does not consider the availability of credits or credit trading in

[4] Section VI discusses NHTSA's proposal to amend regulatory definitions for passenger and non-passenger automobiles in detail and includes examples of manufacturers excluding or including specific features solely to meet regulatory definitions. Two examples discussed in more detail in Section VI include manufacturers discontinuing FWD versions of vehicles after NHTSA properly reclassified over 1 million FWD automobiles as passenger automobiles in line with EPCA and opting to instead manufacture only AWD or 4WD versions to keep more of their products in the non-passenger automobile fleets (74 FR 14196, Mar. 30, 2009), and manufacturers including aerodynamic technologies to increase on-highway functionality instead of opting to meet approach angle requirements, which would make the vehicle more capable of approaching off-highway obstacles and, thus, more off-highway capable.

[5] Non-plug-in hybrid vehicles are not dual-fueled vehicles under Chapter 329 because any electricity generated by the electric motors or other electric components are generated solely by the petroleum-fueled engine and the batteries are incapable of charging from an external source: ''a vehicle which is entirely dependent on a petroleum fuel for its motive power, regardless of whether electricity is used in the powertrain, is powered by petroleum.'' 63 FR 66066 (Dec. 1, 1998).

[6] 49 U.S.C. 32902(a) and (f).

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

[8] 90 FR 8237 (Jan. 28, 2025).

[9] 90 FR 8353 (Jan. 29, 2025).

[10] See DOT, Memorandum: Fixing the CAFE Program (2025), available at: *https://www.transportation.gov/briefing-room/memorandum-fixing-cafe-program* (accessed: Sept. 10, 2025).

[11] 90 FR 24518 (June 11, 2025).

[12] 49 U.S.C. 32904(d).

establishing standards, the agency believes that eliminating inter-manufacturer credit trading will encourage manufacturers to provide for steady improvement in fuel economy across their fleets over time, as opposed to relying upon credits acquired from third-party EV manufacturers. NHTSA recognizes that manufacturers have made investments in particular compliance pathways—pathways that may include purchasing credits from other manufacturers even though the availability of those credits is uncertain—and is proposing this change beginning with MY 2028 to provide manufacturers with adequate transition time, in recognition of any particular reliance interests in the trading program to achieve compliance, before the program ends. However, NHTSA is proposing standards in this notice at levels that do not consider the use of compliance credits, thus minimizing any impacts that this change may have on manufacturers' decisions about compliance pathways. Moreover, this change will not impact automakers' ability to *transfer* earned credits between different categories of vehicles in their own fleets or carry their own credits forwards and backwards across model years, as prescribed by statute.

The agency also proposes a substantial reclassification of the light-duty fleet in a manner intended by Congress in creating the CAFE program—with the passenger car fleet consisting of vehicles primarily designed to move people, and the light truck fleet consisting of vehicles primarily designed to operate off road or move cargo. NHTSA believes these proposed changes are necessary to restore the CAFE program to its intended orbit but recognizes the changes will introduce significant design consideration for manufacturers. Moving a large fraction of vehicles previously classified as light trucks into a manufacturer's passenger vehicle fleet will have a significant effect on the overall fuel economy performance of the manufacturer's passenger fleet—after all, even if based upon the same platform as a passenger car, the additional vehicle height adds significant mass and decreases fuel economy. Meanwhile, removal of vehicles from a manufacturer's light truck fleet will leave that fleet consisting of even heavier and less aerodynamic vehicles, such as large sports utility vehicles and pickup trucks, thereby decreasing the overall average fuel economy of the light truck fleet. Accordingly, while a manufacturer's combined overall fleet fuel economy may remain the same, both its passenger car and light truck fleets will necessarily achieve lower measured fuel economy. NHTSA is also proposing to update the classification criteria from technology-based to performance-based standards where applicable, consistent with best practices for regulation. This proposal intends to take these changes into account through amendments to both the footprint curves and standards applicable to various points within the curves. NHTSA intends that, as a result of this proposed update, automobiles classified as non-passenger will exhibit true non-passenger capabilities that display relevant off-highway vehicle attributes such as approach angle and running clearance or include design features that provide higher payload and towing abilities for transporting property.

By surveying the measured fuel economy performance of gasoline- and diesel-powered passenger cars and light trucks produced for the U.S. market in MY 2022, NHTSA has created a maximum feasible foundation from which to establish standards for subsequent model years. NHTSA is proposing to set fuel economy standards that increase from the newly proposed MY 2022 standards at a rate of 0.5 percent per year through MY 2026 followed by 0.25 percent per year through MY 2031, with MY 2027 stringency as a bridge between the two sets of standards.

In addition to the proposed standards (also referred to as the ''Preferred Alternative'') NHTSA considers a range of regulatory alternatives for each fleet, consistent with the agency's obligations under the Administrative Procedure Act (APA), National Environmental Policy Act (NEPA), and E.O. 12866. The regulatory alternatives are as follows:

Table I-1: Regulatory Alternatives Under Consideration for MYs 2022-2031 Passenger Car and Light Truck CAFE Standards[13]

Name of Alternative	Passenger Car Stringency Changes	Light Truck Stringency Changes
No-Action Alternative	1.5% for MY 2023 8% per year for MYs 2024-2025 10% for MY 2026 2% per year for MYs 2027-2031	1.5% for MY 2023 8% per year for MYs 2024-2025 10% for MY 2026 0% per year for MYs 2027-2028 2% per year for MYs 2029-2031
Alternative 1	80% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.1% for MY 2027 0.3% for MY 2028** 0.25% per year for MYs 2029-2031	80% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.8% for MY 2027 0.6% for MY 2028** 0.25% per year for MYs 2029-2031
Alternative 2 (Preferred)	75% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.35% for MY 2027 0.25% for MY 2028** 0.25% per year for MYs 2029-2031	70% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.7% for MY 2027 0.25% for MY 2028** 0.25% per year for MYs 2029-2031
Alternative 3	70% compliance share* MY 2022 0.50% per year for MYs 2023-2026 1.4% for MY 2027 1.5% for MY 2028** 1% per year for MYs 2029-2031	50% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.4% for MY 2027 0.2% for MY 2028** 1% per year for MYs 2029-2031

* Compliance shares were determined based on the production-weighted share of vehicles that met or exceeded their target function value for each regulatory alternative in MY 2022.
** Stringency change reflects the growth rate in class average standard value from MYs 2027-2028.

NHTSA[13] has concluded tentatively that the levels of standards represented by Alternative 2 are the maximum feasible level for these model years, as discussed in more detail in Section V of this preamble. NHTSA has determined that the proposed standards satisfy the statutory requirements of maximum feasibility across the full range of gasoline- and diesel-powered vehicles currently on the market. These standards will be appropriately stringent in promoting fuel efficiency in the Nation's light-duty vehicle fleet while remaining technologically feasible and economically practicable to achieve without regard to EV dedicated fuel economy or PHEV electric operation. The proposed standards also consider the effect of other Federal regulatory mandates on the fuel economy performance of new motor vehicles, as well as the need of the Nation to conserve energy. NHTSA has tentatively determined that it is both reasonable and congruent with EPCA's energy conservation goals to weigh the need of the United States to conserve energy such that vehicle fuel economy standards require continuous improvements over time, but at sustainable levels for manufacturers, consumers, and society at large. In particular, the diminishing effects attributable to fuel economy improvements from higher standards moderates against weighing the need of the United States to conserve energy too heavily compared to the other statutory factors.[14] Manufacturers have limited supplies of capital for technological advancement and are constrained in recovering those investments by what consumers can afford to pay for technological innovations in new vehicles. Maximum feasible fuel economy standards, when set appropriately weighing economic practicability, should never incentivize manufacturers to add technology that consumers reject at the cost of investments in, or application of, for instance, vehicle safety technologies. Instead, when truly maximum feasible standards apply, manufacturers should be able continually to develop, and apply, both proven fuel-saving and safety-enhancing technologies in such a manner that allows consumers both to desire and to afford the new vehicle.

NHTSA's preliminary conclusion is that this decision best comports with statutory requirements and is justified to reset standards set in final rules issued in 2020, 2022, and 2024, respectively, which were established improperly above the maximum feasible level because NHTSA considered statutorily prohibited factors in establishing those

[13] Percentages in the table represent the year over year reduction in gal/mile applied to the mpg values on the target curves. The reduction in gal/mile results in an increased mpg.

[14] As an example, a vehicle owner who drives a light vehicle 15,000 miles per year and trades in a vehicle with fuel economy of 15 mpg for one with fuel economy of 20 mpg, will reduce their annual fuel consumption from 1,000 gallons to 750 gallons—saving 250 gallons annually. If, however, that owner trades in a vehicle with fuel economy of 30 mpg for one with fuel economy of 40 mpg, then the owner's annual gasoline consumption would drop from 500 gallons/year to 375 gallons/year—a fuel savings of only 125 gallons even though the mpg improvement is twice as large. Going from 40 to 50 mpg would save only 75 gallons/year. Yet each additional fuel economy improvement becomes much more expensive as the easiest to achieve low-cost technological improvement options are exhausted.

standards.[15] Those rules resulted in distortions in the marketplace, which this proposed rule would minimize. These distortions include major non-market-based changes in automobile designs and the introduction of fundamental alterations in their production processes not primarily driven by market demand.

Increasing the stringency of standards at modest annual rates, following a reset to eliminate the consideration of impermissible factors that were applied in setting the current standards, and coupled with a re-examination of the shape of the fuel economy target functions and the vehicle classification definitions, best comports with statutory requirements. Moreover, the level, shape, and applicability of the standards to the proposed passenger and non-passenger automobile fleets are justified by the inappropriate distortions the existing regulations have caused in the marketplace. Those regulations resulted in unnecessary regulatory burdens that did not further statutory purposes because the standards were not attainable for the gasoline- and diesel-powered vehicle fleet.

The proposed CAFE standards remain vehicle-footprint-based, like the current CAFE standards in effect since MY 2011. 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. This means that the standards are defined by mathematical equations that represent constrained linear functions relating vehicle footprint to fuel economy targets for passenger cars and light trucks.[16] For this proposal, NHTSA has updated the mathematical functions (*i.e.,* the target curves relating footprint to fuel economy) for passenger cars and light trucks based on the latest available data. NHTSA has concluded preliminarily, based on this data, that the relationship between footprint and fuel economy has shifted from MY 2008 (the model year on which the current curves are based) and it is thus appropriate to modify the mathematical functions accordingly. NHTSA has also updated the functions that would be applied beginning in MY 2028 to reflect changes based on the proposed reclassified fleet.

NHTSA estimates that the proposed standards would correspond to a combined industry fleetwide average of roughly 34.5 mpg in MY 2031 for passenger cars and light trucks.[17] NHTSA notes that this is a projection, since the actual CAFE standards are the footprint target curves for passenger cars and light trucks. This is important because it means that the ultimate fleetwide levels will vary depending on the mix of vehicles that manufacturers produce for sale in those model years. NHTSA also calculates and presents ''estimated achieved'' fuel economy levels, which differ somewhat from the estimated required levels for each fleet, for each year.[18] Note that the industry-average required and achieved values presented below reflect the end of manufacturers' ability to claim AC and FCIV adjustments, beginning in MY 2028, and updated vehicle classification regulatory definitions, which are also applicable beginning in MY 2028.

For simplification, NHTSA provides industry-wide mpg estimates corresponding to the proposed standards in the table below but reiterates that the coefficients that define the mathematical functions comprise the actual standards.

[15] 85 FR 24174 (Apr. 30, 2020); 87 FR 25710 (May 2, 2022); 89 FR 52540 (June 24, 2024).

[16] 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.

[17] NHTSA notes both that real-world fuel economy is generally 20–30 percent lower than the estimated required CAFE level stated above, since 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) must use the same procedures used for MY 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, AC 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 United States, effective with MY 2008 vehicles.

[18] NHTSA's analysis reflects that almost all manufacturers make the technological improvements prompted by CAFE standards at times that coincide with existing product ''refresh'' and ''redesign'' cycles, rather than unrealistically 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. See the Draft TSD and preamble Section II for additional discussion about manufacturer refresh and redesign cycles.

Table I-2: Estimated Required Average and Estimated Achieved Average of CAFE Levels (mpg) for Passenger Cars and Light Trucks, Preferred Alternative[19]

Model Year	2022[a]	2023[a]	2024	2025[b]	2026[b]	2027	2028[c]	2029	2030	2031
Passenger Car										
Required[d]	36.0	36.0	36.5	36.6	36.8	36.9	37.1	37.2	37.3	37.4
Achieved	39.5	39.2	43.2	-	-	54.3	45.5	45.9	46.1	46.3
Light Truck										
Required[d]	27.7	27.7	27.9	28.0	28.1	28.3	28.4	28.5	28.5	28.6
Achieved	29.8	29.7	32.7	-	-	38.6	31.1	31.5	31.8	32.1
Total LD Fleet										
Required[d]	31.2	29.8	30.1	30.4	30.4	30.4	34.2	34.4	34.4	34.5
Achieved	32.7	32.1	35.4	-	-	42.2	40.4	40.8	41.1	41.3

a: Achieved values do not include the effects of AC and FCIV adjustments.
b: Production for model years not complete. Achieved values neither included nor estimated.
c: Achieved values decline due to removal of AC and FCIV adjustments. Regulatory class achieved values decline due to effects of reclassification.
d: Based on compliance data for MYs 2022-2024. Projected forward for later years using the CAFE Model. MYs 2025-2026 determined using the baseline projection of the fleet in these years and the proposed standards. MYs 2027-2031 determined using the Preferred Alternative's fleet projection and the proposed standards.

To the extent that manufacturers appear to be over-complying with required fuel economy levels in MY 2027, NHTSA notes that this is due to factors including previous application of fuel economy technologies required by standards set improperly for prior model years that unlawfully considered prohibited alternative fuel (*e.g.,* EV) technology applications. Once the program is restored to its intended strictures and standards are established that consider all statutory factors and limitations appropriately, manufacturers that previously applied technologies to meet exaggerated requirements will have relief, while manufacturers that faced certain penalties can continue to improve efficiency to meet maximum feasible standards. NHTSA's review of achieved compliance at the manufacturer level also shows that, while some manufacturers manage to achieve greater over-compliance, other manufacturers are expected to achieve compliance values that will track the levels of the new standards more closely. In addition, NHTSA believes that the proposed standards established for model years prior to the significant MY 2028 fleet reclassification will allow manufacturers to plan strategically with sufficient lead time to manage that transition within their projected model year sales cycles. For all fleets, average requirements and average achieved CAFE levels will depend ultimately on manufacturer and consumer response to standards, technology developments, economic conditions, fuel prices, and other factors.

NHTSA is also proposing new minimum domestic passenger car CAFE standards (MDPCS) for MYs 2022–2026 and MYs 2027–2031 as required by EISA, which are applied to passenger cars that are deemed to be 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 model year; these standards are shown in Table I–3 below. NHTSA continues to apply an offset (albeit a far smaller one than was first used in the 2020 final rule and applied to the 2022 and 2024 final rules) when calculating the MDPCSs for MYs 2027–2031, reflecting prior differences between passenger car footprints forecast originally by the agency and passenger car footprints as they occurred in the real world. The proposed minimum domestic passenger car standards (MDPCS) for each model year are as shown in the table below.

Table I-3: Minimum Domestic Passenger Car Standard (mpg)

2022	2023	2024	2025	2026	2027*	2028*	2029*	2030*	2031*
33.1	33.1	33.5	33.7	33.9	33.8	33.9	34.0	34.0	34.1

*Includes 0.7 percent offset

[19] There is no 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.

NHTSA uses the CAFE Compliance and Effects Modeling System (the CAFE Model) developed and maintained by the Volpe National Transportation Systems Center (Volpe Center or Volpe) as a tool for assessing the likely regulatory effects of the proposal and various regulatory alternatives. The Model does not determine which standards satisfy the requirements of EPCA, and no model can predict precisely the engineering configurations automakers are likely to introduce in response to evolving trends in market demand. However, the analysis developed using the CAFE Model provides further support for NHTSA's preliminary judgment that the standards proposed in this rule are the maximum standards that are technologically feasible and economically practicable for the gasoline- and diesel-powered vehicles covered by the proposed rule, considering the effect of other motor vehicle standards of the Government on fuel economy, and the need of the United States to conserve energy.

One significant modification from previous standard-setting proceedings and previous applications of the CAFE Model is that NHTSA did not include EVs in the base fleet for analysis purposes and did not consider or model the potential production of EVs as a CAFE compliance strategy for automakers. Section 32902 of chapter 49 directs NHTSA to establish fuel economy standards that are feasible and practicable for gasoline- and diesel-powered vehicles without regard to any reliance on non-gasoline- or diesel-powered alternatives. Automakers, of course, are free to produce EVs in response to market demand, and their production and sale of EVs will earn credit toward compliance with the CAFE standards in accordance with the "petroleum equivalency factor," or "PEF," prescribed by the Department of Energy (DOE).[20]

Additional updates to the CAFE Model and its inputs since the 2024 final rule include updating the Market Data Input File to reflect the change in analysis fleet from MYs 2022–2024, updating the modeling capability to allow for vehicle reclassification, updating the Scenarios Input File to set the value of civil penalties at zero,[21] updating the Parameters Input File to set the monetary value of changes in non-criteria emissions at zero, updating other economic values, such as rebound elasticity and the payback periods, and updating fuel price projections using the 2025 Annual Energy Outlook's (AEO) Alternative Transportation Case. These and other updates are described in more detail in Section II and the Draft TSD.

NHTSA estimates that this proposed rule would reduce the average up-front vehicle costs due to CAFE standards by approximately $900, cutting in half what consumers might expect to pay as a result of increased requirements under the No-Action Alternative. NHTSA also estimates that this rule will be net beneficial economically for society. The tables below summarize estimates of selected impacts viewed from both the MY and calendar year (CY) perspectives,[22] for each of the regulatory alternatives, relative to the No-Action Alternative.

Table I-4: Estimated Monetized Costs and Benefits – Passenger Cars and Light Trucks – MY and CY Perspectives by Alternative and Discount Rate[23]

	Alt. 1		Alt. 2 (Preferred Alternative)		Alt. 3	
Monetized Benefits ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1985-2031	-85.2	-53.9	-85.1	-53.8	-73.5	-46.5
CYs 2024-2050	-291.2	-157.4	-291.1	-157.4	-256.5	-138.4
Monetized Costs ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1985-2031	-109.2	-76.1	-109.1	-76.0	-97.1	-67.7
CYs 2024-2050	-393.9	-219.6	-393.8	-219.5	-353.8	-197.2
Monetized Net-Benefits ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1985-2031	24.0	22.2	24.0	22.2	23.7	21.2
CYs 2024-2050	102.8	62.1	102.8	62.1	97.3	58.8

[20] 49 U.S.C. 32904(a)(2)(B); Public Law 96–185, 93 Stat. 1324 (1980). *https://www.congress.gov/96/statute/STATUTE-93/STATUTE-93-Pg1324.pdf*; 10 CFR part 474.

[21] *See* Public Law 119–21, 139 Stat. 72 (July 4, 2025). *https://www.congress.gov/119/plaws/publ21/PLAW-119publ21.pdf.*

[22] The bulk of the analysis for passenger cars and light trucks presents a "model year" perspective rather than a "calendar year" perspective. The model year perspective considers the lifetime impacts attributable to all passenger cars and light trucks produced through MY 2031, accounting for the operation of these vehicles over their entire lives (with some MY 2031 vehicles estimated to be in service as late as 2050). This approach emphasizes the role of the model years for which new standards are being proposed. The calendar year perspective, on the other hand, includes the annual impacts attributable to all vehicles estimated to be in service in each calendar year for which the analysis includes a representation of the entire registered light-duty fleet. For this proposed rule, this calendar year perspective covers each of CYs 2024–2050. Compared to the model year perspective, the calendar year perspective includes model years of vehicles produced in the longer term, beyond those model years for which standards are being proposed.

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

The current estimates of costs and benefits are important considerations, performed as directed by E.O. 12866, and also serve as an informative data point in NHTSA's consideration of the factors that NHTSA is required to balance by statute when determining maximum feasible standards. NHTSA concludes, for the purposes of this proposal, that Alternative 2 is maximum feasible on the basis of these respective factors. NHTSA also considered several sensitivity cases by varying different inputs and concluded that, even when varying inputs resulted in changes to net benefits, those changes were not significant enough to alter the tentative conclusion that Alternative 2 is maximum feasible.

Finally, NHTSA has computed ''annualized'' benefits and costs relative to the No-Action Alternative, as follows:

Table I-5: Estimated Annualized Monetized Costs and Benefits – Passenger Cars and Light Trucks – MY and CY Perspectives by Alternative and Discount Rate[24]

	Alt. 1		Alt. 2 (Preferred Alternative)		Alt. 3	
Monetized Benefits ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1985-2031	-3.4	-3.9	-3.4	-3.9	-2.9	-3.4
CYs 2024-2050	-15.9	-13.1	-15.9	-13.1	-14.0	-11.5
Monetized Costs ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1985-2031	-4.4	-5.6	-4.4	-5.6	-3.9	-4.9
CYs 2024-2050	-21.5	-18.3	-21.5	-18.3	-19.3	-16.4
Monetized Net Benefits ($billion)						
	3% DR	7% DR	3% DR	7% DR	3% DR	7% DR
MYs 1985-2031	1.0	1.6	1.0	1.6	0.9	1.6
CYs 2024-2050	5.6	5.2	5.6	5.2	5.3	4.9

Though NHTSA is prohibited from considering the availability of certain flexibilities in making its determination about the levels of CAFE standards that would be maximum feasible, manufacturers have a variety of flexibilities available to aid their compliance. NHTSA is proposing certain changes to these flexibilities and other features of the CAFE program as shown in Table I–6, and as described further in Section VI of this preamble.

BILLING CODE 4910–59–P

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

Table I-6: Overview of Changes to CAFE Program

Fleet Performance Requirements			
Component	**Applicable Regulation (Statutory Authority)**	**General Description**	**Proposed Changes in NPRM**
Fuel Economy Standards	49 CFR 531.5 and 49 CFR 533.5 (49 U.S.C. 32902)	Fuel economy standards are footprint-based fleet average standards for each of a manufacturer's compliance category (i.e., domestic passenger automobile, import passenger automobile, and non-passenger automobile), which are expressed in miles per gallon (mpg). NHTSA sets average fuel economy standards that are the maximum feasible for each compliance category and model year (i.e., passenger automobiles and non-passenger automobiles). 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.	Amendments to 49 CFR 531.5(a) and 49 CFR 533.5(a) to set standards for MYs 2022-2026 and MYs 2027-2031.
Vehicle Classification	49 CFR part 523	Standards are set for two regulatory categories (i.e., passenger automobiles and non-passenger automobiles). Vehicles are assigned to either the passenger automobile or non-passenger automobile categories based on definitions in EPCA, as implemented through definitions and specific criteria in NHTSA's regulations.	Amendments to 49 CFR part 523 to amend the criteria for non-passenger automobiles.
Minimum Domestic Passenger Car Standards	49 CFR 531.5 (49 U.S.C. 32902(b)(4))	Domestic passenger automobile fleets are required to meet a MDPCS. This standard applies in addition to the footprint-based standard.	Amendments to 49 CFR 531.5(b) to set MDPCS for MYs 2022-2026 and MYs 2027-2031.
Determining Average Fleet Performance			
Component	**Applicable Regulation (Statutory Authority)**	**General Description**	**Proposed Changes in NPRM**
2-Cycle Testing	49 CFR 531.6(a) citing 40 CFR part 600 and 49 CFR 533.6 citing 40 CFR part 600	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).	None

	(49 U.S.C. 32904)		
AC Efficiency FCIVs	49 CFR 531.6(b)(1) citing 40 CFR 86.1868-12 and 49 CFR 533.6(c)(1) citing 40 CFR 86.1868-12 (49 U.S.C. 32904)	This adjustment to the results of the 2-cycle testing 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 for NHTSA. Starting in MY 2027, AC efficiency FCIVs may only be generated by internal combustion engine (ICE) vehicles.	NHTSA is removing consideration of FCIVs from its standard-setting analysis beginning in MY 2028. NHTSA is also proposing technical amendments to 49 CFR 531.6 and 533.6 to remove references to EPA's regulations for AC efficiency FCIVs.
OC FCIVs	49 CFR 531.6(b)(2) and (3) citing 40 CFR 86.1869-12 and 49 CFR 533.6(c)(3) and (4) citing 40 CFR 86.1869-12 (49 U.S.C. 32904)	This adjustment to the results of the 2-cycle testing for fuel consumption improvement from technologies that are not accounted for or not fully accounted for in the 2-cycle testing. The OC FCIV program began in MY 2017 for NHTSA. Starting in MY 2027, OC FCIVs may only be generated by ICE vehicles, with the program phasing out and in ending with MY 2032 under EPA's current regulations.	NHTSA is removing consideration of FCIVs from its standard-setting analysis beginning in MY 2028. NHTSA is also proposing technical amendments to 49 CFR 531.6 and 533.6 to remove references to EPA's regulations for OC FCIVs.
Advanced Full-Size Pickup Truck FCIVs	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 full-size pickup trucks equipped with hybridized or other performance-based technologies. Manufacturers were eligible to earn these adjustments in MYs 2017-2021 and MYs 2023-2024.	None
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 DOE (*see* 10 CFR 474.3) (per 49 U.S.C. 32904(a)(2)).	None
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 for the portion of power energy consumption from the different energy sources. For EVs, EPA uses DOE's petroleum equivalency factor for the electric portion of the vehicle's expected energy use (per 49 U.S.C. 32904(a)(2). Starting in MY 2020 and subject to statutory limit, the average fuel economy of certain dual-fueled vehicles cannot increase a manufacturer's average fuel economy.	None
Earning and Using Credits for Over-compliance 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	None

		exceeds the applicable fuel economy standard, multiplied by the number of vehicles sold in that compliance category (i.e., fleet).	
Carry-Forward Credits	49 CFR part 536 (49 U.S.C. 32903(a)(2))	Manufacturers may carry forward credits up to five model years into the future.	None
Carry-Back Credits	49 CFR Part 536 (49 U.S.C. 32903(a)(1))	Manufacturers may carry back credits up to three model years into the past.	None
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 MDPCS (*see* 49 U.S.C. 32903(g)(4) and 49 CFR 536.9).	None
Credit Trading	49 CFR 536.8 (49 U.S.C. 32903(f))	Manufacturers may trade over-compliance 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 MDPCS (*see* 49 U.S.C. 32903(f)(2) and 49 CFR 536.9).	Amendments to 49 CFR 536.6 and 536.8 to reflect that beginning in MY 2028 credit trading will no longer be allowed.
Civil Penalties	49 CFR 578.6(h) (49 U.S.C. 32912)	Civil penalties may be assessed for CAFE credit shortfalls that are not resolved through credit flexibilities. Pub. L. 119-21 set civil penalties for the CAFE program to $0 starting in MY 2022.	None[25]

BILLING CODE 4910–59–C

The following sections of this preamble discuss the technical foundation for NHTSA's analysis, the regulatory alternatives considered in this proposed rule, 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 for this action consists of this proposed rule, a Draft Technical Support Document (Draft TSD), a Preliminary Regulatory Impact Analysis (PRIA), and a Draft SEIS, along with extensive analytical documentation, supporting references, and many other resources. Most of these resources are available on NHTSA's website,[26] 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. NHTSA seeks comment on all aspects of this proposal and seeks comment on particular topics where indicated in each Section.

II. Technical Foundation for the NPRM Analysis

A. Why is NHTSA conducting this analysis?

When NHTSA promulgates new regulations or amends its existing regulations, it generally presents an analysis that estimates the impacts of those regulations, including the impacts of other regulatory alternatives it considered during the rulemaking. These analyses derive from statutes such as the APA[27] and the National Environmental Policy Act (NEPA),[28] from Executive orders (such as E.O. 12866),[29] and from other administrative guidance (*e.g.,* Office of Management and Budget (OMB) Circular A–4).[30] For this analysis in particular, EPCA contains several requirements governing the scope and nature of fuel economy standard setting.[31] Among these, some have been in place since EPCA was first signed into law in 1975, some were added in the Alternative Motor Fuels Act of 1988 (AMFA)[32] and in the Energy Policy Act of 1992,[33] and others were added in 2007 when Congress

[25] DOT will update the CAFE civil penalties regulations in 49 CFR 578.6(h) to reflect the statutory amendment in section 40006 of Public Law 119–21 in the next DOT-wide annual civil penalties update rulemaking.

[26] See NHTSA, Corporate Average Fuel Economy, Last revised: 2023, *https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy* (accessed: Sept. 10, 2025).

[27] Codified in 5 U.S.C. 551–559.

[28] Codified in 42 U.S.C. 4321–4347.

[29] Regulatory Planning and Review, 58 FR 51735 (Oct. 4, 1993).

[30] Office of Management and Budget, Circular A–4 (Sept. 17, 2003), available at: *https://www.whitehouse.gov/wp-content/uploads/2025/08/CircularA-4.pdf* (accessed Sept. 10, 2025).

[31] Public Law 94–163, 89 Stat. 871 (Dec. 22, 1975). *https://www.govinfo.gov/content/pkg/STATUTE-89/pdf/STATUTE-89-Pg871.pdf.*

[32] Public Law 100–494, 102 Stat. 2441 (Oct. 14, 1988). *https://www.govinfo.gov/content/pkg/STATUTE-102/pdf/STATUTE-102-Pg2441.pdf.*

[33] Public Law 102–486, 106 Stat. 2776 (Oct. 24, 1992). *https://www.govinfo.gov/content/pkg/STATUTE-106/pdf/STATUTE-106-Pg2776.pdf.*

passed the EISA.[34] Most recently, One Big Beautiful Bill Act (OB3) amended EPCA's civil penalty provisions.[35]

These statutes contain a variety of requirements for which NHTSA seeks to account in its analysis. NHTSA captures all of these requirements by presenting 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 various express statutory requirements for the CAFE program (*e.g.,* passenger cars and light trucks must be regulated separately; and the standard for each fleet must be set at the maximum feasible level in each model year). NHTSA's standards are thus supported by, though not dictated by, extensive analysis of potential impacts of the regulatory alternatives under consideration. Together with this preamble, a Draft TSD, a PRIA, and a Draft SEIS provide a detailed enumeration of related analysis methods, estimates, assumptions, and results. These additional analyses can be found in the rulemaking docket for this proposed rule and on NHTSA's website.[36] [37]

This section provides further detail on the key features and components of NHTSA's standard-setting (also known as ''constrained'') analysis. NHTSA's standard-setting analysis reflects statutory limitations on what NHTSA can consider when determining maximum feasible CAFE standards. In determining maximum feasible fuel economy levels, ''the Secretary of Transportation—(1) may not consider the fuel economy of dedicated automobiles; (2) shall consider dual fueled automobiles to be operated only on gasoline or diesel fuel; and (3) may not consider, when prescribing a fuel economy standard, the trading, transferring, or availability of credits.'' [38] NHTSA also conducts an ''unconstrained'' CAFE Model analysis to evaluate, as required by NEPA, the reasonably foreseeable environmental effects of its proposed action and a reasonable range of alternatives that meet the purpose and need for the proposed action.[39] The technical assumptions for EIS simulations are discussed in the Draft EIS Appendix C.

This section also describes how NHTSA's analysis has been constructed specifically to reflect other governing law applicable to CAFE standards, reviews how NHTSA's analysis has been updated to represent relevant statutory provisions more closely, and describes additional technical work recently conducted by the agency. The analysis for this proposed rule aids NHTSA in implementing its statutory obligations, including the weighing of various considerations, by informing decision-makers about the estimated effects of 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 are unknown or 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 ''reference fleet'' containing, among other things, production volumes and fuel economy levels of specific configurations of specific vehicle models produced for sale in the United States. 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'' factor, 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).

In coordination with the DOT Volpe National Transportation Systems Center (Volpe or the Volpe Center), NHTSA uses the CAFE Compliance and Effects Modeling System (CAFE Model or the Model) to simulate and analyze manufacturers' potential responses to new CAFE standards and to estimate various impacts of those responses. NHTSA has used the CAFE Model to perform analyses supporting every CAFE rulemaking since 2001. Working together, NHTSA and Volpe ensure that the CAFE Model's operation reflects the statutory directives discussed in more detail in Section II below.

The CAFE Model first estimates how vehicle manufacturers might respond to a given regulatory scenario; from that potential compliance solution, the system estimates what impact that response will have on fuel consumption, emissions, safety impacts, and economic externalities. The following section summarizes information necessary to understand the analysis, while Draft TSD Chapter 2 and the CAFE Model Documentation present additional details on the Model's operation.

The CAFE Model may be characterized as an integrated system of models that estimate the impact of various policy options. 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). Importantly, the modeling system does not determine the form or stringency of the standards, which must be developed in consideration of statutory factors that must be balanced by policy-makers. Instead, the CAFE 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 and light truck regulatory classes, and stringency of the standards for each model year to be analyzed. For example, a regulatory scenario may define 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.[40] The compliance simulation then attempts to bring each

[34] Public Law 110–140, 121 Stat. 1492 (Dec. 19, 2007). *https://www.govinfo.gov/content/pkg/STATUTE-121/pdf/STATUTE-121-Pg1492.pdf.*

[35] Public Law 119–21, 139 Stat. 72 (July 4, 2025). *https://www.congress.gov/119/plaws/publ21/PLAW-119publ21.pdf.*

[36] Docket Nos. NHTSA–2025–0491; NHTSA–2025–0490.

[37] See NHTSA, Corporate Average Fuel Economy, Last revised: 2023, available at: *https://www.nhtsa.gov/laws-regulations/corporate-average-fuel-economy* (accessed: Sept. 10, 2025).

[38] 49 U.S.C. 32902(h).

[39] 42 U.S.C. 4332.

[40] 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 proposed rule is available on NHTSA's website at *https://www.nhtsa.gov/corporate-average-fuel-economy/cafe-compliance-and-effects-modeling-system.*

manufacturer into compliance with the standards defined by the regulatory scenario contained within an input file developed by the user.

Estimating impacts involves calculating resulting changes in new vehicle costs, estimating a variety of costs (*e.g.,* for fuel expenditures or reduced or increased technology costs) and effects (*e.g.,* gallons of fuel used by the fleet) 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, operating costs, and vehicle price on consumer demand for light-duty vehicles). Both basic analytical elements involve the application of many inputs. Many of these inputs are developed outside of the Model and not by the Model. For example, the Model applies fuel price projections from DOE; it does not estimate fuel prices.

NHTSA also uses EPA's Motor Vehicle Emission Simulator (MOVES) model to estimate ''vehicle'' or ''downstream'' emission factors for criteria pollutants [41] and uses four DOE and DOE-sponsored models to develop inputs to the CAFE Model, including three developed and maintained by DOE's Argonne National Laboratory (Argonne). The agency uses the National Energy Modeling System (NEMS) of DOE's Energy Information Administration (EIA) to estimate fuel prices [42] and uses Argonne's Greenhouse gases, Regulated Emissions, and Energy use in Transportation (GREET) Model to estimate emissions rates from fuel production and distribution processes.[43] DOT also sponsors Argonne to run its Autonomie full-vehicle modeling and simulation system to estimate the fuel economy impacts for over a million combinations of technologies and vehicle types.[44] The Draft TSD and PRIA describe details of the agency's use of these models. In addition, as discussed in the Draft SEIS accompanying this proposed rule, NHTSA relied on a range of models to estimate various environmental impacts.

To prepare for the analysis that supports this proposed rule, DOT has continued to refine and expand the capabilities of the CAFE Model. As examples, and as discussed in more detail below, the reference fleet uses mid-MY 2024 compliance data (the most recent available data at the time of the analysis) and includes the capability (in addition to capabilities integrated into the modeling system) to account for proposed changes to the regulatory vehicle classification definitions. The analysis also employs separate input files for the modeling runs that NHTSA uses for its standard-setting analysis, which excludes the 49 U.S.C. 32902(h) factors that NHTSA cannot consider (constrained analysis), and the modeling runs that NHTSA uses for its analysis of impacts under the National Environmental Policy Act, which does not exclude the 49 U.S.C. 32902(h) factors (unconstrained analysis), and those input files have been updated accordingly. Common to both analyses are routine updates to dollar year values (*e.g.,* 2021$ to 2024$) or routine updates to gas price projections. Some other updates, like updates to manufacturer credit banks, are confined to the unconstrained analysis only and are discussed further in the Draft SEIS Appendix C. The values of many inputs remain uncertain, and NHTSA has conducted sensitivity analyses around selected inputs to attempt to capture some of that uncertainty. These changes reflect DOT's long-standing commitment to ongoing refinement of its approach to estimating the potential impacts of new CAFE standards. These and other updated analytical inputs are outlined in Section II below and discussed in detail in the Draft TSD and PRIA.

2. How do statutory requirements shape NHTSA's analysis?

Multiple requirements govern the scope and nature of CAFE standard setting; the specific requirements regarding the technical characteristics of CAFE standards and the analysis thereof include, but are not limited to, the following:

Corporate Average Standards: 49 U.S.C. 32902 requires that standards apply to the average fuel economy levels achieved by each manufacturer's fleet of vehicles produced for sale in the United States. The CAFE Model calculates the average fuel economy of each manufacturer's fleet based on estimated production volumes and characteristics, including fuel economy levels of distinct vehicle models that could be produced for sale in the United States.

Separate Standards for Passenger and Non-Passenger Automobiles: 49 U.S.C. 32902 requires DOT to set CAFE standards separately for passenger and non-passenger automobiles. The CAFE Model accounts separately for passenger and non-passenger automobiles, including differentiated standards and compliance.

Attribute-Based Standards: 49 U.S.C. 32902 requires DOT to define CAFE standards for passenger and non-passenger automobiles as mathematical functions expressed in terms of one or more attributes related to fuel economy. This means that, for a given manufacturer's fleet of vehicles produced for sale in the United States in a given regulatory class and model year, the applicable minimum CAFE requirement (*i.e.,* the numerical value of the requirement) is computed based on the applicable mathematical function as well as 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: 49 U.S.C. 32902 requires DOT to set CAFE standards (separately for passenger and non-passenger automobiles) at the maximum feasible levels in each model year. The CAFE Model represents each model year explicitly and accounts for the production relationships between model years. For example, a new engine first applied to a given vehicle model/configuration in MY 2030 most likely will be retained in MY 2031 for that same vehicle model 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 this reality, while still respecting applicable statutory constraints.

Separate Compliance for Domestic and Imported Passenger Car Fleets: 49 U.S.C. 32904 requires EPA to determine average fuel economy separately for each manufacturer's fleet of domestic passenger cars and imported passenger

[41] See *https://www.epa.gov/moves.* This proposed rule uses version MOVES5 (the latest version at the time of analysis), available at *https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves.*

[42] See *https://www.eia.gov/outlooks/aeo/.* This proposed rule uses fuel prices estimated using the Annual Energy Outlook (AEO) 2025 version of NEMS. See *https://www.eia.gov/outlooks/aeo/tables_ref.php.*

[43] Information regarding GREET is available at *https://greet.anl.gov/.* This proposed rule uses the R&D GREET 2023 version.

[44] As part of the Argonne simulation effort, individual technology combinations simulated in Autonomie were paired with Argonne'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 Argonne's BatPaC model is available at *https://www.anl.gov/cse/electrochemical-chemical-TEA.* 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/.*

cars. A passenger car is considered to be domestic or imported based on the definitions provided in 49 U.S.C. 32904. The CAFE Model accounts explicitly for this requirement when simulating manufacturers' potential responses to CAFE standards.

Minimum CAFE Standards for Domestic Passenger Car Fleets: 49 U.S.C. 32902 requires that domestic passenger car fleets also meet a minimum CAFE standard, which is calculated as 92 percent of the average fuel economy projected by the Secretary for the combined passenger car fleet manufactured for sale in the United States by all manufacturers in the model year. This projection is published at the time the standard is promulgated. The CAFE Model accounts explicitly for this requirement.

Statutory Basis for Stringency: 49 U.S.C. 32902 requires DOT to set CAFE standards for passenger and non-passenger automobiles at the maximum feasible levels, considering technological feasibility, economic practicability, the need of the U.S. to conserve energy, and the impact of other motor vehicle standards of the Government on fuel economy. The analysis and balancing of these factors necessarily changes in light of current and projected economic and market conditions. Accordingly, NHTSA has continued to expand and refine its qualitative and quantitative analysis to account for these statutory factors in light of such conditions. For example, the simulations of technology effectiveness reflect the agency's judgment that it would not be economically practicable, appropriate, or cost effective for a manufacturer to ''split'' an engine shared among many vehicle models/configurations into myriad versions each optimized to a single vehicle model/configuration.

Civil Penalties for Noncompliance: 49 U.S.C. 32912 (and implementing regulations) prescribe a rate (in dollars per tenth of a mile per gallon (mpg)) at which the Secretary is to levy civil penalties if a manufacturer fails to comply with a CAFE standard for a given fleet in a given model year. When civil penalties are applicable (*i.e.,* when they are not set by statute to a value of $0, as they have been at the time of this analysis of the proposed rule), the CAFE Model will calculate civil penalties for CAFE shortfalls (if directed to do so by the user). However, as stated, civil penalty values are currently set by statute to a value of $0; therefore, the CAFE Model's calculations will always result in zero civil penalties.

Dual-Fueled and Dedicated Alternative Fuel Vehicles: For purposes of calculating CAFE standards used to determine passenger and non-passenger automobile fleet compliance, 49 U.S.C. 32905 and 32906 specify methods for calculating the fuel economy levels of vehicles operating on alternatives to gasoline or diesel fuels. The CAFE Model can account for these requirements explicitly for each relevant vehicle model. However, 49 U.S.C. 32902 also prohibits consideration of the fuel economy of dedicated alternative fuel vehicle (AFV) models (or the non-gasoline or non-diesel calculated fuel economy of dual-fueled AFVs) when NHTSA determines what levels of passenger and non-passenger automobile CAFE standards are maximum feasible. Therefore, the CAFE Model is run in a manner that excludes dedicated AFV technologies and limits the consideration of a dual-fueled AFV's fuel economy to only its gasoline or diesel operation. NHTSA operates the Model with this limitation when performing the analysis that is used to inform the setting of standards. The CAFE Model can also be run without this analytical constraint, and the agency does so in the NEPA analysis described below.

Creation and Use of Compliance Credits: 49 U.S.C. 32903 provides that manufacturers may earn CAFE ''credits'' by achieving an average fuel economy level beyond that required of a given fleet in a given model year 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'' a maximum of five model years, ''carried back'' a minimum of three model years, transferred between regulated classes, and traded between manufacturers. However, credit use is also subject to specific limits: the statute caps the amount of credit that can be transferred between a manufacturer's fleets and prohibits manufacturers from applying traded or transferred credits to offset a failure to achieve the minimum standard for domestic passenger automobiles. The CAFE Model has the capability to simulate manufacturers' potential use of credits carried forward from prior model years or transferred from other fleets; [45] however, this capability is not used in the standard-setting analysis because 49 U.S.C. 32902 prohibits consideration of manufacturers' potential application of CAFE compliance credits when setting maximum feasible CAFE standards for passenger and non-passenger automobiles.

National Environmental Policy Act (NEPA): The Draft SEIS accompanying this proposed rule documents changes in fuel use and emissions as estimated using the CAFE Model and also documents corresponding estimates—based on the application of other models documented in the Draft SEIS—of environmental impacts of the regulatory alternatives under consideration.

3. What updated capabilities and assumptions does the current Model reflect as compared to the version used in the analysis of the 2024 final rule?

DOT has continued its ongoing effort to refine and expand the capabilities of the CAFE Model for use in analyzing regulatory alternatives as considered in this proposal. Any analysis of regulatory actions that will be implemented several years in the future, and whose benefits and costs accrue over decades, requires many assumptions. Over such time horizons, many, perhaps even most, of the relevant assumptions in such an analysis are inevitably uncertain. To help address this, NHTSA updates the assumptions used in each successive CAFE analysis to reflect the current state of the world more accurately and to apply the best current estimates of future conditions. Accordingly, since the 2024 final rule, DOT has made the following changes to the CAFE Model and its inputs:

- Updating the Market Data Input File to reflect the change in analysis fleet from MYs 2022–2024;
- Updating algorithms and settings to remove statutorily prohibited inputs from the standard-setting analysis and to select between different types of analyses (*i.e.,* constrained and unconstrained);
- Updating the base dollar year from 2021$ to 2024$;
- Updating the capability to exclude plug-in hybrid electric vehicle (PHEV) electricity usage when PHEV fuel economy operation is in gasoline-only mode for standard setting;

[45] Note that the CAFE Model does not simulate the potential for manufacturers to carry CAFE credits back (*i.e.,* borrow) from future model years or acquire and use CAFE compliance credits from other manufacturers. NHTSA believes that there is significant uncertainty in 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 1 year may ''coast'' through several subsequent years relying on that prior improvement rather than continuing to make technology improvements year after year, it is harder to assume with confidence that manufacturers will rely on future technology investments to offset prior-year shortfalls, or whether and how manufacturers will trade credits with market competitors rather than make their own technology investments.

• Updating the modeling capability to allow for vehicle reclassification;
• Updating the Market Data Input File to include vehicle reclassification;
• Updating the Model to use a bracketed costing approach to determine prices for the five levels of mass reduction (MR);
• Updating the Scenarios Input File to remove AC and OC FCIVs;
• Updating the Market Data Input File to include advanced truck credits for MY 2024 vehicles, noting that those credits sunset after MY 2024 and are therefore only applicable to that one year;
• Updating the Parameters Input File to set the social cost of carbon at zero;
• Updating the Parameters Input File for changes in other economic variables;
• Updating the Scenarios Input File with an adjusted tax credit phase-out timeframe;
• Updating the Scenarios Input File to set civil penalties to zero;
• Updating selected economic assumptions:
  ○ Rebound elasticity;
  ○ Payback period;
  ○ Value of travel time per vehicle; and
  ○ Numerous other updates based on the 2025 AEO; and
• Updating emission rates based on EPA's ''MOVES5'' model.

These and other updated analytical inputs are discussed in the remainder of this section and in detail in the Draft TSD.

B. What is NHTSA analyzing?

NHTSA is analyzing the effects of different potential CAFE standards on industry, consumers, and society at large. These different potential standards are described as ''regulatory alternatives,'' and, amongst the regulatory alternatives, NHTSA identifies which ones the agency is proposing to select. 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.[46] Thus, the 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.

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 an average fuel economy standard for each year that is unique to each of its regulatory fleets (*i.e.,* passenger automobiles and non-passenger automobiles, consistent with 49 U.S.C. 32902(b)), based on the footprint and production volumes of the vehicle models produced by that manufacturer. The functions are negatively sloped, so that larger vehicles (*i.e.,* vehicles with larger footprints) will generally be subject to lower mpg targets than smaller vehicles. This is because smaller vehicles are typically more capable of achieving higher levels of fuel economy, because they tend not to require as much energy to propel the mass necessary to perform their driving task. Although a manufacturer's fleet average standard could be estimated throughout the model year based on the projected production volume of its vehicle fleet (and is estimated as part of EPA's certification process), the standards with which the manufacturer must comply are determined by its final model year production figures. A manufacturer's calculation of its fleet average standards, as well as its fleets' average performance at the end of the model year, will thus be based on the production-weighted average target and performance of each model in its fleet.[47]

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

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

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

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

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

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

Where:

TARGET$_{FE}$ is the fuel economy target (in mpg) applicable to a specific vehicle model type with a unique footprint combination, and
a, b, c, and *d* are as for passenger cars, but take values specific to light trucks.

Though the general model of the target function equation is the same for passenger cars and light trucks, and the

[46] 49 U.S.C. 32902(a)(3)(A).

[47] 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.

same for each model year, the parameters of the function equation differ for cars and trucks.

The parameters defining the general curve shapes have remained the same since the 2012 final rule. NHTSA periodically reconsiders whether to update the mathematical functions but in each prior instance concluded that the existing curves continued to represent the relationship between footprint and fuel economy reasonably. Consistent with the agency's past practice of reviewing the mathematical functions prior to each rulemaking, NHTSA re-examined the curve shapes for this proposal.

More specifically, NHTSA performed descriptive statistical analyses using manufacturer-reported data for the MY 2022 and MY 2024 fleets. NHTSA used the MY 2022 fleet for analysis of curve shapes relevant to the MYs 2022–2027 standards and used the MY 2024 ''reclassified'' fleet for analysis of curve shapes relevant to the MYs 2028–2031 standards. As discussed in more detail in Draft TSD Chapter 1, the proposed updates to NHTSA's vehicle classification regulations beginning in MY 2028 have material impacts on the relationship between fuel economy and footprint for each regulatory class, as expressed by the standards-defining functions.

To estimate the relationship between fuel economy and footprint and to maintain general consistency with analyses of past rules (and the conformance to statutory prohibitions), the agency excluded all diesel engine vehicles and all plug-in electric vehicles, which include plug-in hybrid electric vehicles, battery electric vehicles (BEV), and fuel cell electric vehicles (FCEV), and applied weighting and other adjustments to the fuel consumption and footprint data. Table II–1 summarizes the methodological approaches that NHTSA considered for reassessing the footprint curves.

Table II-1: Summary of Methodological Approaches Considered for Assessing Footprint Curves

Category	Type	Description	Key Considerations
Regression types	Ordinary Least-Squares (OLS)	Regression solution that minimizes squared errors	Describes the average relationship between footprint and fuel economy; outliers receive additional weight.
	Minimum Absolute Deviation (MAD)	Regression solution that minimizes absolute errors	Describes the median relationship between footprint and fuel economy; does not give outliers as much weight as OLS.
Datapoint weighting	Production weights	Data weighted by production volumes of each vehicle model	High production, mass-market vehicles have a greater influence on the footprint curve form than vehicles with lower production levels.
	Model weights	Each vehicle model receives equal weighting	Estimates treat all vehicle model lines equally and therefore measures footprint curves based on vehicle model offerings (i.e., ignores the effect of sales volume).
Vehicle technology levels	Existing technology	Analysis dataset contains information on current observed technology in the baseline fleet	Represents the existing market, including demand factors; retains existing heterogeneity in technology application across the fleet.
	Simulated maximum technology[48]	Analysis dataset derived from simulation modeling that assumes maximum allowable technology, with multiple candidates for technology limits.	Represents the "engineering" relationship between fuel consumption and footprint by limiting heterogeneity in current technology application across the fleet (i.e., this represents the technology frontier for the current fleet).
Controls	Curb weight (CW) to footprint	Removes variation in fuel consumption caused by above/below average CW-to-footprint.	Limits noise in the observed relationship between fuel consumption and footprint that is introduced by manufacturers optimizing other attributes (e.g., increased acceleration); accounts for some of the variation by body style.
	Horsepower (HP) to CW	Removes variation in fuel consumption caused by above/below average HP-to-CW.	
	Both	Removes variation in fuel consumption caused by above/below average CW-to-footprint and HP-to-CW.	

[48] The maximum technology fleet was simulated with the CAFE Model, assuming a MY 2024 fleet and maximum allowable technology application.

NHTSA believes that the ordinary least-squares (OLS) regression framework continues to be an appropriate method for estimating the relationship of footprint to fuel economy. While the agency relied on the minimum absolute deviation (MAD) regression framework in the 2010 final rule to address the effects of ''outlier'' vehicles in the fleet, the agency addresses outlier vehicles in this reconsideration through technology-based exclusions (*i.e.,* by excluding diesels, PHEVs, BEVs, and FCEVs, as mentioned above) and data normalization through the application of controls, including curb weight (CW) to footprint, horsepower (HP) to CW, and both together, depending on the regulatory fleet under consideration, as it has in each of its CAFE rulemaking actions since 2012. The curves also reflect updated fleet data to reset the ''cutpoints,'' or the places at the lowermost and uppermost bounds of vehicle footprint distributions where the standards remain flat (*i.e.,* the mpg target does not continue to increase as footprint decreases, and vice versa). The resulting footprint curves are shown in Section III's discussion of the regulatory alternatives.

As discussed in Draft TSD Chapter 1, NHTSA considers a variety of technical and policy issues when determining the footprint curve shape in any CAFE rulemaking action. For example, standards that decrease sharply with increasing footprint could create incentives for manufacturers to upsize vehicles, since small changes in vehicle footprint would result in a significant change in the vehicle's fuel economy target; conversely, flatter standards could create a significant amount of additional technology burden for larger vehicles to meet fuel economy targets like those of smaller vehicles. That said, NHTSA performed an analysis for the 2024 final rule showing that vehicle footprints, within vehicle types, have been stable on a sales-weighted basis since MY 2012.[49] The biggest increase to within-type footprints was for the sedan/wagon category, which increased by 3.4 percent (or about 2 square feet) from 2012 (for reference, a 1.5-square foot increase would equate to about a 2-inch increase in the track width of a MY 2022 Toyota Corolla). NHTSA concluded that the disconnect between vehicle class-level characteristics and what was being perceived at the fleet level (*i.e.,* vehicles seemingly getting larger) was traceable to the increase in the share of fleet vehicles classified as light trucks relative to the share of passenger cars. Available data indicate that the use of footprint as an attribute did not appear to lead to manufacturers significantly altering the size of their vehicles within vehicle classes and that the major shift in fleet share was not a result of the shape of the footprint curves.

The footprint curve updates for this proposal are intended to ensure that the agency appropriately captures the footprint-to-fuel economy relationship using the most current data. As discussed in Draft TSD Chapter 1, the observed relationship between footprint and fuel economy for both the passenger car and light truck fleets is on average ''flatter'' (*i.e.,* on average, the fuel economy did not vary as much across footprint levels) than the MY 2008 fleet used to create the footprint curves for the past several rules. While the technical concerns and policy trade-offs associated with the curve shapes still hold to some extent, NHTSA believes it is more likely, as shown from the agency's 2024 analysis and the updated analysis presented in Section VI, that any shift in vehicle attributes present in the market over time has not been due to the shapes of curves or the use of footprint as the relevant attribute. NHTSA seeks comments on this belief, as well as the updated footprint curve shape analysis, discussed in more detail in Draft TSD Chapter 1.

Finally, the required CAFE level applicable to a passenger car (either domestic or import) or light truck fleet in a given model year 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.

Equation II–3: Calculation for Required CAFE Level

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

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 United States, and

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

Additional details about the specific values defining the mathematical functions and visual representations of the fuel economy target curves are presented in Section III, below.

C. What inputs does the compliance analysis require?

The first step in the agency's analysis of the effects of different levels of fuel economy standards is the compliance simulation. As used throughout this rulemaking, ''compliance simulation'' means the simulation of how manufacturers could comply with different levels of CAFE standards by adding fuel economy-improving technology to an existing fleet of vehicles, using the CAFE Model. The CAFE Model uses a variety of data, including data provided by manufacturers, to simulate final fleet sales and performance.[50]

At the most basic level, a model is a set of equations, algorithms,[51] or other calculations used to make predictions about a complex system. A model may consider various inputs, such as technology costs or other relevant factors, and use those inputs to generate output predictions. NHTSA used two separate approaches for which it is proposing to amend the existing CAFE standards, one for MYs 2022–2026 and one for MYs 2027–2031. The sections

[49] NHTSA, Technical Support Document: Corporate Average Fuel Economy Standards for Passenger Cars and Light Trucks for Model Years 2027 and Beyond and Fuel Efficiency Standards for Heavy-Duty Pickup Trucks and Vans for Model Years 2030 and Beyond, NHTSA: Washington, DC, pp. 1–20 (2024).

[50] When NHTSA uses the phase ''the Model'' throughout this section, NHTSA is referring to the CAFE Model. Any other model is specifically named.

[51] See Merriam-Webster ''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.

below discuss the inputs each of those analyses used.

1. What inputs does the analysis require for 2022–2026?

For the MYs 2022–2026 analysis, NHTSA has performed two exercises: first, it has re-evaluated the statistical model used to determine the shape (*i.e.,* slope, intercept, and cutpoints) of the target functions for passenger cars and light trucks. Based on its preferred choice of shape, NHTSA has evaluated the compliance position of manufacturers in MYs 2022–2024 under alternative stringencies and compared results to the manufacturers' achieved average fuel economy in these years. For both exercises, NHTSA relies on compliance data from manufacturer mid-year compliance reports. For its curve fitting analysis, NHTSA uses vehicle model level data on vehicle attributes, including footprint, HP, CW, and 2-cycle fuel economy. NHTSA also uses mid-year estimates of model sales from manufacturer compliance data for this exercise. NHTSA's curve fitting analysis is described in greater detail in Draft TSD Chapter 1. For NHTSA's comparison of achieved fuel economy and proposed standards levels, the agency uses compliance data at the model level for vehicle footprint, 2-cycle fuel economy, and mid-year estimates of vehicle sales.

For MYs 2022–2024, NHTSA uses each proposed standard to calculate vehicle model target function values for each vehicle model in the standard-setting fleet.[52] Consistent with past rulemakings, the agency uses piecewise linear functions of vehicle footprint, which map to a target value of fuel consumption rate in gallons-per-mile.[53] NHTSA determines a vehicle's target fuel economy level in miles per gallon for a given set of standards, and then takes the reciprocal of this value. NHTSA determines the CAFE standards for each manufacturer at the regulatory class level under each alternative by taking the sales-weighted harmonic mean of the relevant models produced by the manufacturer in each regulatory class in each model year. The agency repeats these calculations for each model year under consideration to determine a single value for each regulatory class in which the manufacturer produced vehicles.

NHTSA also computes the MDPCS for each model year by taking the sales-weighted harmonic mean of the model-level target function values for all vehicles in the passenger car fleet in that model year and multiplying the value by 92 percent.[54]

NHTSA determines each manufacturer's achieved fuel economy in miles per gallon separately for each regulatory class using the sales-weighted average of the 2-cycle fuel economy values of all models produced by the manufacturer in the relevant regulatory class. NHTSA then compares this achieved value to the corresponding manufacturer regulatory class standard in each model year to determine whether the fleet of vehicles to which it corresponds would comply with each proposed standard in that model year. To determine the total number of vehicles out of compliance, NHTSA determines compliance for each manufacturer's regulatory fleet in each model year under each proposed alternative, and if a fleet is determined to be out of compliance, the agency sums the total number of vehicles sold in the non-compliant fleet.

As discussed in more detail in Section IV, NHTSA analyzes the difference between each manufacturer's fleet CAFE compliance value and the proposed standard. NHTSA has considered using the CAFE Model to simulate behavior for the MYs 2022–2026 compliance period to estimate how manufacturers and consumers could have responded to different CAFE standards. However, for MYs 2022–2025, production is already closed or is in process, and MY 2026 production plans likely are solidified and underway by the time of this NPRM's publishing. This type of analysis overestimates the ability of manufacturers to optimize in response to the proposed standards for these years and likely leads to different results from the actual outcomes. Thus, simulating a response and any monetized costs or benefits deriving from that do not represent real economic effects from the proposed change in policy.

2. What inputs does the compliance analysis require for 2027–2031?

For the MYs 2027–2031 amendment analysis, NHTSA used the CAFE Model to simulate manufacturers' potential responses to new CAFE standards and to estimate the various impacts of those responses on manufacturers and society. The Model considers various inputs, such as technology effectiveness data, technology costs, and other relevant factors, and uses those inputs to generate output predictions.

NHTSA attempts to ensure that the technology inputs and assumptions that go into the CAFE Model are based on sound science and reliable data and that NHTSA's 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 the agency generates the technology inputs and assumptions that the CAFE Model uses for the compliance simulation.[55] The Draft TSD, CAFE Model Documentation, CAFE Analysis Autonomie Documentation,[56] and other technical reports supporting this proposed rule discuss the agency's technology inputs and assumptions in more detail.

NHTSA incorporates technology inputs and assumptions either directly in the CAFE Model or in the CAFE Model's various input files. The compliance simulation algorithm is at the heart of the CAFE Model's decisions about how to apply technologies to a manufacturer's vehicles to project how the manufacturer could meet CAFE standards. The compliance simulation algorithm consists of several equations that direct the Model to apply fuel economy-improving technologies to vehicles in a way that simulates 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 manufacturers' vehicles now and what technology could be applied to their vehicles in the future. Embedded in the CAFE Model is the universe of technology options that the Model can consider and rules about the order in which it can consider those options, as well as estimates of how effective fuel economy-improving technology is on different types of vehicles (*e.g.,* sedan or pickup truck).

[52] Per 49 U.S.C. 32902(h), dedicated alternative fueled vehicles, such as EVs, are excluded from this analysis. For duel-fueled vehicles, the analysis uses a fuel economy value for the vehicles operating only on gasoline or diesel fuel. *Id.*

[53] See Chapter 1.2 of the Draft TSD discussing footprint functions.

[54] 49 U.S.C. 32902(b)(4).

[55] As explained throughout this section, a NHTSA input is a specific number or datapoint used by the Model, and NHTSA's 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 NHTSA's modeling.

[56] The Argonne 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.''

Technology inputs and assumptions are also located in all four of the CAFE Model Input Files. The Market Data Input File is a spreadsheet file that characterizes the fleet of vehicles used as the starting point for the CAFE Model. There is one row describing each vehicle model and model configuration manufactured for the United States market in a model year (or years) and input and assumption data that links those vehicles to technology and economic, environmental, and safety inputs and assumptions. The Technologies Input File identifies 71 technologies the agency uses in the analysis, along with information used to inform the compliance simulation and effects estimates, including phase-in caps to identify when and how widely each technology can be applied to specific types of vehicles, most of the technology costs (hybrid vehicle battery costs are provided in a separate file), and the fuel share percentage for PHEV to capture the charge sustaining operation. The Scenarios Input File provides the coefficient values defining the standards for each regulatory alternative [57] and other relevant information applicable to modeling each regulatory scenario.[58] Finally, the Parameters Input File contains mainly economic and environmental data.[59]

NHTSA generates these technology inputs and assumptions in several ways, including using data submitted by vehicle manufacturers pursuant to their CAFE reporting obligations; 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 Argonne; and research, testing, and modeling with independent organizations, like IAV GmbH Ingenieurgesellschaft Auto und Verkehr (IAV), Southwest Research Institute (SwRI), National Academy of Sciences (NAS), and FEV North America. NHTSA also considers the work done to develop inputs and assumptions for prior rules to the extent it is still relevant and applicable; feedback from stakeholders on prior rules and from meetings conducted before the commencement of this proposed rule; and NHTSA's own engineering judgment. NHTSA uses the term ''engineering judgment'' throughout this rulemaking to refer to decisions made by a team of NHTSA 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, the agency uses engineering judgment to assess how best to represent vehicle manufacturers' potential responses to different levels of CAFE standards within the boundaries of the agency's modeling tools, as ''a model is meant to simplify reality in order to make it tractable.'' [60] In other words, NHTSA uses engineering judgment to concentrate potential technology inputs and assumptions from millions of discrete data points from hundreds of sources into four external input files and three datasets integrated into the CAFE Model. How the CAFE Model decides to apply technology (*i.e.,* the compliance simulation algorithm), has been developed using engineering judgment, considering factors that manufacturers consider when they add technology to vehicles in the real world. The specific technology inputs and assumptions are discussed in more detail in the following sections and in the associated technical documentation.

a. Technology Options and Pathways

NHTSA begins 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 U.S. market.[61] These are technologies that the agency believes are representative of what vehicle manufacturers currently use on their vehicles, and that vehicle manufacturers could use on their vehicles in the timeframe for the proposed standards (MYs 2027–2031). The technology options include engines, transmissions, hybridization, and road load technologies, which include MR, aerodynamic improvement (aerodynamic drag technology (AERO)), and tire rolling resistance (ROLL) reduction technologies.[62]

Adding a technology to the range of options that the CAFE Model can consider requires several data elements, including a broadly applicable technology definition, estimates of how effective that technology is at improving fuel economy on different vehicle types (*e.g.,* sedan or pickup truck), and the cost to apply that technology to each. Each technology the agency selects is designed to be representative of a wide range of specific technology applications used in the automotive industry. Some manufacturers' systems may perform better or worse than NHTSA's modeled systems, and some may cost more or less than NHTSA's modeled systems. However, selecting representative technology definitions for the agency's analysis ensures the agency captures a reasonable level of costs and benefits that would result from any manufacturer applying the technology.

NHTSA has been refining the technology options it considers since first developing the CAFE Model in 2002. In this context, ''refining'' means both adding and removing technology options depending on current technology availability and projected future availability in the U.S. market, while balancing a reasonable amount of modeling and analytical complexity. In recent years, the agency has refined the internal combustion engine (ICE) technology options, particularly the TURBO and HCR pathways, to reflect better the diversity of engines in the current fleet. Consistent with NHTSA's interpretation of EPCA/EISA, discussed further in Section II.0 and V, the agency includes several hybrid technologies to represent appropriately the diversity of current and anticipated future technology options while ensuring NHTSA's analysis remains consistent with statutory limitations prohibiting the consideration of EVs in establishing standards and considering only the gas or diesel operation of dual fueled automobiles.

The technology options do not include technologies NHTSA has determined will not be available in the rulemaking timeframe. As with past analyses, the agency does not include technologies unlikely to be feasible in the rulemaking timeframe, engine technologies designed for markets other than the United States market required to use unique gasoline,[63] or technologies

[57] The coefficient values are defined in PRIA Chapter 3 for the CAFE standard.

[58] This file also includes information about the amount of fuel consumption improvement values a manufacturer may generate for compliance purposes for model years in which a manufacturer may generate them.

[59] See CAFE Model Documentation for a detailed discussion of what inputs are held in each of the input data files.

[60] Chem. Mfrs. Ass'n v. EPA, 28 F.3d 1259, 1264–65 (D.C. Cir. 1994) (citing Milton Friedman, in Friedman, M., The Methodology of Positive Economics, in Essays in Positive Economics 3, University of Chicago Press: Chicago, IL, pp. 14–15 (1953), available at: *https://www.wiwiss.fu-berlin.de/fachbereich/bwl/pruefungs-steuerlehre/loeffler/Lehre/bachelor/investition/Friedman_the_methology_of_positive_economics.pdf* (accessed: Sept. 10, 2025)).

[61] 40 CFR 86.1806–17, Onboard diagnostics; 40 CFR 86.1818–12, Greenhouse gas emission standards for light-duty vehicles, light-duty trucks, and medium-duty passenger vehicles; Commission Directive 2001/116/EC—European Union emission regulations for new LDVs—including passenger cars and light commercial vehicles (LCV).

[62] Draft TSD Chapter 3 contains discussion on the technology tree and technologies available.

[63] In general, most vehicles produced for sale in the United States have been designed to use ''regular'' gasoline, or 87 octane. See EIA, Gasoline

for which appropriate data are not available for the range of vehicles that the agency models in the analysis (*i.e.,* technologies that are still in the research and development phase and not ready for mass-market production). Each technology section below and Chapter 3 of the Draft TSD discuss these modeling decisions in detail.

In this analysis, 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 NHTSA estimates the costs and benefits for different levels of CAFE standards based on a simulation of the technology manufacturers could apply in the rulemaking timeframe, it is entirely possible and reasonable that manufacturers may use different technology options to meet the agency's standards in the real world and may even use technologies that NHTSA does not include in the analysis. This is because NHTSA's standards do not mandate the application of any particular technology. Rather, NHTSA's standards are performance-based: manufacturers in the real world can and do use a range of compliance solutions that include technology application and encouraging sales shifts from one vehicle model or trim level to another.[64] The agency has determined that the 71 technology options included in the analysis strike a reasonable balance between representing the diversity of technology used by the entire industry and simplifying reality to make modeling workable.[65]

Chapter 3 of the Draft TSD and Section II.0 below describe the technologies that NHTSA uses for the analysis. Each technology has a name that loosely corresponds to its real-world technology equivalent. NHTSA abbreviates the name to a short signifier for the CAFE Model to read. The agency organizes those technologies into groups based on technology type: basic and advanced engines, transmissions, hybridization, and road load technologies, which include MR, aerodynamic improvement, and low rolling resistance tire technologies.

NHTSA then organizes the groups into pathways. The pathways instruct the CAFE Model how and in what order to apply technology. In other words, the pathways define mutually exclusive technologies (*i.e.,* those 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. The respective technology chapters in the Draft TSD and Section 4 of the CAFE Model Documentation include a visual of each technology pathway. In general, the paths are tied to ease of implementation of additional technology and how closely related the technologies are.

As an example, NHTSA's ''Turbo Engine Path'' consists of five different engine technologies that employ different levels of turbocharging technology. A turbocharger is essentially a small turbine 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 cylinders. Having more air in the engine's cylinders allows the engine to burn more fuel, which then creates more power, without needing a physically larger engine. In the agency's analysis, an engine that is turbocharged ''downsizes,'' or becomes smaller. Choosing to turbocharge an engine allows a manufacturer to maintain similar levels of performance to a larger, non-turbocharged engine with a smaller engine that uses less fuel to do the same amount of work. Allowing basic engines to be downsized and turbocharged instead of just turbocharged keeps the vehicle's utility and performance constant so that NHTSA can measure the costs and benefits of different levels of fuel economy improvements, rather than the change in different vehicle attributes. This concept of performance neutrality is discussed further, below.

The Model only allows forward movement along the technology pathways, adding more advanced technology as the Model moves through the technology tree. This ensures that a vehicle that uses a more advanced technology cannot downgrade to a less advanced version of the technology or ensures that a vehicle does not switch to technology that is significantly technically different. This progressive order also realistically represents how manufacturers often start with the lowest and most cost-effective technologies and generally advance along particular technology pathways. 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.[66] Similarly, this vehicle with a TURBOD engine cannot adopt an advanced cylinder deactivation on a dual-overhead camshaft engine (ADEACD) engine.[67] As an example of NHTSA's rationale for ordering technologies on the technology tree, 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 likely would require a different engine block that might not fit in the engine bay of the vehicle without a complete redesign and different technical expertise requiring years of research and development. This change, which would strand capital and impact parts sharing, is why the advanced engine paths restrict most movement between them. The concept of stranded capital is discussed further in Section II.C.2.f.

NHTSA also considers two categories of technology, for model years in which the technology categories are applicable, that the agency could not simulate as part of the CAFE Model's technology pathways. ''Off-cycle'' and AC efficiency are two types of technologies that improve vehicle fuel economy but are not accounted for using 2-cycle testing. To account for the benefits of these technologies, EPA has allowed manufacturers to generate FCIVs when they add these technologies, which are used to improve a manufacturers' certified fuel economy. As an example, manufacturers can generate FCIVs for technology like active seat ventilation and solar reflective surface coatings that make the cabin of a vehicle more comfortable for the occupants without using less efficient accessories like heat or AC. Instead of including OC and AC efficiency technologies in the technology pathways, NHTSA includes the improvement as a defined benefit that gets applied to a manufacturer's entire fleet in applicable model years instead of to individual vehicles. The defined benefit that each manufacturer receives in the analysis for using OC and AC efficiency technology on their vehicles is located in the Market Data

Explained: What is octane?, Last revised: Nov. 17, 2022, available at: *https://www.eia.gov/energyexplained/gasoline/octane-in-depth.php* (accessed: Sept. 10, 2025).

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

[65] For each technology option, the analysis includes distinct technology cost and effectiveness values for 10 different types of vehicles, resulting in nearly half a million different technology effectiveness and cost data points.

[66] TURBO0 is the baseline turbocharged engine and TURBOD is TURBO0 with the addition of cylinder deactivation (DEAC). Chapter 3 of the Draft TSD provides more discussion on engine technologies.

[67] ADEACD is a dual-overhead camshaft engine with advanced cylinder deactivation. Chapter 3 of the Draft TSD provides more discussion on engine technologies.

Input File. Chapter 3.7 of the Draft TSD provides more discussion on how OC and AC efficiency technologies are developed and modeled. Preamble Section VI contains discussion of this program's updates in this rule.

To illustrate how NHTSA simulates technology application, throughout this section NHTSA follows the hypothetical vehicle mentioned above that begins the compliance simulation with a TURBOD engine. The agency's 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, the agency determines that it has technology that loosely fits within the following technologies that the agency considers 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. NHTSA tracks the technologies on each vehicle using a ''technology key,'' which is the string of technology abbreviations for each vehicle. The vehicle technologies and their abbreviations that the agency considers in this analysis are shown in Draft TSD Chapter 2. The technology key for the Ravine Runner F Series is ''TURBOD; AT10L2; SS12V; ROLL0; AERO5; MR3.''

b. Defining Manufacturers' Current Technology Positions in the Analysis Fleet

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 the fleet of vehicle models each manufacturer produced for sale in the United States for MY 2024. This provides the starting point from which the CAFE Model adds fuel economy-improving technology. NHTSA calls this fleet the ''analysis fleet.'' The analysis 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.

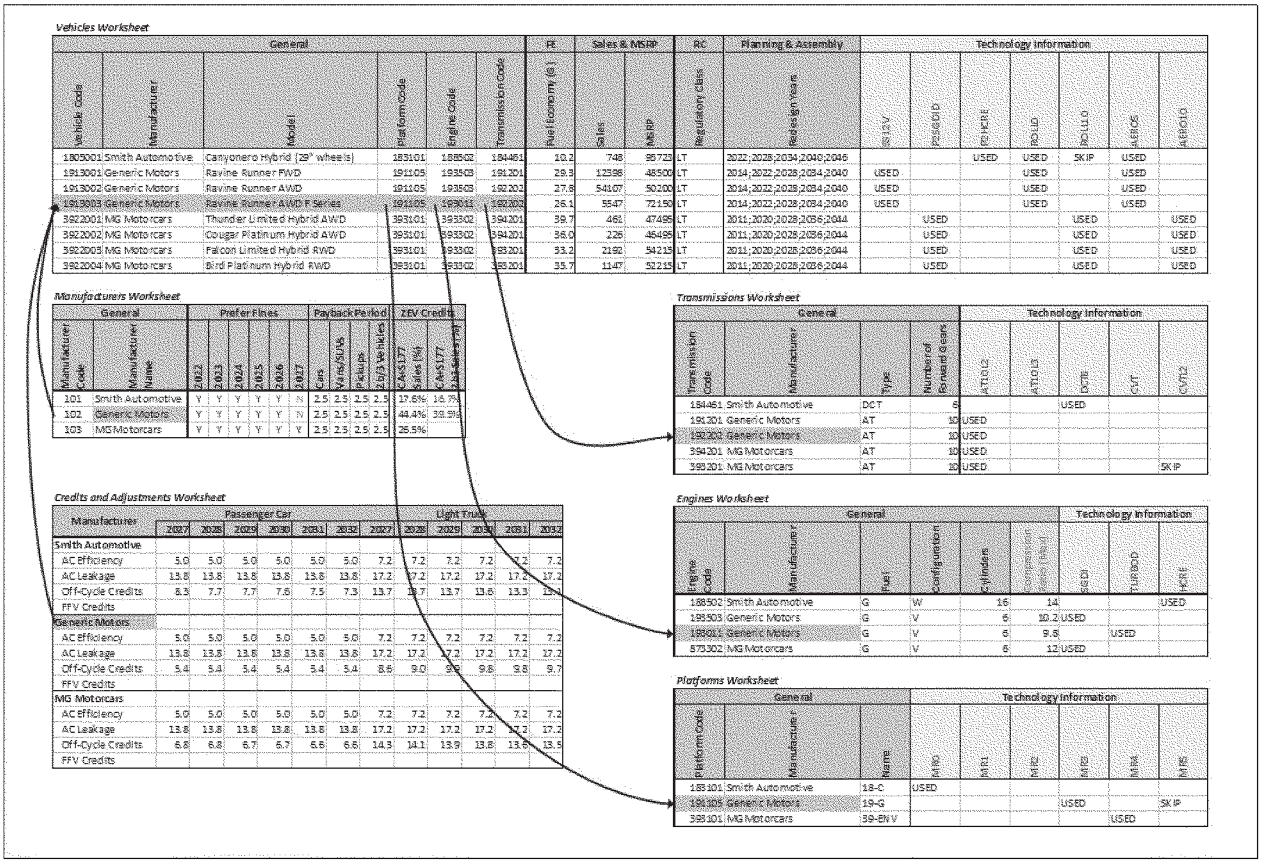
The ''Vehicles'' tab contains a separate row for each vehicle model. Vehicle models are vehicles that share the same fuel economy value and vehicle footprint. This means that vehicle models with different configurations that affect the vehicle's certification fuel economy value are distinguished in separate rows in the Vehicles tab. For example, the agency's Ravine Runner example vehicle comes in three different configurations—the Ravine Runner FWD, Ravine Runner AWD, and Ravine Runner F Series—which would result in three separate rows.

In each row, NHTSA also designates a vehicle's engine, transmission, and platform codes.[68] 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 has been developed to treat vehicles, platforms, engines, and transmissions as separate entities, which allows the modeling system to evaluate technology improvements on multiple vehicles that may share a common component concurrently. 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. Section 2.1 and Section 4.4 of the CAFE Model Documentation contain additional information about the initial state of the fleet, as well as technology evaluation and inheriting within the CAFE Model.

Figure II–1 below shows how NHTSA separates the different configurations of the hypothetical Ravine Runner. NHTSA sees 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 for vehicles that differ in drive type (drive type meaning whether the vehicle has AWD, 4-wheel drive (4WD), front-wheel drive (FWD), or rear-wheel drive (RWD). While it is simpler to aggregate vehicles by model, ensuring that NHTSA captures model variants with different fuel economy values improves the accuracy of the analysis and the potential that estimated costs and benefits from different levels of standards are appropriate. NHTSA includes 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.

[68] Each numeric engine, transmission, or platform code designates important information about that vehicle's technology; for example, a vehicle's 6-digit transmission code includes information about the manufacturer, the vehicle's drive configuration (*e.g.,* front-wheel drive, all-wheel drive, 4WD, or rear-wheel drive), transmission type, number of gears (*i.e.,* a 6-speed transmission has 6 gears), and the transmission variant.

Figure II-1: Generic Motors' Ravine Runner F Series in the Market Data Input File[69]



Vehicles Worksheet

Vehicle Code	Manufacturer	Model	Platform Code	Engine Code	Transmission Code	Fuel Economy (G)	Sales	MSRP	Regulatory Class	Redesign Years	SS12V	P2SGDID	P2HCRE	ROLL0	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	54213	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

Manufacturer Code	Manufacturer Name	Prefer Fines 2022	2023	2024	2025	2026	2027	Payback Period Cars	Vans/SUVs	Pickups	2b/3 Vehicles	ZEV Credits CA+S177 Sales (%)	CA+S177 [illegible]
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%	39.9%
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 2027	2028	2029	2030	2031	2032	Light Truck 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	[illegible]	13.7	13.6	13.3	[illegible]
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	[illegible]	9.8	9.8	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

Transmission Code	Manufacturer	Type	Number of Forward Gears	AT10L2	AT10L3	DCT6	CVT	CVT12
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

Engine Code	Manufacturer	Fuel	Configuration	Cylinders	Compression Ratio (Max)	SGDI	TURBO0	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	
573302	MG Motorcars	G	V	6	12	USED		

Platforms Worksheet

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	

Moving from left to right on the Vehicles tab, after including general information about vehicles and their compliance fuel economy value, NHTSA includes sales and manufacturer's suggested retail price (MSRP) data, regulatory class information (*e.g.,* domestic passenger automobile, import passenger automobile, or non-passenger automobile), and information about how NHTSA classifies 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 fleet to meet its CAFE standard or estimate the impacts of higher fuel economy standards on vehicle sales.

Next, NHTSA includes vehicle information necessary for applying different types of technology; for example, designating a vehicle's body style allows NHTSA to apply aerodynamic technology appropriately, and designating starting CW values allows the agency to apply MR technology more accurately. Importantly, this section also includes vehicle footprint data, which is needed because NHTSA sets footprint-based standards.

NHTSA also sets product design cycles, which are the years in which the CAFE Model can apply technologies 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 MY 2019 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.[70] Setting these product design cycles provides realistic durations of product stability and ensures that the CAFE Model simulates the opportunities manufacturers have to apply technologies in line with refresh and redesign cycles.

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 or refresh schedule as the component apply these technology improvements during the same model year. 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). Section 4.4 of the CAFE Model Documentation contains 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

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

[70] GM Authority, 2022 Chevy Silverado, Last revised: 2022, available at: *https://gmauthority.com/blog/gm/chevrolet/silverado/2022-chevrolet-silverado/* (accessed: Sept. 10, 2025).

different vehicle types. MR technologies lower the vehicle's CW, which may change crash compatibility and safety, depending on the type of vehicle. NHTSA assigns 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 starting CW.[71] [72]

The CAFE Model includes procedures to consider the direct labor impacts of manufacturers' responses to CAFE regulations, considering the assembly location of vehicles, engines, and transmissions; the percent U.S. content (based on the percent U.S. and Canadian content, as reported by manufacturers to NHTSA); and the dealership employment associated with new vehicle sales. Estimated 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. Chapter 6.2.5 of the Draft TSD contains additional discussion of the labor utilization analysis.

NHTSA then assigns the 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 the agency has 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 NHTSA's analysis (*e.g.,* drag coefficients and body styles can be used to determine a vehicle's AERO level), and the agency's engineering judgment.

As discussed further below, the agency uses information directly from manufacturers to populate some fields in the Market Data Input File, like vehicle HP ratings and vehicle weight. NHTSA also uses manufacturer data as an input to various other models that calculate how a manufacturer's real-world technology equates to a technology level in the agency's model. For example, the agency calculates initial MR, aerodynamic drag reduction, and ROLL levels by looking at industry-wide trends and calculating—through models or equations—levels of improvement for each technology. The models and algorithms that the agency uses 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.

Recall the Ravine Runner F Series example with the technology key ''TURBOD; AT10L2, SS12V; ROLL0; AERO5; MR3.'' For this example, Generic Motor's publicly available spec sheet for the Ravine Runner F Series says that it uses Generic Motor's Turbo V6 engine with proprietary Adaptive Cylinder Management Engine (ACME) technology. Generic Motor's 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. Based on this information, NHTSA would conclude that this engine is turbocharged and uses a form of cylinder deactivation, meaning it would be appropriately classified as TURBOD. 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.[73]

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

In addition to the Vehicles Tab that houses the analysis 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 behaviors. For this analysis, the compliance simulation assumes that manufacturers continue to apply technology to the extent practicable to reach compliance. This modeling change is made by indicating in the ''Manufacturers'' tab that all manufacturers will comply with NHTSA's standards and is consistent with the recent amendment to EPCA that set civil penalties (*i.e.,* fines) to $0 effective for MY 2022 vehicles and beyond.[74] The CAFE Model's compliance simulation algorithm is discussed in Section II.C.2.f.

Finally, NHTSA designates a ''payback period'' for each manufacturer. The payback period represents an assumption that consumers are willing to buy vehicles with more fuel economy technology because the fuel economy technology saves them money on gas in the long run. For the past several rulemaking analyses using the CAFE Model the agency has assumed that in the absence of CAFE or other regulatory standards, manufacturers apply technology that ''pays for itself''—by saving the consumer money on fuel—in 30-months, or 2.5 years. NHTSA has updated the agency's payback period for this proposed rule to assume a full 3-year payback period based on an examination of empirical economics literature. This is discussed in detail in Section II.E.1.a below, and in the Draft TSD and PRIA.

Before the agency begins building the Market Data Input File for any analysis, NHTSA must consider what model year vehicles comprise the analysis fleet. There is an inherent time delay in the data the agency can use for any particular analysis because NHTSA receives compliance data after a model year has been completed.

Using recent data for the analysis fleet is more likely to reflect the current vehicle fleet than older data. Recent data reflects (1) manufacturers' realized decisions on what fuel economy-improving technology to apply; (2) mix shifts in response to consumer preferences; (*e.g.,* more recent data reflects manufacturer and consumer preference towards larger vehicles),[75] and (3) industry sales volumes that incorporate substantive macroeconomic events. Using an analysis fleet year that

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

[72] NPRM preamble Section II.H.1 and Draft TSD Chapter 7.3 provides more in depth discussion on the impacts of mass reduction on safety.

[73] Like the transmission codes discussed above, the engine codes include information identifying the manufacturer, engine displacement (how many liters the engine is), whether the engine is naturally aspirated or force-inducted (turbocharged), and other unique engine attributes.

[74] *See* Public Law 119–21, 139 Stat. 72, sec. 40006 (July 4, 2025), *https://www.congress.gov/119/plaws/publ21/PLAW-119publ21.pdf.*

[75] See EPA, The 2024 EPA Automotive Trends Report, Greenhouse Gas Emissions, Fuel Economy, and Technology since 1975, EPA–420–R–24–022, pp. 17—21 (2024), available at: *https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=P101CUU6.TXT* (accessed: Sept. 10, 2025) (hereinafter, ''2024 EPA Automotive Trends Report'').

has been impacted by these transitory shocks may not represent trends in future years; however, on balance, updating to using the most complete set of available fleet data provides the most accurate analysis fleet 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 model years.[76]

At the time NHTSA starts building the analysis fleet, data received from vehicle manufacturers [77] offers the best snapshot of vehicles for sale in the United States in a model year. The mid-model year reports include information about individual vehicles at the vehicle configuration level. NHTSA uses the vehicle configuration, certification fuel economy, sales, regulatory class, and 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 Vehicles Tab. Additional technology data comes from publicly available information, including vehicle specification sheets, manufacturer press releases, owner's manuals, and websites. NHTSA also generates some assumptions in the Market Data Input File for data fields where there is limited data, like refresh and redesign cycles for future model years, and technology levels for certain road load reduction technologies like MR and aerodynamic drag reduction.

For this analysis, the light-duty analysis fleet consists of every vehicle model in MY 2024 in nearly every configuration that has a different compliance fuel economy value. This results in nearly 4,000 individual rows in the Vehicles Tab of the Market Data Input File.

The next section discusses how the agency's analysis evaluates how effectively adding technology to a vehicle in the analysis fleet improves that vehicle's fuel economy value.

c. Technology Effectiveness Values

The CAFE Model uses technology effectiveness values to allow it to know which technologies to apply. Without these values, it does not 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) other technologies on the vehicle or being added to the 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, NHTSA partners with Argonne. Argonne has developed and maintains a modeling and simulation tool called Autonomie that generates technology effectiveness estimates for the CAFE Model. The Autonomie 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 environmental conditions (such as ambient temperature and barometric pressure). The Autonomie Model simulates vehicle behavior over time.

NHTSA simulates a vehicle model's behavior over the two-cycle tests used to measure vehicle fuel economy.[78] The two-cycle test is carried out by operating a vehicle on a dynamometer. Using a dynamometer is like running a car on a treadmill following a program—or more specifically, two programs. The programs are the Federal Test Procedure (FTP) and the Highway Fuel Economy Test (HFET). The FTP and HFET are also commonly referred to as the urban cycle and highway cycle, respectively. For the FTP drive cycle, the vehicle meets certain speeds at certain times during the test, or in technical terms, the vehicle must follow a designated speed trace.[79] The FTP is meant to simulate stop-and-go city driving, and the HFET is meant to simulate steady flowing highway driving at about 50 miles per hour (mph). The agency also uses Society of Automotive Engineers (SAE) recommended practices to simulate hybridized drive cycles,[80] which involves the test cycles mentioned above as well as additional test cycles to measure battery energy consumption and range. For PHEVs, this analysis utilizes only the gasoline (charge-sustaining) mode for the drive cycles.

Measuring every vehicle's fuel economy value by using the same test cycles ensures that the fuel economy certification results are repeatable for each vehicle model and comparable across all of the different vehicle models. When performing physical vehicle cycle testing, sophisticated test and measurement equipment is calibrated according to strict industry standards, which ensures repeatability and comparability of the results. Testing variables can include dynamometers, environmental conditions, types and locations of measurement equipment, and precise testing procedures. These physical tests provide the benchmarking empirical data used to develop and verify Autonomie's vehicle control algorithms and simulation results. Autonomie's inputs are discussed in more detail later in this section.

Full-vehicle modeling and simulation are also essential to measuring how all technologies on a vehicle interact. For example, if technology A improves a particular vehicle's fuel economy by 5 percent and technology B improves a particular vehicle's fuel economy by 10 percent, an analysis using single or limited point estimates may erroneously assume that applying both of these technologies together would achieve a simple additive fuel economy improvement of 15 percent. 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 or 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. Any oversimplification of these complex factors could lead to less accurate technology effectiveness estimates.

[76] For example, in this analysis, the CAFE Model must apply technology to the MY 2024 fleet from MYs 2025–2026 for the compliance simulation that begins in MY 2027. While manufacturers have already built MY 2024 and beyond vehicles, the most current, complete dataset with regulatory fuel economy test results to build the analysis fleet at the time of writing remains MY 2024 data for the light-duty fleet.

[77] 49 U.S.C. 32907(a)(2) and 49 CFR part 537.

[78] NHTSA is 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. . . . [T]he 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.'').

[79] EPA, Emissions Standards Reference Guide: EPA Federal Test Procedure (FTP), Last revised: Mar. 13, 2025, available at: *https://www.epa.gov/emission-standards-reference-guide/epa-federal-test-procedure-ftp* (accessed: Sept. 10, 2025).

[80] SAE, Recommended Practice for Measuring the Exhaust Emissions and Fuel Economy of Hybrid-Electric Vehicles, Including Plug-in Hybrid Vehicles, SAE Standard J1711_202302 (2023), SAE International: Warrendale, PA, available at: *https://www.sae.org/standards/content/j1711_202302/* (accessed: Sept. 10, 2025); SAE, Battery Electric Vehicle Energy Consumption and Range Test Procedure, SAE Standard J1634_202104 (2021), SAE International: Warrendale, PA, available at: *https://www.sae.org/standards/content/j1634_202104/* (accessed: Sept. 10, 2025).

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 initial vehicle configurations and incrementally adding technologies to those 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.

Argonne does not build an individual vehicle model for every single-vehicle configuration in NHTSA's light-duty Market Data Input File. This would be nearly impossible, because Autonomie requires very detailed data on hundreds of different vehicle attributes (*e.g.,* the weight of the vehicle's fuel tank, the weight of the vehicle's transmission housing, the weight of the engine, or the vehicle's 0–60 mph time) to build a vehicle model. For practical reasons, NHTSA cannot acquire 4,000 vehicles and obtain these measurements every time the agency promulgates a new rule, and the agency cannot acquire vehicles that have not yet been built. Rather, Argonne builds a discrete number of vehicle models representative of the most popular vehicles on sale today. The agency refers 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,'' NHTSA can connect it to the Autonomie effectiveness estimate that best represents how effective the technology would be on the vehicle, accounting for vehicle characteristics like body style (*e.g.,* sedan or pickup truck) 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 10 technology classes for this 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).

NHTSA uses 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, the agency determines the vehicle's size. At the second step, NHTSA determines the vehicle's performance level. Both algorithms consider several metrics about the individual vehicle and compare that vehicle to other vehicles in the analysis fleet. This process is discussed in detail in Draft TSD Chapter 2.2.

Consider NHTSA's example Ravine Runner F Series, which is a medium-sized performance SUV. The exact same combination of technologies on the Ravine Runner F Series operate differently in a compact car or pickup truck because they are different vehicle sizes. The example Ravine Runner F Series also achieves slightly better performance metrics than other medium-sized SUVs in the analysis fleet. By ''performance metrics,'' the agency means power, acceleration, handling, braking, and so on. For the performance versus standard technology classification, the agency considers the vehicle's estimated 0–60 mph time compared to an average 0–60 mph time for the vehicle's technology class. Accordingly, the ''technology class'' for the Ravine Runner F Series in the agency's analysis is ''MedSUVPerf,'' because it meets the criteria of a ''performance'' 0–60 mph acceleration time.

Table II–2 shows how vehicles in different technology classes that use the exact same fuel economy technology have very different absolute fuel economy values. Note that the Autonomie absolute fuel economy values are not used directly in the CAFE Model; NTHSA calculates the ratio between two Autonomie absolute fuel economy values (one for each technology key for a specific technology class) and applies that ratio to an analysis fleet vehicle's starting fuel economy value.

Table II-2: 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

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, NHTSA presents 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 NHTSA's example from above, turbocharging technology and dynamic cylinder deactivation (DEAC) technology both improve fuel economy by reducing the engine displacement and accordingly burning less fuel. Turbocharging allows a manufacturer to use a smaller engine that can offer performance equivalent to a larger naturally aspirated engine, and its fuel efficiency improvements are, in part, due to the reduced displacement. DEAC effectively makes an engine with a particular displacement intermittently offer some of the fuel economy benefits of a smaller displacement engine by deactivating cylinders when the work demand does not require the full engine displacement and reactivating them as-needed to meet higher work demands;

the greater the displacement of the deactivated cylinders, the greater the fuel economy benefit. Therefore, a manufacturer upgrading to an engine that uses both a turbocharger and DEAC technology, like the TURBOD engine in the example above, would not see the full combined fuel economy improvement from that specific combination of technologies. Table II–3 shows a vehicle's fuel economy value when using the first-level DEAC technology and when using the first-level turbocharging technology, compared to the agency's example vehicle that uses both of those technologies combined with a TURBOD engine.

Table II-3: 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

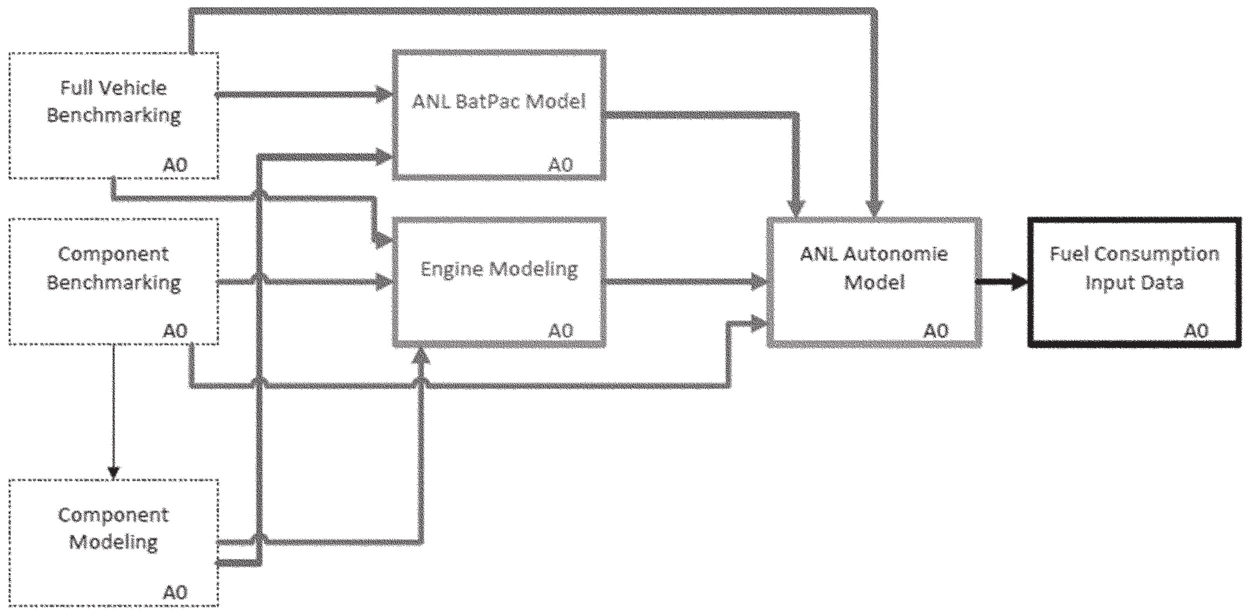
As expected, the percent improvement in Table II–3 between the first and second rows is 1.7 percent and between the third and fourth rows is 0.3 percent, even though the only difference within the two sets of technology keys is the DEAC technology (note that the agency only compares technology keys within the same technology class). This is because there are complex interactions between all fuel economy-improving technologies. The agency models these individual technologies and groups of technologies to reduce the uncertainty and improve the accuracy of the CAFE Model outputs.

Some technology synergies that NHTSA discusses in Section II.D include advanced engine and hybrid powertrain technology synergies. As an example, NHTSA does not see a particularly high effectiveness improvement from applying advanced engines to existing parallel strong hybrid (*e.g.,* P2) architectures.[81] 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-saving mechanisms results in a lower effectiveness when the technologies are added to each other. Again, NHTSA expects that different combinations of technologies will provide different effectiveness improvements on different vehicle types. These examples all illustrate relationships observed using only full-vehicle modeling and simulation.

Just as NHTSA's 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–2 below shows the suite of fuel consumption input data used in the Autonomie modeling to generate the fuel consumption input data NHTSA uses in the CAFE Model.

[81] A parallel strong hybrid powertrain is fundamentally similar to a conventional powertrain but adds one electric motor to improve efficiency. Draft TSD Chapter 3 shows all of the parallel strong hybrid powertrain options that NHTSA has modeled in this analysis.

Figure II-2: Fuel Consumption Input Data Used in the Autonomie Modeling



As shown in Figure II–2 above, full-vehicle benchmarking is a major source of data for the Autonomie model. For full-vehicle benchmarking, vehicles are instrumented with sensors and tested on both the road and chassis dynamometers (*i.e.,* the full-vehicle treadmills used to exercise the vehicle to provide means to calculate vehicle's fuel economy values) under different conditions and duty-cycles. Vehicles are selected for benchmarking with the goal of selecting a mix of vehicles most representative of vehicle fleet and available technologies, taking into account sales volume, cost, and availability. Some examples of full-vehicle benchmark testing performed in conjunction with the agency's partners at Argonne include a 2019 Chevrolet Silverado, a 2021 Toyota Rav4 Prime, and a 2022 Hyundai Sonata Hybrid.[82] NHTSA has produced a report for each vehicle benchmarked, which can be found in the docket. As discussed further below, full-vehicle benchmarking data are 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, the agency instruments a single production component or prototype component with sensors and tests it on a similar duty-cycle as a full vehicle. Examples of components NHTSA benchmarks include 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, or function and modeled in the same scenario. As an example, NHTSA 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.

NHTSA uses a range of models to do the component modeling. As shown in Figure II–2, battery pack modeling using Argonne's BatPaC Model and engine modeling are two of the most significant component models used to generate data for the Autonomie modeling. NHTSA discusses BatPaC in detail in Section II.D, but briefly, BatPaC is the battery pack modeling tool used to estimate the cost of vehicle battery packs for all hybridized vehicles, which is 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 captured 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, simulating knock characteristics through a kinetic fit knock model,[83] and using physics-based heat flow and friction models, among others. NHTSA simulates these constraints using data gathered from component benchmarking as well as engineering and physics calculations.

IAV develops the engine map models, using their GT–POWER modeling tool, by creating a base, or root, engine map and then modifying that root map, incrementally, to isolate the effects of the added technologies. The engine maps are based on real-world engine

[82] For all Argonne full-vehicle benchmarking reports, see Docket No. NHTSA–2023–0022–0010.

[83] 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; rather one or more pockets of air/fuel mixture explode outside of the envelope of the normal combustion front. Engine knock can result in unsteady operation and damage to the engine.

designs. An important feature of the engine maps is that they use a knock model. As noted above, a knock model ensures that any engine size or specification that the agency models in the analysis does not result in engine knock, which could damage engine components in a real-world vehicle. Though 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 has 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.

Argonne also compiles a database of vehicle attributes and characteristics reasonably representative of the vehicles in that technology class used to build the vehicle models. Relevant vehicle attributes may include a vehicle's fuel efficiency, HP, 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. Argonne has identified representative vehicle attributes and characteristics for the light-duty fleet from publicly available information and automotive benchmarking databases, such as A2Mac1,[84] Argonne's Downloadable Dynamometer Database (D^3),[85] EPA compliance and fuel economy data,[86] EPA guidance on 2-cycle tests,[87] and industry partnerships.[88] 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.

Argonne 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 not exactly) correlate to the technology abbreviations that NHTSA uses 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 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. NHTSA includes quantitative performance metrics in the agency's 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 NHTSA uses in the Autonomie modeling for light-duty vehicles are low-speed acceleration (the time required to accelerate from 0 to 60 mph), high-speed passing acceleration (the time required to accelerate from 50 to 80 mph), gradeability (the ability of the vehicle to maintain constant 65 mph speed on a 6-percent upgrade), and towing capacity for light-duty pickup trucks. The agency has been using these performance metrics for the last several CAFE Model analyses, and vehicle manufacturers have agreed that these performance metrics are representative of the metrics considered in the automotive industry.[89] Argonne simulates the vehicle model driving the two-cycle tests (*i.e.,* running its treadmill ''programs'') to ensure that it meets its applicable performance metrics (*i.e.,* NHTSA's MedSUVPerf does not have to meet the towing capacity performance metric because it is not a pickup truck). These metrics are based on commonly used metrics in the automotive industry, including SAE J2807 tow requirements.[90] Additional details about how NHTSA sizes light-duty 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 vehicle models are ready for simulation. Specifically, the sizing and optimization process is more complex for hybridized vehicles, which include hybrid electric vehicle (HEVs) and PHEVs, compared to vehicles with only ICE engines, as discussed further in the Draft TSD Chapter 3.3.4. 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

[84] A2Mac1: Automotive Benchmarking (proprietary data), available at: *https://www.a2mac1.com* (accessed: Sept. 10, 2025). 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, and transmissions, among many other components. These components are weighed and documented for key specifications, which are then available to subscribers.

[85] Argonne National Laboratory, Downloadable Dynamometer Database, Last revised: 2025, available at: *https://www.anl.gov/taps/downloadable-dynamometer-database* (accessed: Sept. 10, 2025).

[86] EPA, Compliance and Fuel Economy Data: Data on Cars Used for Testing Fuel Economy, Last revised: May 19, 2025, available at: *https://www.epa.gov/compliance-and-fuel-economy-data/data-cars-used-testing-fuel-economy* (accessed: Sept. 10, 2025).

[87] EPA PD TSD, at pp. 2–265—2–266.

[88] North American Council for Freight Efficiency, Research & Analysis Are Fundamental (2025), available at: *https://www.nacfe.org/research/overview* (accessed: Sept. 10, 2025).

[89] See 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. [NHTSA and EPA] 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 high-speed 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.)'').

[90] SAE, Performance Requirements for Determining Tow-Vehicle Gross Combination Weight Rating and Trailer Weight Rating, SAE Standard J2807_202411, SAE International: Warrendale, PA, available at: *https://doi.org/10.4271/J2807_202411* (accessed: Sept. 10, 2025).

meet the performance requirements of the SAE standardized drive cycles mentioned above in electric-only mode. Autonomie follows EPA's regulatory guidance and uses the SAE J1711 test procedure to model the incremental effectiveness of adding PHEV technology to a vehicle. The procedure from this guidance is divided into several phases that model ''charge sustaining,'' ''charge depleting,'' and ''cold operation'' [91] calculations for different test cycles. This is described in detail in the CAFE Analysis Autonomie Documentation.[92] Draft TSD Chapter 3.3.4 and the CAFE Analysis Autonomie Documentation contain more information on PHEV effectiveness.

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.[93]

In addition to using performance metrics commonly used by automotive manufacturers, NHTSA instructs Autonomie to mimic real-world manufacturer decisions by resizing engines only at specific intervals 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. NHTSA discusses how the agency's modeling captures vehicle refreshes and redesigns in more detail below, but the details are easier to understand if the agency starts by discussing some straightforward yet important concepts. 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.[94] However, manufacturers will use that same basic engine, with only minor changes, across multiple vehicle models. NHTSA models 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 consistently told NHTSA 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 use a resized engine only at certain MR application levels, as a representation of how manufacturers update their engine technologies. Again, this is intended to reflect manufacturers' comments that it would be unreasonable and unaffordable to resize powertrains for every unique combination of technologies. NHTSA has determined that the agency's rules about performance neutrality and technology inheritance result in a fleet that is essentially performance neutral.

NHTSA's analysis ensures that vehicle models maintain consistent performance levels to allow NHTSA to estimate the costs and benefits of different levels of fuel economy standards more accurately. For its analysis, NHTSA wants to capture only the costs and benefits that result from NHTSA changing its CAFE standards. For example, a manufacturer may add a turbocharger to its engine without downsizing the engine and then direct all the additional engine work to additional vehicle HP instead of vehicle fuel economy improvements. If NHTSA modeled increases or decreases in performance because of fuel economy-improving technology, then that increase in performance has a monetized benefit attached to it that is not specifically due to the agency's fuel economy standards. By ensuring that the agency's vehicle modeling remains performance neutral, NHTSA can better ensure that the agency is reasonably capturing the costs and benefits due only to potential changes in the fuel economy standards.

Autonomie then adopts one single fuel-saving technology to the initial 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 driving the optimized vehicle models for each technology class on the test cycles NHTSA described above. As an example, the Autonomie modeling could start with 10 initial vehicle models (one for each technology class in the analysis). Those 10 initial vehicle models use a 5-speed automatic transmission (AT5). Argonne then builds 10 new vehicle models; the only difference between the 10 new vehicle models and the first set of vehicle models is that the new vehicle models have a 6-speed automatic transmission (AT6). 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. Argonne then ensures that the new vehicle models with the 6-speed automatic transmission meet their performance metrics. Argonne has 20 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 10 separate datasets, each with over

[91] SAE J1711 cold test operation occurs in both Charge Sustaining and Charge Depleting modes.

[92] Chapter ''Vehicle Sizing Process'' of the CAFE Analysis Autonomie Documentation.

[93] Merriam-Webster, Definition: Regression analysis, available at: *https://www.merriam-webster.com/dictionary/regression%20analysis* (accessed: Sept. 10, 2025) (''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, NHTSA is estimating engine weight by looking at the relationship between engine weight and engine power.

[94] 2015 NAS Report, at p. 256. It is likely that manufacturers have made improvements in the product lifetime and development cycles for engines since this NAS report and the report that NAS relied on, but NHTSA does not have data on how much. NHTSA believes 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.

100,000 results, which include information about a vehicle model made of specific fuel economy-improving technology and the fuel economy value that the vehicle model achieved by driving its simulated test cycles.

NHTSA condenses the million-or-so datapoints from Autonomie into three datasets used in the CAFE Model. These three datasets include (1) the fuel economy value that each modeled vehicle achieved while driving the test cycles, for every technology combination in every technology class (converted into ''fuel consumption,'' which is the inverse of fuel economy; fuel economy is mpg and fuel consumption is gallons per mile); (2) the fuel economy value for PHEVs driving those test cycles, when those vehicles drive on gasoline only; and (3) optimized battery costs for each vehicle that adopts some sort of hybridized powertrain (discussed in more detail below). NHTSA then uses these datapoints to produce the technology effectiveness values in the CAFE Model.

Technology effectiveness values allow the CAFE Model to simulate how manufacturers can improve fuel economy relative to a consistent reference point by adding technology and combinations of technologies. The effectiveness values represent the simulated relative improvement of fuel economy that can be applied to a vehicle when new technology is added. These values are calculated based on comparing the achieved fuel economies simulated using the Autonomie full-vehicle models.

NHTSA adds the technology effectiveness values to the CAFE Model as inputs. When the CAFE Model runs a simulation, the effectiveness values for that vehicle's class determine how much the vehicle's fuel economy improves with the application of each technology. The CAFE Model's compliance simulation begins with actual fuel economy values derived from compliance data. As the CAFE Model adds technology, the technology effectiveness values are applied to estimate the new fuel economy value for the vehicle, and the CAFE Model runs millions of combinations of technologies on different vehicles to find the most cost-effective means of compliance for each manufacturer and fleet.

Return to the Ravine Runner F Series example, 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, or ROLL0. In MY 2028, the CAFE Model determines that Generic Motors needs to redesign the Ravine Runner F Series to reach Generic Motors' new CAFE standard. The Ravine Runner F Series now has new fuel economy-improving technology, a parallel strong HEV with a TURBOE engine, an integrated 8-speed automatic transmission, 30-percent improvement in ROLL, 20-percent aerodynamic drag reduction, and 10-percent lighter glider (*i.e.,* MR). Its new technology key is now P2TRBE, ROLL30, AERO20, MR3. Table II–4 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-4: 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 NHTSA obtains from the Autonomie modeling are based on the city and highway test cycles (*i.e.,* the two-cycle test) described above. This is because NHTSA's analysis is based on the EPA procedures used for calculating fuel economy for CAFE compliance, which uses two-cycle testing.[95] 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 and are significantly more representative than the previous two-cycle test values at representing real-world fuel economy. Though the compliance modeling uses two-cycle fuel economy values, the agency uses 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)[96] 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

[95] 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.'').

[96] NHTSA applied a certain percentage 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.

fuel savings that consumers will experience from real-world driving. PRIA Chapter 4.3.1 and Section 5.3.2 of the CAFE Model Documentation contain more information about these calculations. NHTSA's discussion of the effects analysis is presented later in this section.

In sum, NHTSA uses Autonomie to generate modeling and simulation technology effectiveness estimates. These estimates ensure that the modeling captures differences in technology effectiveness due to (1) vehicle size and performance relative to other vehicles in the analysis fleet; (2) other technologies on the vehicle or being added to the vehicle at the same time; and (3) how the vehicle is driven. The modeling approach allows the isolation of technology effects in the analysis supporting an accurate assessment and comports with the NAS 2015 recommendation to use full-vehicle modeling supported by the application of lumped improvements at the sub-model level.[97]

In NHTSA's 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. NHTSA adds the difference between two Autonomie-generated fuel economy values to a vehicle in the Market Data Input File's CAFE compliance fuel economy value. NHTSA then calculates the costs and benefits of different levels of fuel economy standards using the incremental improvement required to bring an analysis fleet 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, NHTSA describes the process of generating costs for the Technologies Input File.

d. Technology Costs

NHTSA estimates present and future costs for fuel-saving technologies by taking into consideration the type of vehicle or type of engine when technology costs vary by application. These cost estimates are based on three main inputs. First, direct manufacturing costs (DMCs), or the component and labor costs of producing and assembling the physical parts and systems, are estimated assuming high-volume production. Second, NHTSA estimates indirect costs. DMCs generally do not include the indirect costs of tools, capital equipment, financing, engineering, sales, administrative support, or return on investment. NHTSA accounts for these indirect costs via a scalar markup of DMCs, which is termed the retail price equivalent (RPE). Finally, the costs for technologies may change over time as industry streamlines design and manufacturing processes. To model this, the agency estimates potential cost improvements with cost learning. The retail cost of equipment in any future year is estimated to be equal to the product of the DMC, RPE, and cost learning. Considering the retail cost of equipment, instead of merely DMCs, allows NHTSA 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 as well as 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. NHTSA uses agency-sponsored tear-down studies of vehicles and parts to estimate the DMCs of individual technologies, in addition to independent tear-down studies, other publications, and confidential business information (CBI). In the simplest cases, NHTSA sponsors studies to produce results that confirm or refute third-party industry estimates and determine alignment with confidential information provided by manufacturers and suppliers. In cases where the tear-down study results differ significantly from credible independent sources, the agency scrutinizes the study assumptions and sometimes revises or updates the analysis accordingly.

Due to the variety of technologies and their applications and the cost and time required to conduct detailed tear-down analyses, NHTSA did not sponsor teardown studies for every technology. In addition, the analysis includes some fuel-saving technologies that are pre-production or sold in very small pilot volumes, but for whom appropriate data are available for the range of vehicles the agency models. For those technologies, NHTSA could not conduct a tear-down study to assess costs because the product is not yet in the marketplace for evaluation. In these cases, the agency relies upon third-party estimates and confidential information from suppliers and manufacturers; however, there are some concerns with relying on CBI to estimate costs. The agency and the source may have had incongruent or incompatible definitions of the reference point from which to measure costs. The source may have provided DMCs at a date many years in the future and assumed very high production volumes, important caveats to consider for agency analysis. In addition, a source may provide incomplete information. In other cases, intellectual property considerations and strategic business partnerships may have contributed to a manufacturer's cost information and could be difficult to account for in the CAFE Model, as not all manufacturers may have access to proprietary technologies at stated costs. In light of these concerns, NHTSA carefully evaluates new information, especially regarding emerging technologies.

While costs for fuel-saving technologies reflect the best estimates available today, technology cost estimates likely will change in the future as technologies are deployed, production is expanded, and nascent technologies mature. For emerging technologies, NHTSA uses the best information available at the time of the analysis and continues to update cost assumptions for any future analysis. Chapter 3 of the Draft TSD discusses each category of technologies (*e.g.,* engines, transmissions, or hybridization) and the cost estimates the agency uses for this analysis.

As discussed above, direct costs represent the cost associated with acquiring raw materials, fabricating parts, and assembling vehicles with the various technologies that manufacturers are expected to use to improve the fuel economy of their fleets. They include materials, labor, and variable energy costs required to produce and assemble the vehicle. However, they do not include overhead costs required to develop and produce the vehicle, costs incurred by manufacturers or dealers to sell vehicles, or the profit manufacturers and dealers make from their investments. These items together contribute to the price consumers ultimately pay for the vehicle. Table II–5 illustrates how these components can affect retail prices.

[97] 2015 NAS Report, at p. 292.

Table II-5: 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, and operations	Cost of maintaining and operating manufacturing facilities and equipment
Corporate Overhead	
General and Administrative	Salaries of nonmanufacturing labor, operations of corporate offices, and others
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
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), NHTSA multiplies a technology's DMCs by an indirect cost factor (the RPE) to represent the average price for fuel-saving technologies at retail. 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 in which manufacturers engage.

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. That is, the retail price is approximately 1.5 times the direct cost expenditures.[98] This ratio has been 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, based on data from 1972–1997 and 2007.[99] During this timeframe, 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 learning effects on direct costs, a higher average in later years. Many automotive industry stakeholders have either endorsed the 1.5 markup or have estimated alternative RPE values. As seen in Table II–6, all estimates range between 1.4 and 2.0, and most are in the 1.4 to 1.7 range.[100]

[98] Rogozhin, A. et al., Automobile Industry Retail Price Equivalent and Indirect Cost Multipliers, Finale, EPA–420–R–09–003, EPA: Ann Arbor, MI (2009), available at: *https://nepis.epa.gov/Exe/ZyPDF.cgi/P100AGJ1.PDF?Dockey=P100AGJ1.PDF* (accessed: Sept. 10, 2025); Spinney, B.C. et al., Advanced Air Bag Systems Cost, Weight, and Lead Time Analysis Summary Report, National Highway Traffic Safety Administration: Washington, DC (1999).

[99] Data is not available for intervening years, but results for 2007 seem to indicate no significant change in the historical trend.

[100] See Comment of the Alliance of Automobile Manufacturers, Docket No. EPA–HQ–OAR–2018–0283–6186 at 143 (Oct. 26, 2018), available at: *https://www.regulations.gov/comment/EPA-HQ-OAR-2018-0283-6186* (accessed: Sept. 10, 2025) ("The Alliance supports the use of retail price equivalents in the compliance cost modeling . . . .").

Table II-6: Alternate Estimates of the RPE[101]

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, 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 American Automobile Association, 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 mean 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. On average, over time and across the vehicle fleet, consumers spend about $1.50 for each dollar of direct costs incurred by manufacturers. Based on NHTSA's own evaluation and the widespread use and acceptance of the RPE by automotive industry stakeholders, the agency has determined that the RPE provides a reasonable indirect cost markup for use in the analysis. A detailed discussion of indirect cost methods and the basis for the agency's 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.[102]

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.

NHTSA estimates 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 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 where 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 NHTSA estimates technology cost reductions by applying a fixed percentage to the projected cumulative production of a given fuel economy technology in a given model year.[103] The agency estimates the cost to produce the first unit of any given technology by identifying the DMC for a technology in a specific model year. As discussed in detail below, and in Chapter 3 of the Draft TSD, NHTSA's 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 model years, the agency identifies the ''base'' model years for each technology where the learning factor is equal to 1.00. Then, the agency applies 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 or identified by NHTSA.[104] Many fuel economy

[101] Duleep, K.G., Analysis of Technology Cost and Retail Price, Presentation to Committee on Assessment of Technologies for Improving LDV Fuel Economy, Detroit, MI (2008); Jack Faucett Associates, Update of EPA's Motor Vehicle Emission Control Equipment Retail Price Equivalent (RPE) Calculation Formula, Report, No. 68–03–3244, EPA: Ann Arbor, MI (1985), available at: *https://nepis.epa.gov/Exe/ZyPURL.cgi?Dockey=940047LI.txt* (accessed: Sept. 10, 2025); McKinsey & Company, Preface to the Auto Sector Cases, New Horizons Multinational Company Investment in Developing Economies (2023); Transportation Research Board and National Research Council, Effectiveness and Impact of Corporate Average Fuel Economy (CAFE) Standards, National Academies Press: Washington, DC, pp. 5, 12 (2002), available at: *https://nap.nationalacademies.org/catalog/10172/effectiveness-and-impact-of-corporate-average-fuel-economy-cafe-standards;* National Research Council, Assessment of Fuel Economy Technologies for Light-Duty Vehicles, National Academies Press: Washington, DC (2011), available at: *https://nap.nationalacademies.org/catalog/12924/assessment-of-fuel-economy-technologies-for-light-duty-vehicles* (accessed: Sept 10, 2025); NRC, Cost, Effectiveness, and Deployment of Fuel Economy Technologies in LDVs, National Academies Press (2015); Sierra Research, Inc, 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 (2007); Vyas, A. et al., Comparison of Indirect Cost Multipliers for Vehicle Manufacturing, Center for Transportation Research: Argonne, IL (2000), available at: *https://publications.anl.gov/anlpubs/2000/05/36074.pdf* (accessed: Sept. 10, 2025).

[102] NHTSA and EPA, FRIA: The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Year 2021–2026 Passenger Cars and Light Trucks (2020), available at: *https://www.nhtsa.gov/sites/nhtsa.gov/files/documents/final_safe_fria_web_version_200701.pdf* (accessed: Sept. 10, 2025).

[103] NHTSA uses statically projected cumulative volume production estimates because the CAFE Model does not support dynamic projections of cumulative volume at this time.

[104] Simons, J.F., 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, pp. 30–33 (2017), available at: *https://downloads.regulations.gov/NHTSA-2021-0053-1643/attachment_44.pdf* (accessed: Oct. 2, 2025); Argote, L. et al., The Acquisition and Depreciation of Knowledge in a Manufacturing Organization—Turnover and Plant Productivity, Working Paper, Graduate School of Industrial Administration, Carnegie Mellon University (1997); Benkard, C.L., Learning and Forgetting: The Dynamics of Aircraft Production, *The American Economic Review.* Vol.

technologies that have existed in vehicles for some time will have a gradual sloping learning curve implying that cost reductions from learning is moderate and eventually becomes less steep toward MY 2050. Conversely, newer technologies have an initial steep learning curve where cost reduction occurs at a high rate. Mature technologies generally have a flatter curve and may not incur much cost reduction, if at all, from learning. Draft TSD Chapter 2.4.4 provides an illustration showing various slopes of learning curves.

The agency assigns groups of similar technologies or technologies of similar complexity to each learning curve. While the grouped technologies differ in operating characteristics and design, NHTSA chooses 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, the agency considers most basic engine and transmission technologies to be mature technologies that do not experience any additional improvements in design or manufacturing. Other basic engine technologies, like VVL, SGDI, and DEAC, 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. NHTSA expects the cost to decrease as production volumes increase, manufacturing processes are improved, and economies of scale are achieved. The agency has assigned advanced engine technologies 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, the agency estimates 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.

For technologies that have been in production for many years, like some engine and transmission technologies, this approach produces reasonable estimates that NHTSA can compare against other studies and publicly available data. Generating the learning curve for battery packs for hybrid vehicles in future model years is significantly more complicated, and NHTSA discusses how the agency generated those learning curves in detail in Chapter 3.3 of the Draft TSD. NHTSA's battery pack learning curves recognize that there are many factors that could potentially lower battery pack costs over time outside of cost reductions from improvements in manufacturing processes due to knowledge gained through experience in production.

Table II–7 shows how some of the technologies on the MY 2024 Ravine Runner F Series 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-7: Absolute Costs for Example Ravine Runner F Series Technologies in 2024$

Technology (MedSUVPerf)	2024	2027	2031
TURBOD (8C2B)	$10,118.42	$10,090.64	$10,061.14
AT10L2	$3,213.19	$3,190.24	$3,172.38
SS12V	$309.44	$289.97	$273.68
AERO5	$60.52	$57.87	$55.36

e. Simulating Tax Credits

The Inflation Reduction Act (IRA) included several tax credits intended to encourage the adoption of clean vehicles.[105] OB3 amended these credits and removed many of the clean vehicle credits.[106] Consistent with prior rulemakings, NHTSA also assumes that hybrids do not qualify for the IRA tax credits because their battery size is below the minimum thresholds set within the IRA. As noted throughout this preamble, NHTSA is statutorily prohibited from considering the fuel economy of dedicated automobiles and therefore has excluded dedicated vehicles from the analysis. The agency considers the fuel-based efficiency of dual-fueled vehicles, such as PHEVs, which are the only vehicles the agency models that are eligible for tax credits.

NHTSA models three provisions of the IRA only through MY 2025 and does not model any of these provisions from MY 2026 forward. The first is the advanced manufacturing production tax credit (AMPC), which 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).[107]

90(4): pp. 1034–54 (2000), available at: *https://www.aeaweb.org/articles?id=10.1257/aer.90.4.1034* (accessed: Oct. 2, 2025); Epple, D. et al., 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 (1991), available at: *https://www.jstor.org/stable/2634939* (accessed: Oct. 2, 2025); Epple, D. et al., An Empirical Investigation of the Microstructure of Knowledge Acquisition and Transfer Through Learning by Doing, *Operations Research,* Vol. 44(1): pp. 77–86 (1996), available at: *https://ideas.repec.org/a/inm/oropre/v44y1996i1p77-86.html* (accessed: Oct. 2, 2025); Levitt, S.D. et al., Toward an Understanding of Learning by Doing: Evidence From an Automobile Assembly Plant, Journal of Political Economy, Vol. 121(4): pp. 643–81 (2013), available at: *https://www.nber.org/papers/w18017* (accessed: Sept. 10, 2025).

[105] Public Law 117–169, 136 Stat. 1818 (Aug. 16, 2025). *https://www.congress.gov/117/plaws/publ169/PLAW-117publ169.pdf.*

[106] Enacted as Public Law 119–21, 139 Stat. 72 (July 4, 2025) *https://www.congress.gov/119/plaws/publ21/PLAW-119publ21.pdf.*

[107] 26 U.S.C. 45X. If a manufacturer produces a battery module without battery cells, it is eligible to claim up to $45 per kWh for the battery module. Two other provisions of the AMPC are not modeled at this time; (1) a credit equal to 10 percent of the manufacturing cost of electrode active materials and (2) a credit equal to 10 percent of the manufacturing cost of critical minerals for battery production. NHTSA is not modeling these credits directly because of how battery costs are estimated, and to avoid the potential to double-count the tax credits if they are included into other analyses that feed into NHTSA's inputs. For a full account of the credit and any limitations, please refer to the statutory text.

NHTSA also models two credits available to new vehicle buyers, the clean vehicle credit (30D)[108] and the credit for qualified commercial clean vehicles (45W)[109] (collectively, the Clean Vehicle Credits or ''CVCs''). The30D credit provides up to $7,500 toward the purchase of clean vehicles with critical minerals either extracted or processed in the United States or a country with which the United States has a free trade agreement or recycled in North America and battery components manufactured or assembled in North America.[110] In contrast to 30D, the 45W credit does not have the same critical minerals and production restraints, but instead the credit value is the lesser of the incremental cost to purchase a comparable ICE vehicle or 15 percent of the cost basis for PHEVs up to $7,500 for vehicles with GVWR less than 14,000. To date, the Department of the Treasury has allowed all eligible vehicles to qualify for the maximum value provided by statute based on DOE's Incremental Purchase Cost Methodology and Results for Clean Vehicles report.[111] The 45W credit is also available only to commercial purchasers; however, the Department of the Treasury determined that leased vehicles qualify given that the ''purchaser'' is the financing company.

NHTSA assumes, based on the updated constraints in OB3 that the impact of the credits would be *de minimis,* particularly for the vehicles and model years considered in this analysis. Thus, the agency removes the availability of CVCs consistent with the AMPC tax credit discussed below. NHTSA includes a sensitivity case related to the AMPC, which is discussed in detail in PRIA Chapter 9, and monitors this area to develop assumptions related to the updated AMPC provisions to include for the final rule. NHTSA also does not model individual state tax credits or rebate programs. State clean vehicle tax credits and rebates vary from jurisdiction to jurisdiction and are subject to more uncertainty than their Federal counterparts.[112] 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.

NHTSA jointly models the CVCs. Both credits are available at the time of sale and provide up to $7,500 towards the purchase of light-duty vehicles placed in service before the end of 2025. Since only one of the CVCs may be claimed for purchasing a given vehicle, NHTSA models them jointly.

As mentioned above, NHTSA is including the tax credits in its analysis through MY 2025. This was a natural terminal point for the CVCs, which are set to expire this year. The agency elected not to model the AMPC in future model years because of the more stringent foreign entity of concern (FEOC) constraints (*i.e.,* constrained eligibility for the tax credit based on materials sources) and American component threshold percentages. NHTSA conducts a sensitivity analysis in which the tax credits are included in the analysis for taking effect through the standard-setting years.

The agency assumes that manufacturers and consumers will each capture half of the dollar value of the AMPC and CVCs. The agency assumes that manufacturers' shares of both credits will offset part of the cost to supply models eligible for the credits—PHEVs, specifically. The subsidies reduce the costs of eligible vehicles and increase their attractiveness to buyers. Because the AMPC credit scales with battery capacity, NHTSA determines average battery energy capacity for passenger cars, and light trucks based on Argonne simulation outputs. Draft TSD Chapter 2.3.2 contains a detailed discussion of these assumptions. NHTSA accounts for all the eligibility requirements of 30D, and the AMPC, such as the location of final assembly and battery production, the origin of critical minerals, and the income restrictions of 30D through the credit schedules constructed in part based off of these factors and allows all PHEVs produced and sold during the timeframe that tax credits are offered to be eligible for those credits subject to the MSRP restrictions discussed above.[113]

To account for the agency's inability dynamically to model sourcing requirements and income limits for 30D, NHTSA uses projected values of the average value of 30D and the AMPC for the proposal. The projections increase throughout the analysis due to the expectation that gradual improvements in supply chains over time would allow more vehicles to qualify for the credits.

NHTSA uses a DOE report that provides combined values of the CVCs.[114] These values consider the latest information of PHEV penetration rates, PHEV retail prices, the share of United States PHEV sales that meet the critical minerals and battery component requirements, the share of vehicles that exclude suppliers that are ''Foreign Entities of Concern,'' and lease rates for vehicles that qualify for the 45W CVC. The DOE projections are the most detailed and rigorous projections of credit availability that NHTSA is aware of at this time. If DOE releases projections that reflect the passing of OB3 into law, NHTSA will consider using those projections for the final rule. According to DOE's analysis, the average credit value for the CVCs across all PHEV sales in a given year never reaches its full $7,500 value for all vehicles. DOE, therefore, projects a maximum average credit value of $6,000. Draft TSD Chapter 2.5.3 includes more information on the average AMPC credit per kWh that NHTSA uses in this proposal.

The CAFE Model accounts for the statutory MSRP restrictions of 30D by assuming that the CVCs cannot be applied to cars with an MSRP above $55,000 or other vehicles with an MSRP above $80,000, which are ineligible for 30D. 45W does not have the same MSRP restrictions; however, because NHTSA is unable to model the CVCs separately at this time, the agency has to choose whether to model the restriction for both CVCs or not to model the restriction at all. NHTSA chooses to include the restriction for both CVCs to be conservative.[115] Chapter 2.5.2 of the Draft TSD contains additional details on

[108] 26 U.S.C. 30D. For a full account of the credit and any limitations, please refer to the statutory text.

[109] 26 U.S.C. 45W. For a full account of the credit and any limitations, please refer to the statutory text.

[110] Vehicle price and consumer income limitations apply to § 30D credits, as well. See Congressional Research Service, Tax Provisions in the Inflation Reduction Act of 2022 (H.R. 5376) (2022), available at: *https://www.congress.gov/crs-product/R47202* (accessed: Sept. 10, 2025).

[111] See Internal Revenue Service, Frequently Asked Questions Related to New, Previously-Owned and Qualified Commercial Clean Vehicle Credits, Q4 and Q8 (2022), available at: *https://www.irs.gov/pub/taxpros/fs-2022-42.pdf* (accessed: Sept. 10, 2025).

[112] States have additional mechanisms to amend or remove tax incentives or rebates. Sometimes, even after these programs are enacted, uncertainty persists. See Farah, N., The Untimely Death of America's ''Most Equitable'' EV Rebate, Last revised: Jan. 30, 2023, available at: *https://www.eenews.net/articles/the-untimely-death-of-americas-most-equitable-ev-rebate/* (accessed: Sept. 10, 2025).

[113] *See* 88 FR 56179 (Aug. 17, 2023) for a more detailed explanation of the process used for the previous proposal.

[114] U.S. Department of Energy, Estimating Federal Tax Incentives for Heavy Duty Electric Vehicle Infrastructure and for Acquiring Electric Vehicles Weighing Less Than 14,000 Pounds, Memorandum (Mar. 11, 2024).

[115] Bureau of Transportation Statistics, New and Used Passenger Car and Light Truck Sales and Leases, available at: *https://www.bts.gov/content/new-and-used-passenger-car-sales-and-leases-thousands-vehicles* (accessed: Sept. 10, 2025).

how NHTSA implements the IRA and OB3 tax credits.

NHTSA uses real dollars for future costs and benefits, such as technology costs in future model years. Including the tax credits as nominal dollars instead of real dollars artificially raises the value of the credits in respect to other costs, so NHTSA converts the DOE projections to real dollars.

The CAFE Model projects vehicles in model year cohorts rather than on a calendar year basis. Given that model years and calendar years can be misaligned (*e.g.,* a MY 2024 vehicle could be sold in CYs 2023, 2024, or even 2025), choosing which calendar year a model year falls into is important for assigning tax credits that are phased out during the analytical period. NHTSA analyzes the timing of new vehicle sales and new vehicle registrations and determines that, for this proposed rule, it is appropriate to assume that credits available in a given calendar year are available to all vehicles sold in the following model year. By contract, NHTSA models vehicles in a given model year as eligible for credits available in the same calendar year. As a result, NHTSA applies the credits to MYs 2024–2025 in this analysis.

f. Technology Applicability Equations and Rules

As NHTSA describes above, the CAFE Model simulates cost-effective ways that vehicle manufacturers could comply with CAFE standards, subject to limits that ensure that the Model reasonably replicates manufacturers' 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 the agency believes 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 the agency includes those in the technology inputs and assumptions in the analysis.

For each manufacturer's fleet, the CAFE Model first determines whether any technology should be ''inherited'' from an engine, transmission, or platform that currently uses the technology and should be applied to a vehicle that is due for a refresh or redesign. NHTSA describes above how vehicle manufacturers use the same or similar engines, transmissions, and platforms across multiple vehicle models, and the agency tracks vehicle models that share technology by assigning Engine, Transmission, and Platform Codes to vehicles in the analysis fleet. As an example, variants of the Ford 10R80 10-speed transmission are 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, and the 2020-present Ford Explorer/Lincoln Aviator. The 2WD variant of the 10R80, as applied to the CAFE Model, is shared by the 2WD Expedition models, 2WD F–150 models, and the Mustang, thus linking these models by the same Transmission Code. If one of these three vehicle model types receives a transmission upgrade, the other two would automatically receive the same upgrade at their next redesign or refresh.

After applying inherited technologies, the Model begins the process of evaluating what technologies could be applied to the manufacturer's vehicles. The CAFE Model applies the most cost-effective technology out of the universe of technology options that the Model could potentially apply. To determine whether a particular technology is cost effective, the Model calculates the ''effective cost'' of multiple technology options and chooses the option that results in the lowest ''effective cost.'' A technology that has an effective cost less than zero (Equation II–4 results in a negative number) is considered cost effective, as a negative effective cost implies that the technology ''pays for itself.'' The ''effective cost'' calculation is actually multiple calculations, but this section describes only the highest levels of that logic; interested readers can consult the CAFE Model Documentation for additional information on the calculation of effective cost. Equation II–4 shows the CAFE Model's effective cost calculation for this analysis.

Equation II-4: CAFE Model Effective Cost Calculation

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

Where:

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

$TaxCredits_{Total}$:
the cumulative value, if any, 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;

Δ*Fines:*
the change in manufacturer's fines in the analysis year, if applicable;

Δ*ComplianceCredits:*
the change in manufacturer's CAFE compliance credits in the analysis year (denominated in thousands of gallons);

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

The components of this ''cost per credit'' effective cost calculation are described further here. The CAFE Model considers the total cost of a technology (TechCost) that could be applied to a group of connected vehicles, just as a vehicle manufacturer might consider what new technologies it has 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 (TaxCredits) available for a technology that could be applied to a group of vehicles and subtracts that total incentive from the total technology costs. The total fuel cost savings (FuelSavings) are the savings in fuel expense resulting from switching from one technology to another. For this, 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.[116] As

[116] This fuel cost savings is calculated using the miles driven over 3 years, based on the assumption that consumers are likely to buy vehicles with fuel

Continued

technology is applied to vehicles in groups, the total fuel cost for the vehicle is then multiplied by the sales volume of a vehicle in a model year to equal total fuel cost savings, which is then subtracted in the numerator of the effective cost equation. Finally, in the numerator, the agency subtracts the change in a manufacturer's expected fines (ΔFines), which are set at $0 for this analysis as a result of Public Law 119–21, before and after application of a specific technology, if any.[117] This approach can be thought of as subtraction of the fines *avoided* by upgrading to a certain technology. Then, the result from the sequence above is divided by the change in compliance credits (Δ*ComplianceCredits*), which means a manufacturer's credits earned in a compliance category before and after the application of a technology to a group of vehicles. This approach can be thought of as dividing the result by the *gain* in credits resulting from upgrading to a certain technology.

After inherited technologies and cost-effective technologies are applied, the CAFE Model determines whether the manufacturer's fleet meets its CAFE standard. If the manufacturer is still not in compliance, the Model applies non-cost-effective technologies (which have an effective cost greater than zero) until it runs out of technology options.

The Model runs the compliance simulation successively and accounts for technology added during each previous model year by carrying forward technologies between model years once they are applied. The CAFE Model does this by mirroring real-world decisions of manufacturers to carry forward most technologies between model years, concentrating the application of new technology to vehicle redesigns or mid-cycle "freshenings," and design cycles vary widely among manufacturers and specific products. Comments from manufacturers and Model peer reviewers for past CAFE rules have strongly supported explicit year-by-year simulation. The multi-year planning capability increases the Model's ability to simulate manufacturers' real-world behavior, accounting for the fact that manufacturers will seek out compliance paths for several model years at a time, while accommodating the year-by-year requirement.

In addition to the Model's technology application decisions pursuant to the compliance simulation algorithm, several technology inputs and assumptions work together to determine which technologies the CAFE Model can apply. The technology pathways, discussed in detail above, are one significant way that the agency instructs the CAFE Model to apply technology. Again, the pathways define mutually exclusive technologies (*i.e.,* those 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, NHTSA uses several technology applicability rules to replicate better 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, 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 and connecting rods, and the same engine architecture may include both 6- and 8-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 the agency also may apply a SKIP to a particular engine technology where it is known 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 can define a "common" engine platform in different ways. Some manufacturers consider engines as "common" if the engines share an architecture, components, or manufacturing processes. Other manufacturers take a narrower approach and consider engines "common" only 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 crankshaft, 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. NHTSA considers engines to be on a common platform (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 differ slightly in compression ratio (CR), HP, and displacement.

Parts sharing also includes the concept of sharing manufacturing lines (the systems, tooling, and assembly processes discussed above), because manufacturers are unlikely to build a new manufacturing line to build a completely new engine. A new engine designed to be mass manufactured on an existing production line has 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

economy-improving technology that pays for itself within 3 years.

[117] See Section VI noting the value of civil penalties are set to $0 in this analysis.

conveyance line design to produce one unit of a product. The restrictions are 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,[118] is the MacPherson strut suspension. It is a popular low-cost suspension design, and manufacturers use it across their fleets. As the agency 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, the CAFE Model accounts 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 account for stranded capital indirectly. Adoption features specific to each technology, if applied on a manufacturer-by-manufacturer basis, are discussed in each technology section.

D. Technology Pathways, Effectiveness, and Cost

The previous section has discussed, at a high level, how NHTSA generates the technology inputs and assumptions used in the CAFE Model. The process for generating these inputs and assumptions involves NHTSA using engineering judgment to evaluate and synthesize data from a variety of sources, including data submitted by vehicle manufacturers; consolidated publicly available data, such as press materials, marketing brochures, and other information; data from collaborative research, testing, and modeling with other Federal agencies and laboratories; data from research, testing, and modeling with independent organizations; data and assumptions from work done for prior rules; and feedback from stakeholders on prior rules and meetings conducted prior to the commencement of this rulemaking, to the extent it is still relevant and applicable.

This section discusses the specific technology pathways, effectiveness, and cost inputs and assumptions used in the compliance analysis. As an example, NHTSA has explained 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. This section then explains how NHTSA bases the transmission technology DMCs on estimates from NAS.

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

Technologies 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 do not result in a simple additive fuel economy improvement from each individual technology. In particular, NHTSA expects this result 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 combinations of engine technologies that work to reduce the effective displacement of the engine.

The effectiveness of a technology depends on the type of vehicle to which the technology is being applied. When discussing ''vehicle type'' in the analysis, NHTSA is referring to the 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 start with very different fuel economy values; so, when the exact same technology is added to both of those vehicles, the technology provides a different effectiveness improvement for each of those vehicles.

The cost and effectiveness values for each technology are 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 manufacturers' systems may perform better or worse than the modeled systems and some may cost more or less than the modeled systems; however, employing this approach ensures that, on balance, the analysis captures a reasonable level of costs and benefits that would result from any manufacturer applying the technology.

A consistent reference point 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, this analysis uses a set of engine map models developed by starting with a small number of engine configurations, and then, in a 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 NHTSA is capturing accurate effectiveness values for each technology combination.

The following sections discuss the engine, transmission, hybridization, MR, aerodynamic, tire rolling resistance, and other vehicle technologies considered in this analysis. The following sections discuss:

• How NHTSA defines technology in the CAFE Model;[119]

[118] Pilla, S. et al., 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, SAE International: (2021), available at: *https://doi.org/10.4271/2021-01-0235* (accessed: Sept. 10, 2025).

[119] Note: Due to the diversity of definitions industry employs for technology terms, or in

Continued

• How NHTSA assigns 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;
• Technology effectiveness values; and
• Technology cost.

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 model years, for specific vehicle classes. The Technologies Input File contains all absolute technology costs used in the analysis across all model years.

1. Engine Paths

ICE vehicles convert chemical energy in fuel to useful mechanical power. The chemical energy in the fuel is released and converted to mechanical power by being oxidized, or burned, inside the engine. The air/fuel mixture entering the engine and the 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.[120] The generated mechanical power is used to perform useful work, such as vehicle propulsion.[121]

NHTSA classifies the extensive variety of light-duty vehicle ICE 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 timeframe. 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 are presented in Chapter 3.1.1 of the Draft TSD.

The Engine Paths have been selected and refined over a period of more than 10 years, based on engines in the market, stakeholder comments, and engineering judgment, subject to the following factors: the included technologies are those most likely available during the rulemaking timeframe and within the range of potential performance levels for each technology, and excluded technologies are those unlikely to be feasible in the rulemaking timeframe, unlikely to be compatible with U.S. fuels, or for which there was not appropriate data available to allow the simulation of effectiveness across all vehicle technology classes in this analysis.

The Engine Paths begin with one of the three base engine configurations: dual-overhead camshaft (DOHC) engines have two camshafts per cylinder head (one operating the intake valves and one operating the exhaust valves), single overhead camshaft (SOHC) engines have a single camshaft, and overhead valve (OHV) engines also have a single camshaft located inside of the engine block (beneath the valves rather than overhead) connected to a rocker arm through a pushrod that actuates the valves. DOHC and SOHC engine configurations are common in the light-duty fleet.

The next step along an Engine Path is 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 a 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, more optimal spark timing for improved efficiency, or both. DEAC disables the intake and exhaust valves and turns off fuel injection and spark ignition on select cylinders, which effectively allows the engine to operate temporarily as if it were smaller while also reducing pumping losses to improve efficiency. For this proposal, NHTSA has integrated variable valve timing (VVT) technology in all non-diesel engines, so there is not a separate box for it on the Basic Engine Path. VVL, SGDI, and DEAC can be applied to an engine individually or in combination with each other.

Moving beyond the Basic Engine Path technologies are the ''advanced'' engine technologies, which means that applying the technology—both in NHTSA's analysis and in the real world—requires 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).[122] An engine operating at low-speed/low-torque conditions can save fuel by operating at a fraction of its total displacement. NHTSA models two ADEAC technologies, advanced cylinder deactivation on a single overhead camshaft engine (ADEACS), and 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 to support combustion, increasing the specific power of the engine. The first-level turbocharged downsized technology (TURBO0) engine represents a basic level of forced air induction technology being applied to a DOHC engine. A cooled exhaust gas recirculation (CEGR) system takes engine exhaust gases, passes them through a heat exchanger to reduce their temperature, then mixes them with incoming air in the intake

describing the specific application of technology, the terms defined here may differ from how the technology is defined in some parts of the industry.

[120] Heywood, J. B., Internal Combustion Engine Fundamentals, McGraw-Hill Education (2018), Chapter 1 (hereinafter, Heywood (2018)).

[121] *Ibid,* containing 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 components.

[122] See Tula Technology, Inc. Dynamic Skip Fire, available at: *https://www.tulatech.com/combustion-engine/* (accessed: Sept. 10, 2025), discussing how the company's proprietary cylinder deactivation technology operates in real-world situations. NHTSA's modeled ADEAC system is not based on this specific system, and therefore the effectiveness improvement is different in NHTSA's analysis than with this system; however, the theory still applies.

manifold to reduce peak combustion temperature, thereby improving fuel efficiency and emissions. NHTSA models the base TURBO0 turbocharged engine with the addition of cooled exhausted recirculation (TURBOE), basic cylinder deactivation (TURBOD), variable valve lift (TURBO1), and advanced cylinder deactivation (TURBOAD). Advancing further into the Turbo Engine Path leads to an engine with a higher BMEP, which is a function of displacement and power. In other words, the higher the BMEP, the higher the power density of the engine. NHTSA models an advanced turbocharging technology (TURBO2) that runs increasingly higher turbocharger boost levels, burning more fuel and making more power for a given displacement. This analysis pairs turbocharging with engine downsizing, meaning that the turbocharged downsized engines improve vehicle fuel economy by using less fuel to power the smaller engine while maintaining vehicle performance.

The technology pathways represent an increase in the level or combinations of technologies being applied, with lower levels at the top and higher levels at the bottom of the path. Chapter 3.1.1 of the Draft TSD shows the technology pathways for visualization purposes; however, the CAFE Model could apply any cost-effective combinations of technologies from those given pathways. Levels of improvement are dependent upon the vehicle class and the technology combinations. Again, in general, the paths are tied to ease of implementation of additional technology and how closely related the technologies are. An example of how this applies to the TURBO family of technologies is described below. The pathways are not aligned from ''least effective'' to ''most effective'' because assuming so would ignore several important considerations, including how technologies interact on a vehicle, how technologies interact on vehicles of different sizes that have different power requirements, and how hardware changes may be required for a particular technology For example, the scenario below describes how, once a manufacturer downsizes an engine accompanying the application of a turbocharger, it would most likely not re-upsize the engine to add a less advanced turbocharger. The interaction of these technology combinations is discussed in more detail in Draft TSD Chapter 2.

While TURBO0 is modeled with cooled EGR (TURBOE) and with DEAC (TURBOD), these technologies do not apply to TURBO1 or TURBO2; this decision is intentional. NHTSA defines TURBO1 in the analysis by adding VVL to the TURBO0 engine, and TURBO2 is the highest turbo downsized engine with a high BMEP. The benefits of cooled EGR and DEAC on TURBO1 and TURBO2 technologies would occur at high engine speeds and loads, which do not occur on the two-cycle tests. Because NHTSA measured technology effectiveness in this analysis based on the delta in improvements in vehicles' two-cycle test fuel consumption values, adding cooled EGR and DEAC to TURBO1 and TURBO2 would provide little effectiveness improvement for the corresponding increase in cost, a technology decision that the agency does not believe manufacturers would adopt in the real world. NHTSA's modeling effectively captured these complex interactions among technologies—an example of why effectiveness values from different technologies cannot simply be added together.[123] This potential for added costs with limited efficiency benefit is also an example of why the CAFE Model technology tree is not ordered from least to most effective technology and why particular technologies are included on the technology tree while others are not. Draft TSD Chapter 2 provides more discussion on interactions among individual technologies in the full-vehicle simulations.

Consistent with the approach of preventing moving backward in the technology tree, the Model does not allow a vehicle assigned a TURBO2 technology to adopt a TURBOE technology. A vehicle in the analysis fleet that is assigned the TURBO2 technology indicates a manufacturer made the decision to either skip over or move on from lower levels of force induction technology. Moving backwards in the technology tree from TURBO2 to any of the lower turbo technologies would require the engine to be upsized to meet the same performance metrics as the analysis fleet vehicle. As discussed further in Section II.C.2.c, NHTSA ensures the vehicles in this analysis meet similar performance levels after the application of fuel economy-improving technology, because the agency's objective is to measure the costs and benefits of manufacturers responding to CAFE standards in this analysis, and not the costs or benefits related to changing performance metrics in the fleet. Moving from a higher to a lower turbo technology works counter to saving fuel as the engine would grow in displacement, requiring more fuel, adding frictional losses, and increasing weight and cost. Accordingly, the agency believes that the Turbo engine pathway appropriately captures the ways manufacturers might apply increasing levels of turbocharging technology to their vehicles.

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.[124] These engines operate on a modified Atkinson cycle, allowing for improved fuel efficiency under certain engine load conditions while still offering enough power not to 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 is unique, as each manufacturer must balance not only fuel efficiency considerations, but also emissions, on-board diagnostics, and safety considerations, which include the vehicle being able to operate responsively to the driver's demand.

NHTSA defines HCR engines as being naturally aspirated, gasoline, spark ignition (SI), using a geometric CR of 12.5:1 or greater,[125] and able dynamically to 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 air/fuel mixture in the combustion chamber), increasing the effective CR, reducing over-expansion, and sacrificing efficiency for increased power density.[126] However, there is a

[123] NHTSA–2021–0053–0007–A3 at 15; NHTSA–2021–0053–0002–A9, at pp. 21–23.

[124] 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. The 2015 NAS Report, Appendix D, includes a short discussion on thermodynamic engine cycles.

[125] 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 NHTSA's analysis, as discussed below. NHTSA looks at a number of factors to perform baseline engine assignments.

[126] Variable valve actuation is a general term used to describe any single or combination of VVT, VVL,

Continued

limit to how much the air-fuel mixture can be compressed before ignition in the HCR engine due to the potential for engine knock.[127] Engine knock can be mitigated in HCR engines with higher octane fuel; however, the fuel specified for use in most vehicles is not higher octane fuel. 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.[128] 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.

The phrase ''low power density issues'' translates to a low torque density,[129] meaning that the engine cannot create the torque required at necessary engine 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; more importantly, an engine designer would not allow a particular engine design to be used in conditions where the engine has the potential to operate in unsafe conditions in the first place. Instead, a manufacturer could significantly increase an engine's displacement (*i.e.,* size) to overcome those low power density issues,[130] or could add an electric motor and battery pack to provide the engine with more power; however, a far more effective pathway would be to apply a different type of engine technology, like a downsized, turbocharged engine.[131]

Because of these limitations with HCR engines, NHTSA restricts the Model from applying this technology to vehicles that would be negatively impacted by the technology, like pickup trucks.[132]

Vehicle manufacturers' intended performance attributes for a vehicle—like payload and towing capability, features for off-road use, and other attributes that affect aerodynamic drag and rolling resistance—dictate whether an HCR engine can be a suitable technology choice for that vehicle.[133] As vehicles require higher payloads and towing capacities,[134] experience road load increases from larger all-terrain tires or less aerodynamic designs, or experience driveline losses for AWD and 4WD configurations, more engine torque is required at all engine speeds. When more engine torque is required, the application of HCR technology becomes less effective and more limited.[135] For these reasons, and to maintain a performance-neutral analysis, NHTSA limits non-hybrid and non-plug-in-hybrid HCR engine application to certain categories of vehicles.[136]

NHTSA includes three HCR Engine Path technology options in this analysis: (1) a first-level Atkinson-enabled engine (HCR) with VVT and SGDI; (2) an Atkinson-enabled engine with cooled exhaust gas recirculation (HCRE); and, (3) an Atkinson-enabled engine with DEAC (HCRD). This updated family of HCR engine map models also reflects the 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.'' [137]

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 a P2 hybrid powertrain (*e.g.,* P2HCR, P2HCRE, PHEV20H, and PHEV50H); those hybridization path options are discussed in Section II.D.3 below. In contrast, Atkinson engines in NHTSA's power-split hybrid powertrains (SHEVPS, PHEV20PS, and PHEV50PS) run the Atkinson Cycle full time but are connected to an electric motor. The full-time Atkinson engines are also discussed in Section II.D.3.

The Miller cycle is another alternative combustion cycle that effectively uses an extended expansion stroke, similar to the Atkinson cycle but with the application of forced induction 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.[138] To address the impacts of the extended expansion stroke on power density during high load operating conditions, the Miller cycle operates in combination

and variable valve duration used to dynamically alter an engine's valvetrain during operation.

[127] 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 rather, one or more pockets of air/fuel mixture explode outside of the envelope of the normal combustion front.

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

[129] Torque = radius × force.

[130] 2024 EPA Trends Report at 54 (''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.''). The discussion below describes why NHTSA does not believe manufacturers will increase the displacement of HCR engines to make the necessary power because of the negative impacts it has on fuel efficiency.

[131] See Toyota, 2024 Toyota Tacoma Makes Debut on the Big Island, Hawaii (2023), available at: *https://pressroom.toyota.com/2024-toyota-tacoma-makes-debut-on-the-big-island-hawaii/* (accessed: Sept. 10, 2025). The 2024 Toyota Tacoma comes in eight ''grades,'' all of which use a turbocharged engine.

[132] Draft TSD Chapter 3.1.1.2.3 includes more discussion on HCR and HCR restrictions.

[133] 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, at 6; Feng, R. et al. Investigations of Atkinson Cycle Converted from Conventional Otto Cycle Gasoline Engine, SAE Technical Paper 2016–01–0680, (2016), available at: *https://www.sae.org/publications/technical-papers/content/2016-01-0680/* (accessed: Sept. 10, 2025).

[134] See Tucker, S., What Is Payload: A Complete Guide. Kelly Blue Book, (last revised: Feb. 2, 2023), available at: *https://www.kbb.com/car-advice/payload-guide/#link3* (accessed: Sept. 10, 2025). (''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.'').

[135] See Supplemental Comments of Toyota Motor North America, Inc., Docket Nos: NHTSA–2018–0067 and EPA–HQ–OAR–2018–0283 at 6, 8 (March 25, 2019), available at: *https://www.regulations.gov/comment/NHTSA-2018-0067-12376* (accessed: Sept. 10, 2025) (Supplemental Toyota Comments) (''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.'').

[136] To maintain performance neutrality when sizing powertrains and selecting technologies, NHTSA performs a series of simulations in Autonomie, which are further discussed in the Draft 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.2.c, Technology Effectiveness Values, and additional reasons why NHTSA maintains a performance neutral analysis are discussed in Section II.C.2.f, Technology Applicability Equations and Rules.

[137] 87 FR 25796 (May 2, 2022).

[138] National Research Council, Assessment of Technologies for Improving Fuel Economy of Light-Duty Vehicles—2025–2035, National Academies Press: Washington, DC (2021), available at: *https://doi.org/10.17226/26092* (accessed: Sept. 10, 2025) (hereinafter, ''2021 NAS report'').

with a forced induction system. In NHTSA's analysis, the first-level 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 for the adjustment of key geometric characteristics of the turbocharging 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. NHTSA's second level of VTG engine technology (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. NHTSA included two levels of diesel engine technology in the analysis: the first-level diesel engine technology (Advanced Diesel Engine (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 light-duty diesel engine maps are based on a modern 3.0L turbo-diesel engine.

Finally, compressed natural gas (CNG) systems are ICE vehicles that run on natural gas as a fuel source. The fuel storage and supply systems for these engines differ tremendously from gasoline, diesel, and flexible-fuel vehicles.[139] The CNG engine option has been included in past analyses; however, the light-duty analysis fleet does not include any dedicated CNG vehicles. As with the last analyses, CNG engines are included as an analysis fleet-only technology and are not applied to any vehicle that did not already include a CNG engine.

There are other vehicle technologies that work in various ways to improve fuel efficiency, such as turbo compounding, negative valve overlaps in-cylinder fuel reforming (NVO), passive prechamber combustion (PPC), and high energy ignition; however, NHTSA's analysis did not include these technologies. While suitable explanations for their exclusion could be that these technologies are in various stages of development and some, like PPC, are in very limited production, the primary reason NHTSA opted not to include them in the analysis is that the agency believes these technologies will not gain enough adoption during the rulemaking timeframe. This topic was discussed in detail in the 2022 final rule,[140] and the agency has not found evidence of significant development since then that would indicate manufacturers are now pursuing these costly technologies within the same standard-setting years.

The first step in assigning engine technologies to vehicles in the analysis fleet is to use data for each manufacturer to determine which vehicle platforms share engines. Within each manufacturer's fleet, NHTSA develops and assigns unique engine codes based on configuration, technologies applied, displacement, CR, and power output. NHTSA also assigns engine technology classes, which are codes that identify engine architecture (*i.e.,* how many cylinders the engine has, whether it is a DOHC or SOHC, and so on) to account accurately for engine costs in the analysis.

When assigning engine technologies to vehicles in the analysis fleets, it is important to consider the actual technologies on a manufacturer's engine and compare them to the engine technologies in the analysis. NHTSA has over 250 unique engine codes in the light-duty analysis fleet, meaning that the technologies present on those engines in the real world must be identified and matched to the 29 engine map models (and therefore engine technology on the technology tree)[141] that best represents those real-world engines. When considering how best to fit each of those 250 engines to the 29 engine technologies and engine map models, NHTSA uses specific technical elements contained in manufacturer publications, press releases, vehicle benchmarking studies, technical publications, manufacturer's specification sheets, occasionally CBI (for specific technologies, displacement, CR, and power mentioned above), and engineering judgment. For example, an engine having a 13.0:1 CR is a good indication that the engine would be considered an HCR engine. Some engines that achieve a slightly lower CR (*e.g.,* 12.5), may also be considered an HCR engine depending on other technology on the engine, such as the inclusion of SGDI, increased engine displacement compared to other competitors, reduction of engine parasitic losses through variable or electric oil and water pumps, or the combination of these technologies. Importantly, engine technologies are never assigned based on one factor alone but rather using data and engineering judgment to assign complex real-world engines to their corresponding engine technologies in the analysis. NHTSA believes that the 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, in addition to the 29 engine map models used in the Engine Paths Collection, there are 16 additional potential powertrain technology assignments available in the Hybridization 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,[142] and SKIP logic. Path logic defines technology adoption by preventing an engine design from moving from one advanced engine tree to another. Once in an advanced engine tree, it must stay there. For example, any light-duty basic engine can adopt one of the TURBO engine technologies, but vehicles that have turbocharged engines in the analysis fleet stay on the

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

[140] 87 FR 25784 (May 2, 2022).

[141] NHTSA assigns 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.

[142] Though NHTSA applies 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. The Draft TSD contains more information on engine phase-in caps.

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 is when manufacturers amortize research, development, and tooling expenses over many years. Besides technology path logic, which applies to all manufacturers and technologies, NHTSA places additional constraints on the adoption of VCR and HCR technologies.

VCR technology requires a complete redesign of the engine and, in the analysis fleet, Nissan is the only manufacturer (including the Infiniti brand) to incorporate this technology. VCR engines are complex, costly by design, and address many of the same efficiency losses as mainstream technologies like turbocharged downsized engines. This makes it unlikely that a manufacturer that has already started down an incongruent technology path would adopt VCR technology. Because of these issues, VCR engine technology adoption is limited to original equipment manufacturers (OEMs) that have already employed the technology and their partners. NHTSA does not believe any other manufacturers will invest in developing and market this technology in their fleet in the rulemaking timeframe.

As recognized in past analyses,[143] 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. Accordingly, HCR engines are subject to three limitations.

First, vehicles with 405 or more HP, and (to simulate parts sharing) vehicles that share engines with vehicles with 405 or more HP, are not allowed 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.[144] Because 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. NHTSA does not believe manufacturers will increase the displacement of their engines to accommodate HCR technology adoption, because as displacement increases, so do friction, pumping losses, and fuel consumption. 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.[145] Separately, as seen in the analysis fleet, manufacturers generally use HCR engines in applications where the vehicle's power requirements fall significantly below the agency's HCR HP threshold. In fact, the average HP for the sales-weighted average of vehicles in the analysis fleet that use HCR Engine Path technologies is 194 hp, demonstrating that HCR engine use has indeed been limited to lower hp applications, and well below the 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.[146]

Second, to maintain a performance-neutral analysis,[147] pickup trucks and (to simulate parts sharing) [148] vehicles that share engines with pickup trucks are excluded from receiving HCR engines that are not accompanied by a hybrid powertrain. In other words, pickup trucks and vehicles that share engines with pickup trucks can receive HCR-based engine technologies only in the Hybridization Paths Collection of technologies. Pickup trucks and vehicles that share engines with pickup trucks are excluded from receiving HCR engines not accompanied by a hybrid powertrain because these often-heavier vehicles have higher low-speed torque needs, higher base road loads, increased payload and towing requirements,[149] and have powertrains sized and tuned to perform this additional work beyond 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 aerodynamic drag and rolling resistance—dictate whether an HCR engine can provide a reasonable fuel economy improvement for that vehicle.[150] For example, road loads are composed of aerodynamic loads, which include vehicle frontal area and its drag coefficient, along with tire rolling resistance, all of which contribute to higher engine loads as vehicle speed increases.[151] NHTSA assumes 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.

Finally, HCR engine application is restricted for some heavily performance-focused manufacturers that have demonstrated a significant commitment to power-dense technologies such as

---

[143] The discussions at 83 FR 43038 (Aug. 24, 2018), 85 FR 24383 (Apr. 30, 2020), 86 FR 49658 and 49661 (Sept. 3, 2021), and 87 FR 25786 and 25790 (May 2, 2022) are incorporated here by reference.

[144] Heywood (2018) at Chapter 5.

[145] See 2024 EPA Trends Report at 54, 85.

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

[147] As discussed in detail in Section II.C.2.c and II.C.2.f above, NHTSA maintains 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.

[148] See Section II.C.2.f.

[149] See SAE, Performance Requirements for Determining Tow-Vehicle Gross Combination Weight Rating and Trailer Weight Rating, SAE Standard J2807_202411, SAE International: Warrendale, PA, available at: *https://doi.org/10.4271/J2807_202411* (accessed: Sept. 10, 2025).; Reed, T, SAE J207 Tow Tests—The Standard, Motortrend (2015), available at: *https://www.motortrend.com/how-to/1502-sae-j2807-tow-tests-the-standard/* (accessed: Sept. 10, 2025). When stating ''increased payload and towing requirements,'' NHTSA is 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 to give consumers the ability to ''cross-shop'' between different manufacturers' vehicles. As discussed in detail above in Section II.C.2.c and II.C.2.f, NHTSA maintains a performance-neutral analysis to ensure that the analysis is only accounting for the costs and benefits of manufacturers adding technology in response to CAFE standards. This means that adoption features, like the HCR application restriction, are applied 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.

[150] ICCT asked NHTSA to stop quoting a 2019 Toyota comment explaining why NHTSA does not allow HCR engines in pickup trucks, stating that Toyota's purpose in explaining that the Tacoma and Camry achieve different effectiveness improvements using their HCR engines is being misinterpreted. See NHTSA–2018–0067–12387 NHTSA disagrees. Toyota's comment is still relevant for this proposed rule as the limitations of the technology have not changed, which Toyota describes in the context of comparing why the technology provides a benefit in the Camry that one should not expect to see in the Tacoma. See Supplemental Toyota Comments at 6, 8. Note that Toyota also submitted a second set of supplemental comments (NHTSA–2018–0067–12431) that confirms NHTSA's understanding of the most important concept to support NHTSA's decision to limit HCR adoption on pickup trucks, which is that Atkinson operation is limited on pickup trucks. See Supplemental Comments of Toyota Motor North America, Inc., in the NHTSA Docket No. NHTSA–2018–0067–12376–A1 at 8–9 in *Regulations.gov*. See Supplemental Comments of Toyota Motor North America, Inc., Docket Nos. NHTSA–2018–0067 and EPA–HQ–OAR–2018–0283 at 2–3 (July 15, 2019), available at: *https://www.regulations.gov/comment/NHTSA-2018-0067-12431* (accessed: Sept. 10, 2025).

[151] 2015 NAS Report, at pp. 207–242.

turbocharged downsizing,[152] such that their fleets use nearly 100 percent turbocharged downsized engines. This means that no vehicle manufactured by these manufacturers can receive an HCR engine. Again, this adoption feature is implemented to avoid an unquantified amount of stranded capital that would be realized if these manufacturers switched from one technology to another.

Note that these adoption features apply only to vehicles that receive HCR engines that are not accompanied by a hybrid 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.

NHTSA realizes that engine technology, vehicle type, and their applications are always evolving. The Hyundai Santa Cruz, a unibody pickup truck with a 4-cylinder HCR engine, is one example of a pickup truck with a non-hybrid HCR engine. However, the Santa Cruz is not comparable in capability to other pickup models like the Tacoma, Colorado, and Canyon, and it therefore cannot be assumed that those pickup models should be able to adopt non-hybrid HCR technology as well. Small unibody pickup trucks like the Santa Cruz and the Ford Maverick do not have the same capabilities and functionality as a mid-size body-on-frame pickup like the Toyota Tacoma.[153] NHTSA believes that its current restrictions for HCR are reasonable and appropriate, and the agency has not been presented with any new information that would suggest otherwise. NHTSA's stance on this issue has also borne out in real-world trends. Manufacturers who currently offer HCR engines in their fleets and therefore had the potential to introduce HCR technologies on recently redesigned vehicles that previously used high-displacement NA engines (such as Toyota Tacoma or Chevrolet Colorado) or TURBO technologies (such as the Mazda CX–90 replacing CX–9) have instead opted to introduce or continue to pursue turbocharged or hybrid engines. NHTSA does not believe HCR in its current state can provide enough fuel efficiency benefit for us to remove the current HCR restrictions; however, this by no means precludes manufacturers from developing and deploying HCR technology for future iterations of their pickup trucks.

NHTSA also emphasizes that, in the real world, manufacturers are not required to follow the technology pathways to compliance that the agency models in the standard-setting analysis but can instead take their own pathway based on their respective business models, technology availability, market share, and others. The CAFE Model simulates an example of a low-cost compliance pathway, and no manufacturer has to comply with the pathway as it has been modeled. Instead, manufacturers are free to choose their own path to compliance. NHTSA has added features and restrictions into the CAFE Model to make the compliance simulation more representative of how manufacturers make decisions about technology adoption in the real world. This is to ensure that the CAFE Model does not simulate unrealistic compliance pathways. For example, if the CAFE Model simulated manufacturers abandoning one technology in favor for another, particularly with respect to HCR technology for pickup trucks and high HP vehicles, the results and corresponding costs and benefits would be unrealistic and could lead to NHTSA setting standards that are more stringent than maximum feasible. For this and other reasons, the agency endeavors to model the most realistic and low-cost pathway to compliance. NHTSA's standard-setting analysis is also restricted in ways that manufacturers are not, increasing the likelihood that manufacturers will not follow the technology pathways projected in the standard-setting analysis.[154]

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 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 are used as inputs to the CAFE Model. Chapter 2.4 of the Draft TSD and the CAFE Analysis Autonomie Documentation provide a full discussion of the Autonomie modeling. 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 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. The engine maps developed to model the behavior of the engines in this analysis are referred to as engine map models.

The engine map models used in this analysis are representative of technologies currently in production or expected to be available in the rulemaking timeframe. The engine map models are developed to be representative of the performance achievable across the industry for a given technology, and they are not intended to represent the performance of a single manufacturer's specific engine. NHTSA targets a broadly representative performance level because the same combination of technologies produced by different manufacturers will differ in performance, due to manufacturer-specific designs for engine hardware, control software, and emissions calibration. Accordingly, the agency expects that the engine maps developed for this analysis will differ from engine maps for manufacturers' specific engines. However, it is intended and expected 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 engine map models used 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.[155] SwRI developed the light-duty diesel engine maps for this analysis. SwRI has been providing automotive science, technology, and engineering services for over 70

[152] Three manufacturers that meet the criteria (near 100 percent turbo downsized fleet, and future hybrid systems are based on turbo downsized engines) described and are excluded: BMW, Mercedes-Benz, and Jaguar Land Rover.

[153] The specification of 2024 Ford Maverick, Toyota Tacoma, and Hyundai Santa Cruz are in the docket accompanying this proposed rule.

[154] 49 U.S.C. 32902(h).

[155] IAV Automotive Engineering, available at: *https://www.iav.com/* (accessed: Sept. 10, 2025).

years.[156] Both IAV and SwRI developed these 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.[157]

Just like Argonne optimizes a single vehicle model in Autonomie following the addition of a singular technology to the vehicle model, these engine map models were built in GT–POWER by incrementally adding engine technology to an initial 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. One of the basic assumptions the agency makes when developing these engine maps is using 87 octane Tier 3 gasoline because it is the most common octane rating on which engines are designed to operate, and it is the test fuel manufacturers will have to use for EPA fuel economy testing.[158 159 160] A small number of initial engine configurations with well-defined BSFC maps are used, and then, in a systematic and controlled process, specific well-defined technologies are added to optimize a BSFC map for each unique technology combination. This could theoretically be done through engine or vehicle testing, but such an approach would require conducting tests on a single engine, and each configuration would require physical parts and associated engine calibrations to assess the impact of each technology configuration. This 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. Both NHTSA and the automotive industry use modeling as an approach to assess an array of technologies with more limited physical testing. Modeling offers the opportunity to isolate the effects of individual technologies by using a single or small number of initial engine configurations and incrementally adding technologies to those initial configurations. This provides a consistent reference point for the BSFC maps for each technology and for combinations of technologies that enable us to identify and quantify carefully the differences in effectiveness among technologies.

Before its 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.[161] IAV and SwRI also validated the effectiveness values from the simulation results against detailed engine maps produced from the Argonne engine benchmarking programs, as well as published information from industry and academia.[162] This ensures reasonable representation of simulated engine technologies. Additional details and assumptions that are used 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 absolute BSFC levels are never applied from the engine maps to any vehicle model or configuration for the rulemaking analysis; only the absolute fuel economy values from the full-vehicle Autonomie simulations are used 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, NHTSA applies 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 the agency refers to as ''analogous effectiveness values.'' These are used when an engine map model is not available for a particular technology combination. To generate an analogous effectiveness value, data from analogous technology combinations for available engine map models are used by conducting a pairwise comparison to generate a data set of emulated performance values for adding technology to an initial application. Analogous effectiveness values are used only for four SOHC technologies. NHTSA has 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.

The engine technology effectiveness values for all vehicle technology classes can be found in Chapter 3.1.4 of the Draft TSD. These values show the calculated improvement for upgrading the listed engine technology for a given combination of other technologies. The range of effectiveness values listed 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 Argonne 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 gray shading indicate the median and 1.5X interquartile range (IQR), which is a helpful metric to identify outliers. After comparing these histograms to the box and whisker plots

[156] Southwest Research Institute, available at: *https://www.swri.org* (accessed: Sept. 10, 2025).

[157] This weblink has additional information on the GT–POWER tool: *https://www.gtisoft.com/gt-power/.*

[158] 79 FR 23414 (Apr. 28, 2014).

[159] DOE, Selecting the Right Octane Fuel, available at: *https://www.fueleconomy.gov/feg/octane.shtml#:~:text=You%20should%20use%20the%20octane%20rating%20required%20for,others%20are%20designed%20to%20use%20higher%20octane%20fuel* (accessed: Sept. 10, 2025).

[160] It is also important to note that regulation of fuels used for determining CAFE compliance is outside the scope of NHTSA's authority. 49 U.S.C. 32904(c).

[161] Friedrich, I. et al., Automatic Model Calibration for Engine-Process Simulation with Heat-Release Prediction, SAE Technical Paper 2006–01–0655, Warrendale, VA: SAE International (2006), available at: *https://doi.org/10.4271/2006-01-0655* (accessed: Sept. 10, 2025); Rezaei, R. et al., Zero-Dimensional Modeling of Combustion and Heat Release Rate in DI Diesel Engines, *SAE International Journal Of Engines.* Vol. 5(3) at 874–85 (2012), available at: *https://doi.org/10.4271/2012-01-1065* (accessed: Sept. 10, 2025); Berndt, R. et al., Multistage Supercharging for Downsizing with Reduced Compression Ratio, *MTZ Worldwide.* Vol. 76 at 10–11 (2015), available at: *https://doi.org/10.1007/s38313-015-0036-4* (accessed: Sept. 10, 2025); Neukirchner, H. et al., Symbiosis of Energy Recovery and Downsizing, *MTZ Worldwide,* Vol. 75 at 4–9 (2014), available at: *https://doi.org/10.1007/s38313-014-0219-4* (accessed: Sept. 10, 2025).

[162] Bottcher, L., Grigoriadis, P., ANL—BSFC map prediction Engines 22–26, Washington, DC: National Highway Traffic Safety Association (2019), available at: *https://lindseyresearch.com/wp-content/uploads/2021/09/NHTSA-2021-0053-0002-20190430_ANL_Eng-22-26-Updated_Docket.pdf* (accessed: Sept. 10, 2025); Reinhart, T., Engine Efficiency Technology Study, Final Report, SwRI Project No. 03.26457, San Antonio, TX: Southwest Research Institute (2022), available at: *https://downloads.regulations.gov/EPA-HQ-OAR-2022-0829-0230/attachment_17.pdf* (accessed: Aug. 18, 2025).

presented in prior CAFE program rule documents, the number of effectiveness outliers is extremely small.

The engine costs in NHTSA's analysis are the product of engine DMCs, RPE, and the LE, updated to a consistent dollar year. Engine DMCs are obtained from multiple sources but primarily from the 2015 NAS report.[163] For VTG and VTGE technologies (*e.g.,* Miller Cycle), NHTSA uses cost data from a FEV technology cost assessment performed for International Council on Clean Transportation (ICCT),[164] which is aggregated using individual component and system costs from the 2015 NAS report. Costs from the 2015 NAS report that have referenced a Northeast States Center for a Clean Air Future (NESCCAF) 2004 report [165] are considered, but NHTSA believes 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 model years 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, pumps, and other components), which reduce parasitic losses.

NHTSA models only automatic transmissions in the light-duty analysis. The three subcategories of automatic transmissions that are modeled in this analysis include traditional automatic transmissions (AT), dual-clutch transmissions (DCT), and continuously variable transmissions (CVT and eCVT).[166] The agency also includes high efficiency gearbox (HEG) technology improvements as options to the transmission technologies (designated as L2 or L3 in the analysis to indicate level of technology improvement).[167] There has been a significant reduction in manual transmissions over the years, and they make up less than 1 percent of the vehicles produced in MY 2024.[168] Due to the declining trend of manual transmissions and their current low production volumes, NHTSA has removed manual transmissions from this analysis and assigned vehicles using manual transmissions as DCTs in the analysis fleet.

To assign transmission technologies to vehicles in the analysis fleets, NHTSA identifies which Autonomie transmission model is most like a vehicle's real-world transmission, considering the transmission's configuration, costs, and effectiveness. As with engines, data from manufacturers' CAFE reports and publicly available information are used to assign transmissions to vehicles and determine which platforms share transmissions. Transmission codes that include information about the manufacturer, drive configuration, transmission type, and number of gears are used to link shared transmissions in a manufacturer's fleet. Just as manufacturers share transmissions in multiple vehicles, the CAFE Model treats transmissions as ''shared'' if they share a transmission code and transmission technologies will be adopted together.

While identifying an AT's gear count is fairly easy, identifying HEG levels for ATs and CVTs is more difficult. NHTSA reviews 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 the analysis fleet. NHTSA finds 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. The agency assigns eight-speed automatic transmissions and CVTs newly introduced for the light-duty market in MY 2016 and later as HEG Level 2. All other automatic transmissions are assigned to their respective transmission's initial technology level (*e.g.,* AT6, AT8, and CVT). For DCTs, the number of gears in the assignments usually match the number of gears listed by the data sources, with some exceptions (dual-clutch transmissions with seven and nine gears are assigned to DCT6 and DCT8, respectively). NHTSA assigns any vehicle in the light-duty analysis fleet with a power-split hybrid (SHEVPS) powertrain an electronic continuously variable transmission (eCVT). Finally, the limited number of manual transmissions in the light-duty fleet are assigned as DCTs, as manual transmissions are not modeled 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 DCT. NHTSA also prevents ''branch hopping'' as a proxy for stranded capital, which is discussed in more detail in Section II.C and Chapter 2.6 of the Draft TSD.

The automatic transmission path precludes adoption of other transmission types once a platform progresses past an AT8. This restriction is used 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 has been 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

[163] Table S.2, at pp. 7–8 of National Research Council, Cost, Effectiveness, and Deployment of Fuel Economy Technologies for Light-Duty Vehicles, National Academies Press: Washington, DC (2015), available at: *https://doi.org/10.17226/21744* (accessed: Sept. 10, 2025) (hereinafter, ''2015 NAS report'').

[164] Isenstadt A. et al., Downsized, Boosted Gasoline Engines, Draft, International Council on Clean Transportation (2016), available at: *https://theicct.org/publication/downsized-boosted-gasoline-engines-2/* (accessed: Sept. 10, 2025).

[165] NESCCAF, Reducing Greenhouse Gas Emissions from Light-Duty Motor Vehicles, Final Report (2004), available at: *https://www.nesccaf.org/documents/rpt040923ghglightduty.pdf* (accessed: Sept. 10, 2025).

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

[167] 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. NHTSA considers three levels of HEG improvements in this analysis based on the NAS 2015 recommendations and CBI data.

[168] 2024 EPA Automotive Trends Report.

overwhelmingly moved to 8-speed and 10-speed transmissions.[169]

Vehicles that do not originate with a CVT or vehicles with multispeed transmissions beyond AT8 in the analysis 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 allowed to apply only 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 light-duty vehicles 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. NHTSA believes the 300 lb.-ft restriction represents an increase over current levels of torque capacity that is likely to be achieved during the rulemaking timeframe. This restriction aligns with CVT application in the analysis fleet, in that CVTs are seen only on vehicles with under 280 lb.-ft of torque.[170] In addition, this restriction is used to avoid stranded capital. Finally, the analysis allows vehicles in the analysis 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.[171]

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. NHTSA populates transmission template models in Autonomie with characteristics data to model specific transmissions.[172] 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.[173] HEG improvements are modeled via improvements to the efficiency map of the transmission. As an example, the AT8 model data comes from a transmission characterization study.[174] The AT8L2 has the same gear ratios as the AT8; however, gear efficiency map values are increased 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. There are 15 transmissions in the light-duty analysis, and each transmission is modeled in Autonomie with defined gear ratios, gear efficiencies, gear spans, and unique shift logic for the technology configuration to which the transmission is applied. 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 light-duty technology classes, are shown in Chapter 3.2.4 of the Draft TSD. Note that the effectiveness for the AT5 and eCVT technologies is not shown. The eCVT transmissions do not have standalone effectiveness values because those technologies are implemented only as part of hybrid-electric powertrains. The AT5 has no effectiveness values because it is a reference-point technology against which all other transmission technologies are compared.

NHTSA's transmission DMCs come from the 2015 NAS report and studies cited therein. The costs are taken almost directly from the 2015 NAS report adjusted to the current dollar year or for the appropriate number of gears. Chapter 3.2 of the Draft TSD discusses the specific 2015 NAS report costs used to generate these transmission cost estimates, and all transmission costs across all model years can be found in the CAFE Model's Technologies Input File. NHTSA has used the 2015 NAS report transmission costs for the last several light-duty CAFE Model analyses (since re-evaluating all transmission costs for the 2020 final rule) and has not received comments or feedback on these costs.

3. Hybridization Paths

The hybridization paths each include a set of technologies that share common hybrid powertrain components, like batteries and electric motors, for certain vehicle functions that were powered solely by ICEs traditionally. 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 hybridization than others, allowing the vehicle to use less gasoline or other fuel.

As explained elsewhere, NHTSA endeavors to model how manufacturers could apply technology to respond to CAFE standards. Hybrid technologies can improve fuel economy, and NHTSA believes that the inputs and assumptions selected to represent hybrid technologies are reasonable to use in NHTSA's CAFE Model. NHTSA provides details of the inputs and assumptions in the Draft TSD accompanying this proposed rule and provides more information regarding the agency's rationale and approach throughout Section II and III of this preamble.

Unlike with other technologies in the analysis, Congress placed specific limitations on how NHTSA considers the fuel economy of alternative fueled vehicles, which includes not only BEVs and FCEVs but also PHEVs.[175] For PHEVs, which are discussed in this section in addition to other hybrid technologies, NHTSA restricts its analysis by using fuel economy values that assume ''charge sustaining''

[169] 2024 EPA Automotive Trends Report, at p. 79, Figure 4.24.

[170] Market Data Input File.

[171] 2024 EPA Automotive Trends Report, at p. 79, Figure 4.24.

[172] Autonomie Input and Assumptions Description Files.

[173] Argonne National Laboratory, Downloadable Dynamometer Database, Last revised: 2025, available at: *https://www.anl.gov/taps/downloadable-dynamometer-database;* Kim, N. et al., Advanced Automatic Transmission Model Validation Using Dynamometer Test Data, SAE 2014–01–1778, presented at the SAE World Congress: Detroit, MI (2014); Kim, N. et al., Development of a Model of the Dual Clutch Transmission in Autonomie and Validation With Dynamometer Test Data, *International Journal of Automotive Technologies,* Vol. 15(2): pp. 263–71 (2014), available at: *https://www.sae.org/publications/technical-papers/content/2014-01-1778/* (accessed: Sept. 10, 2025).

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

[175] 49 U.S.C. 32902(h)(1) and (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.''

(gasoline-only) operation only.[176] The fuel economies of BEVs and FCEV technologies are excluded entirely from NHTSA's standard-setting analysis.[177] Draft TSD Chapter 2.2 contains discussion of NHTSA's consideration of PHEVs, BEVs, and FCEVs in the EIS analysis.

Among the simpler configurations with the fewest hybrid components is micro HEV technology (SS12V), which 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 engine from a stop and provides some regenerative braking functionality.[178] 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 stop/start, regenerative braking, electric motor assist of the engine at higher speeds and power demands with the ability to provide limited all-electric propulsion. Common SHEV powertrain architectures, classified by the interconnectivity of common hybrid vehicle components, include both a series-parallel architecture by power-split device (SHEVPS) as well as a parallel architecture (SHEVP2). SHEVP2s—though enhanced by the electric components, including just one electric motor—remains fundamentally similar to a conventional powertrain.[179] In contrast, SHEVPS powertrains are considerably different than a conventional powertrain, as they use two electric motor/generators, which allows the use of a lower power-density engine. This results in a higher potential for fuel economy improvement compared to a SHEVP2, though the SHEVPS engine power density is lower.[180] 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.'' [181] In contrast, ''[o]ne of the main reasons for using parallel hybrid architecture is to enable towing and meet maximum vehicle speed targets.'' [182] This is an important distinction to understand why NHTSA allows certain types of vehicles to adopt SHEVP2 powertrains and not SHEVPS powertrains.

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.[183] The analysis includes PHEVs with an AER of 20 and 50 miles to encompass the range of PHEV AER in the market today. Draft TSD Chapter 3.3 contains more information on every hybrid technology considered in the analysis, including common acronyms and a brief description of each hybrid technology. For brevity, NHTSA refers to technologies by their acronyms in this section.

As with previous CAFE analyses, there are a number of engine options available for SHEVs and PHEVs. These engines better represent the variety of different hybrid architectures and engine options available in the real world for SHEVs and PHEVs while still maintaining a reasonable level of analytical complexity.

NHTSA did not include additional mild hybrid technology such as more capable, higher output 48-volt mild hybrid systems beyond P0 mild hybrids, such as ''P2, P3, or P4 configurations'' [184] which offer additional benefits of ''electric power take-offs'' [185] (*i.e.,* launch assist) or ''slow-speed electric driving'' [186] on the vehicle's drive axle(s). NHTSA will consider mild hybrid advancements in future analysis if they become more prevalent in the U.S. market.

As described in Draft TSD Chapter 3.3, NHTSA assigns hybrid technologies to vehicles in the analysis fleet [187] using manufacturer-submitted CAFE compliance information, publicly available technical specifications, marketing brochures, articles from reputable media outlets, and data subscriptions.[188] Draft TSD Chapter 3.3.2 shows the penetration rates of hybrid technologies in the standard-setting analysis fleets. Over half the analysis fleet has some level of hybridization, with the vast majority—over 50 percent of the fleet—being micro hybrids. Like the other technology pathways, as the CAFE Model adopts hybrid technologies for vehicles, more advanced levels of hybrid 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 may adopt micro and mild hybrid technology only if the vehicle did not already have a more advanced level of hybridization.

The adoption features that NHTSA applies to strong hybrid technologies include path logic, powertrain substitution, and vehicle class restrictions. Per the technology pathways, SHEVPS, P2x, P2TRBx, and the P2HCRx technologies are considered mutually exclusive. 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

[176] NHTSA has estimated two sets of technology effectiveness values using the Argonne full-vehicle simulations: one set does not include the electrification portion of PHEVs, and one set includes the combined fuel economy for both ICE operation and electric operation. Draft TSD Chapter 3.3 has more information.

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

[178] See 2015 NAS Report, at p. 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).'').

[179] Kapadia, J. et al., Powersplit or Parallel—Selecting the Right Hybrid Architecture, *SAE International Journal of Alternative Power,* Vol. 6(1): pp. 68—76 (2017), available at: *https://doi.org/10.4271/2017-01-1154* (accessed: Sept. 10, 2025) (hereinafter, ''Kapadia et al. (2017)''). Parallel hybrids architecture typically adds the electrical system components to an existing conventional powertrain.

[180] *Id.*

[181] 2015 NAS Report, at p. 134.

[182] Kapadia et al. (2017).

[183] 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.

[184] John German, Docket No. NHTSA–2023–0022–53274–A1 at 6–7.

[185] MECA, Docket No. NHTSA–2023–0022–63053–A1 at 13.

[186] ICCT, Docket No. NHTSA–2023–0022–54064–A1 at 20.

[187] The standard-setting analysis fleet does NOT contain BEVs or FCEVs; the EIS fleet considers all technologies, including BEVs and FCEVs.

[188] Wards Intelligence, U.S. Car and Light Truck Specifications and Prices, 22 Model Year (2022), available at: *https://omdia.tech.informa.com/welcome* (accessed: Sept. 10, 2025).

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.[189] For P2s, NHTSA picks 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,[190] therefore it is representative of the fleet now. NHTSA also thinks that 8-speed transmissions are representative of the transmissions that will continue to be used in these hybrid vehicles, as NHTSA anticipates 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 NHTSA has picked to supersede the vehicle's prior transmission when adopting the SHEVPS powertrain.

SKIP logic is also used to constrain adoption of SHEVPS and PHEVx0PS technologies. These technologies are ''skipped'' for vehicles with engines [191] that meet one of the following conditions: the engine belongs to an excluded manufacturer; [192] the engine belongs to a pickup truck (*i.e.,* the engine is on a vehicle assigned the ''pickup'' body style); the engine's peak HP is more than 405 hp; or 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 NHTSA applies 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 NHTSA does not apply SKIP logic to P2s but does apply SKIP logic to SHEVPSs. Note the difference between SHEVP2 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.[193] No SKIP logic applies to P2s because NHTSA believes that this type of hybridized powertrain is sufficient to meet all the performance requirements for all types of vehicles. Manufacturers have proven this with vehicles like the Ford F–150 Hybrid and Toyota Tundra Hybrid.[194] If NHTSA were to size (in the Autonomie simulations) the SHEVPS motors and engines to achieve ''not optimum'' performance, the electric motors would be unrealistically large (on both a size and cost basis), and the accompanying engine also would have to be a very large displacement engine, which is not characteristic of how vehicle manufacturers apply SHEVPS to ICE vehicles in the real world. Instead, for vehicle applications that have particular performance requirements—which the analysis defines as vehicles with engines that belong to an excluded manufacturer, engines belonging to a pickup truck or shared with a pickup truck, or the engine's peak HP is more than 405 hp—those vehicles can adopt P2 architectures that should be able to handle the vehicle's performance requirements.

While strong hybridization is allowed on all vehicle types, NHTSA allows different types of strong hybrid powertrains to be applied to different types of vehicles for the reasons discussed above. NHTSA believes that allowing SHEVPS and P2 powertrains to be applied subject to the base vehicle's performance requirements is a reasonable approach to maintaining a performance-neutral analysis.

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 in the fleet; Draft TSD Chapter 3.3 provides more details on different system combinations of hybridization. A vehicle adopting PHEV20PS/50PS receives a hybrid full-time Atkinson cycle engine, and a vehicle adopting PHEV20H/PHEV50H receives an HCR engine. For PHEV20T/50T, the vehicle receives a TURBO1 engine.

Autonomie determines the effectiveness of each hybridized 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, which contribute to the effectiveness of a hybridized powertrain in the analysis include the vehicle's battery, electric motors, power electronics, and accessory loads. Autonomie identifies components for each hybridized powertrain type and then interlinks those components to create a powertrain architecture. Autonomie then models each hybridized powertrain architecture and provides an effectiveness value for each architecture. For example, Autonomie determines a PHEV's efficiency in part by considering the efficiencies of the battery (including charging efficiency), the electric traction drive system (ETDS) (the electric machine and power electronics), and mechanical power transmission devices.[195] Autonomie further combines the modeled hybrid components of the hybrid powertrain to include the ICE and related power for transmission components.[196] Argonne uses data from their Advanced Mobility Technology Laboratory (AMTL) to develop Autonomie's hybrid 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 hybrid technology. NHTSA discusses the procedures for modeling each of these subsystems in detail in the Draft TSD and in the CAFE Analysis Autonomie Documentation and provides a summary below.

The fundamental components of a hybrid powertrain's propulsion system—the electric motor and inverter—ultimately determine the vehicle's performance and efficiency. For this analysis, Autonomie employs a set of electric motor efficiency maps created by Oak Ridge National Laboratory (ORNL), one for a traction

[189] This engine type is designated as Eng26 in the list of engine map models used in the analysis. Draft TSD Chapter 3.1.1.2.3 provides more information.

[190] NHTSA is aware that some Hyundai vehicles use six-speed transmissions, and some Ford vehicles use 10-speed transmissions, but NHTSA has observed that the majority of P2s use eight-speed transmissions.

[191] This refers to the engine assigned to the vehicle in the 2022 analysis fleet.

[192] Excluded manufacturers include BMW, Daimler, and Jaguar Land Rover.

[193] Kapadia et al. (2017).

[194] Buchholz, K., 2022 Toyota Tundra: V8 Out, Twin-Turbo Hybrid Takes Over, Warrendale, VA: SAE International, Last revised: Aug. 22, 2021, available at: *https://www.sae.org/news/2021/09/2022-toyota-tundra-gains-twin-turbo-hybrid-power* (accessed: Sept. 10, 2025); Visnic, B., Hybridization the Highlight of Ford's All-New 2021 F–150, Last revised: June 30, 2020, available at: *https://www.sae.org/articles/hybridization-highlight-fords-new-2021-f-150-sae-ma-03885* (accessed: Sept. 10, 2025).

[195] Iliev, S. et al., Vehicle Technology Assessment, Model Development, and Validation of a 2021 Toyota RAV4 Prime, DOT HS 813 356, NHTSA: Washington, DC (2023), available at: *https://downloads.regulations.gov/NHTSA-2023-0022-0010/attachment_6.pdf* (accessed: Sept. 10, 2025).

[196] See the CAFE Analysis Autonomie Documentation.

motor and an inverter, the other for a motor/generator and inverter.[197] The electric motor efficiency maps, created from production vehicles like the 2007 Toyota Camry hybrid and the 2011 Hyundai Sonata hybrid, 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. Argonne uses the maps to determine the efficiency characteristics of the motors, which include some of the losses due to power transfer through the electric machine.[198] Specifically, Argonne scales the efficiency maps, specific to powertrain type, to have total system peak efficiencies ranging from 96 to 98 percent [199]—such that their peak efficiency value corresponds to the latest state-of-the-art technologies, as opposed to retaining dated system efficiencies (90 to 93 percent).[200]

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 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 these factors. Accessory loads during test cycles vary by powertrain type and vehicle technology class, since distinctly different powertrain components and vehicle masses consume different amounts of energy.

The analysis fleets consist of different vehicle types with varying accessory electrical power demand. For instance, vehicles with different motor and battery sizes require different sizes of electric cooling pumps and fans to manage component temperatures optimally. Autonomie has built-in models that can simulate these varying subsystem electrical loads. However, for this analysis, NHTSA uses 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. NHTSA intends and expects 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.[201] [202] NHTSA aggregates electrical accessory load modeling assumptions for the different powertrain types (hybridized and conventional) and technology classes from data from the Draft TAR, EPA Proposed Determination,[203] data from manufacturers,[204] research and development data from DOE's Vehicle Technologies Office,[205] [206] [207] and DOT-sponsored vehicle benchmarking studies completed by Argonne'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,[208] and the modeled hybrid 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 specific, optimized components, but they must also operate in varying driving modes. While the conventional powertrain sizing algorithm must consider only the power of the engine, the more complex algorithm for hybridized 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 hybridized 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.[209] For vehicles with conventional powertrains and micro hybrid powertrains, Autonomie simulates the vehicles using the 2-cycle test procedures and guidelines.[210] For mild HEVs and strong HEVs, 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; SAE J1711 also provides test cycle guidance for testing specific to plug-in

[197] Burress, T. et al., Evaluation of the 2007 Toyota Camry Hybrid Synergy Drive System, ORNL: Washington, DC (2008), available at: *https://doi.org/10.2172/928684* (accessed: Sept. 10, 2025) (hereinafter, ''Burress et al. (2008)''); Olszewski, M., Annual Progress Report for the Power Electronics and Electric Machinery Program, ORNL/TM–2011/263, ORNL: Washington, DC (2011), available at: *https://info.ornl.gov/sites/publications/files/Pub31483.pdf* (accessed: Sept. 10, 2025) (hereinafter, ''Olszewski (2011)'').

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

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

[200] Burress et al. (2008); Olszewski (2011).

[201] Technical Assessment Report at Chapter 5 (2016).

[202] EPA Proposed Determination TSD at pp. 2–270 (2016).

[203] *Id.*

[204] Alliance of Automobile Manufacturers (now Auto Innovators) Comments on Draft TAR, at p. 30.

[205] DOE, Electric Drive Systems Research and Development, Office of Energy Efficiency & Renewable Energy (EERE) (2025), available at: *https://www.energy.gov/eere/vehicles/electric-drive-systems-research-and-development* (accessed: Sept. 10, 2025).

[206] Argonne National Laboratory, Advanced Mobility Technology Laboratory (AMTL) (2025), available at: *https://www.anl.gov/taps/advanced-mobility-technology-laboratory* (accessed: Sept. 10, 2025).

[207] DOE's lab years are 10 years ahead of manufacturers' potential production intent (*e.g.,* 2020 lab year is MY 2030).

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

[209] EPA, How Vehicles are Tested (2025), available at: *https://www.fueleconomy.gov/feg/how_tested.shtml* (accessed: Sept. 10, 2025); Good, D., EPA Test Procedures for Electric Vehicles and Plug-in Hybrids, Draft Summary, EPA: Washington, DC (2017), available at: *https://www.fueleconomy.gov/feg/pdfs/EPA%20test%20procedure%20for%20EVs-PHEVs-11-14-2017.pdf* (accessed: Sept. 10, 2025); CAFE Analysis Autonomie Documentation, chapter titled ''Test Procedure and Energy Consumption Calculations.''

[210] 40 CFR part 600.

HEVs.[211] PHEVs have a different range of modeled effectiveness during ''standard-setting'' CAFE Model runs, in which the PHEV operates under a ''charge sustaining'' (gasoline-only) mode—similar to how SHEVs function.

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 hybrid 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 hybrid technologies used 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 results in some modeled effectiveness values being close to real-world measured values and some modeled values departing 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 hybrid technologies applied in the fleet is shown in Draft TSD Figure 3–23 and Figure 3–24.

Some advanced engine technologies indicate low effectiveness values when paired with hybrid architectures. The low effectiveness results 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 to capture instances of both complementary technologies and non-complementary technologies. In developing its hybrid engine maps, NHTSA considers the engine, engine technologies, electric motor power, and battery pack size. The hybrid engine maps are calibrated to operate in their respective hybrid architecture most effectively and to allow the electric machine to provide propulsion or assistance in regions of the engine map that are less efficient. As the Model sizes the powertrain for any given application, it considers all these parameters as well as performance neutrality metrics to provide the most efficient solution. 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-saving mechanisms results in a lower effectiveness when the technologies are added to each other.

The technology effectiveness values are developed specifically to support analyses for a rulemaking timeframe. For example, the hybrid Atkinson engine peak thermal efficiency was updated based on 2017 Toyota Prius engine data.[212] As mentioned above, Argonne scales the efficiency maps, specific to powertrain type, to have total system peak efficiencies ranging from 96 to 98 percent [213]—such that their peak efficiency value corresponds to the latest state-of-the-art technologies, as opposed to retaining dated system efficiencies (90 to 93 percent).[214] The 2016 maps scaled to peak efficiency are equivalent to (if not exceed) efficiencies seen in vehicles today and in the future. Though the base references for these technologies are from a few years ago, NHTSA has worked with Argonne to update individual inputs to reflect the latest improvements. Accordingly, NHTSA has made no changes to the electric machine efficiency maps for this proposed rule analysis.

When the CAFE Model turns a vehicle powered by an ICE into a hybridized vehicle, it must remove the parts and costs associated with the ICE (and, potentially, the transmission—depending on the hybridization level and powertrain type) and add the costs of a battery pack and other non-battery hybridization components, such as the electric motor and power inverter. To estimate battery pack costs for this analysis, NHTSA needs 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 learning effect NHTSA applied to battery pack costs in this analysis is discussed below. NHTSA estimates base year battery pack costs for most hybrid technologies using BatPaC, which is an Argonne model designed to calculate the cost of hybrid 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, charging constraints, or combinations of these factors, 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 the analysis have hybridized powertrains, meaning that NHTSA 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, Argonne 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 these large-scale simulation runs.

Just like with other vehicle technologies, the specifications of different vehicle manufacturers' battery packs are extremely diverse. NHTSA, therefore, endeavored to develop battery pack costs that reasonably encompass the cost of battery packs for vehicles in each technology class.

In conjunction with the agency's partners at Argonne working on the CAFE analysis Autonomie modeling, NHTSA references assessment and outlook reports,[215] vehicle teardown reports,[216] and stakeholder

[211] 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.

[212] Atkinson Engine Peak Efficiency is based on 2017 Prius peak efficiency scaled up to 41 percent. Autonomie Model Documentation at 138. See ANL—All Assumptions_Summary_NPRM_022021.xlsx, ANL—Summary of Main Component Performance Assumptions_NPRM_022021.xlsx, Argonne Autonomie Model Documentation_NPRM.pdf and ANL—Data Dictionary_NPRM_022021.XLSX, which can be found in the rulemaking docket (NHTSA–2023–0022) by filtering for Supporting & Related Material.

[213] See CAFE Analysis Autonomie Documentation, chapter titled ''Electric Machine Peak Efficiency Scaling.''

[214] Burress et al. (2008); Olszewski (2011).

[215] Rho Motion, EV Battery subscriptions, available at: *https://rhomotion.com/* (accessed: Sept. 10, 2025); BNEF, Electric Vehicle Outlook 4Q 2023: Growth Ahead, Last revised: Jan. 4, 2024, available at: *https://about.bnef.com/insights/clean-transport/electrified-transport-market-outlook-4q-2023-growth-ahead/* (accessed: Sept. 10, 2025); Benchmark Mineral Intelligence, Cathode, Anode, and Gigafactories subscriptions, available at: *https://benchmarkminerals.com/* (accessed: Sept. 10, 2025); International Energy Agency, Global EV Outlook 2022: Securing Supplies For an Electric Future, International Energy Agency (2022) available at: *https://iea.blob.core.windows.net/assets/ad8fb04c-4f75-42fc-973a-6e54c8a4449a/GlobalElectricVehicleOutlook2022.pdf* (accessed: Sept. 10, 2025).

[216] Hummel, P. et al., UBS Evidence Lab Electric Car Teardown—Disruption Ahead? UBS: Zurich, Switzerland (2017), available at: *https://neo.ubs.com/shared/d1ZTxnvF2k* (accessed: Sept. 10, 2025); A2Mac1: Automotive Benchmarking, (proprietary data), available at: *https://portal.a2mac1.com/* (accessed: Sept. 10, 2025).

discussions [217] to determine common battery pack chemistries for each modeled hybrid 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.[218] For mild hybrids, NHTSA uses the lithium iron phosphate (LFP)–G [219] 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. NHTSA uses NMC622–G [220] for all other hybrid vehicle technology base (MY 2022) battery pack cost calculations. NHTSA believes that, based on available data,[221] NMC622 is more representative for the 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 in the battery cost learning effects. The learning effects estimate potential cost savings for *future* battery advancements (a learning rate applied to the battery pack DMC); this proposed rule includes a dynamic NMC/LFP cathode mix over each future model year (for PHEVs). The battery chemistry that NHTSA uses is intended to represent reasonably what is used in the MY 2022 U.S. fleet, which is the DMC base year for the BatPaC calculations.[222]

NHTSA also looks at vehicle sales volumes for MY 2022 to determine a reasonable base production volume assumption.[223] 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 PHEV in its vehicle lineup 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. NHTSA has examined battery pack designs for vehicles sold in MY 2022 to determine a reasonable manufacturing plant production volume assumption. NHTSA considers each assembly line designed for a specific battery pack and for a specific PHEV as an individual battery plant. Since battery technologies and production are still evolving, it is likely to be some time before battery cells can be treated as commodities where the specific numbers of cells are used for varying battery pack applications and all other metrics remain the same.

Similar to previous rulemakings, NHTSA uses 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,[224] NHTSA calculates an average production volume per manufacturer metric to approximate hybrid vehicle production volumes for this analysis. This metric is calculated by taking an average of all of one hybrid vehicle type (for example, all PHEVs) battery energies reported in a vehicle manufacturer's pre-MY 2022 reports [225] and dividing by the averaged sales-weighted energy per-vehicle; the resulting volume is then rounded to the nearest 5,000. Manufacturers are not required to report gross battery pack sizes for the pre-model year or mid-model year compliance reports, so NHTSA estimates pack size for each vehicle based on proprietary data and publicly available data, like a manufacturer's published or announced specifications. This process is repeated for all hybrid vehicle technologies. NHTSA believes this provided a reasonable base year plant production volume—especially in the absence of actual production data—since the compliance report data from manufacturers already includes accurate related data, such as vehicle model and estimated sales information metrics.[226] The final battery manufacturing plant production volume assumptions for different hybrid technologies are as follows: mild hybrid and strong hybrids are manufactured assuming 200,000 packs and PHEVs are manufactured assuming 20,000 packs.

As mentioned above, the BatPaC Lookup Tables provide $/kWh battery pack costs based on vehicle power and energy requirements. As the total cost of a battery pack increases the higher the power/energy requirements, the cost per kWh decreases. 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 3–78 in Draft TSD Chapter 3.3.5 shows an example of the BatPaC-based lookup tables for SHEVPS technology classes.

Note that the values in the table discussed above should *not* be considered the total battery $/kWh costs that are used for vehicles in the analysis in future model years. As detailed below, battery costs are also projected to decrease over time as manufacturers improve production processes, shift battery chemistries, and make other technological advancements. In addition, select modeled tax credits further reduce the estimated costs; additional discussion of those tax credits is located throughout this preamble, Draft TSD Chapter 2.3, and PRIA Chapters 8 and 9.

The CAFE Analysis Autonomie Documentation details other specific assumptions that Argonne used to simulate battery packs and their associated base year costs for the full-vehicle simulation modeling, including updates to the battery management unit

[217] 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 in the rulemaking docket (NHTSA–2023–0022) by filtering for Supporting & Related Material.

[218] CAFE Analysis Autonomie Documentation chapter titled ''Battery Performance and Cost Model—BatPac Examples From Existing Vehicles in the Market.''

[219] Lithium iron phosphate ($LiFePO_4$) cathode and graphite anode.

[220] Lithium nickel manganese cobalt oxide ($LiNiMnCoO_2$) cathode and graphite anode.

[221] Rho Motion, EV Battery subscriptions, available at: *https://rhomotion.com/* (accessed: Sept. 10, 2025); International Energy Agency, Global EV Outlook 2023, International Energy Agency (2023), available at *https://www.iea.org/reports/global-ev-outlook-2023* (accessed: Sept. 10, 2025).

[222] For this analysis, 2021$ costs have been updated to 2024$; this is not reflected directly in the base Battery Cost csv file, however, as this conversion was performed external to the file itself.

[223] See Chapter 2.2.1.1 of the Draft TSD for more information on data NHTSA uses for sales volumes.

[224] Zhou, Y. et al., Lithium-Ion Battery Supply Chain for E-Drive Vehicles in the United States: 2010–2020, ANL/ESD–21/3, Argonne, IL: Argonne National Laboratory (2021), available at: *https://publications.anl.gov/anlpubs/2021/04/167369.pdf* (accessed: Sept. 10, 2025); Gohlke, D. et al., Quantification of Commercially Planned Battery Component Supply in North America Through 2035, Final Report, ANL–24/14, ANL: Alexandria, VA (2024), available at: *https://publications.anl.gov/anlpubs/2024/03/187735.pdf* (accessed: Sept. 10, 2025).

[225] 49 CFR 537.7.

[226] NHTSA uses publicly available range and pack size information and linked the information to vehicle models.

costs and the range of power and energy requirements used to bound the lookup tables.[227] CAFE Analysis Autonomie Documentation and Chapter 3.3 of the Draft TSD provide further information about how NHTSA used BatPaC to estimate base year battery costs. The full range of BatPaC-generated battery DMCs is in the file ANL—Summary of Main Component Performance Assumptions_NPRM_2206.[228] 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.

The DOE and Argonne have developed battery cost correlation equations from BatPaC for use in the 2024 CAFE final rule analysis—cost equations that continue to be used in this analysis.[229] These cost equations—developed for use through MY 2035—are tailored for different vehicle segments,[230] different levels of hybridization,[231] and anticipated plant production volumes.[232] These equations represent cost improvements achieved from advanced manufacturing, pack design, and cell design with current and anticipated future battery chemistries,[233] design parameters, forecasted market prices, and vehicle technology penetration. Argonne's Cost Analysis and Projections for U.S.-Manufactured Automotive Lithium-ion Batteries report contains a detailed discussion of the inputs and assumptions used to generate these cost equations.[234]

While batteries and relative battery components are the biggest cost drivers of hybridization, non-battery hybridization components, such as electric motors, power electronics, and wiring harnesses, also add to the total cost required to electrify a vehicle. Different levels of hybrid vehicles have variants of non-battery hybridization components and configurations to accommodate different vehicle classes and applications with respective designs. For instance, some SHEVs may be engineered with only one electric motor, while other SHEVs may be engineered with two or even three electric motors within their powertrains to provide AWD functionality. In addition, some hybrid vehicle types still include conventional powertrain components, like an ICE and transmission.

For all hybrid vehicle powertrain types, NHTSA groups non-battery hybridization components into four major categories: electric 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 systems. NHTSA further groups the components into those composing the electric traction drive system, and all other components. Though each manufacturer's ETDS and power electronics vary between the same hybrid vehicle types and between different hybrid vehicle types, NHTSA considers the ETDS for this analysis to be composed of the electric motor and inverter, power electronics, and thermal system.

When researching costs for different non-battery hybridization components, NHTSA finds that different reports vary in components considered and cost breakdown. This is not surprising, as vehicle manufacturers use different non-battery hybridization components in different vehicle systems, or even in the same vehicle type, depending on the application. In order of the component categories discussed above, NHTSA examines cost teardown studies discussed in Draft TSD Chapter 3.3.5 on Table 3–82. Using the best available estimate for each component from the different reports captures components in most manufacturers' systems but not all; NHTSA believes, however, that this is a reasonable metric and approach for this analysis, given the non-standardization of hybrid powertrain designs and subsequent component specifications. Other sources NHTSA uses for non-battery hybridization component costs include an EPA-sponsored FEV teardown of a 2013 Chevrolet Malibu ECO with eAssist for some BISG component costs,[235] which were validated against a 2019 Dodge Ram eTorque system's publicly available retail price,[236] and the 2015 NAS report.[237] Broadly, the total BISG system cost, including the battery, fairly matches these other cost estimates. NHTSA is not making any changes to hybrid vehicle costs for this proposed rule, outside of transitioning to 2024$.

For the non-battery electrification component learning curves, NHTSA uses cost information from Argonne's 2016 Assessment of Vehicle Sizing, Energy Consumption, and Cost Through Large-Scale Simulation of Advanced Vehicle Technologies report.[238] The report provides estimated cost projections from the 2010 lab year to the 2045 lab year for individual vehicle components.[239] NHTSA considers the component costs used in EVs and determines the learning curve by evaluating the year over year cost change for those components. Argonne 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.[240] The learning estimates generated using the 2016 report align in the middle of the high and low cost estimates from the Argonne reports, and therefore NHTSA continues to apply the learning curve estimates based on the 2016 report. There are many sources that NHTSA could have picked to develop learning

[227] CAFE Analysis Autonomie Documentation chapter titled ''Battery Performance and Cost Model—Use of BatPac in Autonomie for FRM runs.''

[228] The DMCs in the Argonne file are in 2021$ (from the 2024 final rule).

[229] Argonne National Laboratory, Cost Analysis and Projections for U.S.-Manufactured Automotive Lithium-Ion Batteries. ANL/CSE–24/1, (2024), available at: *https://publications.anl.gov/anlpubs/2024/01/187177.pdf* (accessed: Sept. 10, 2025) (hereinafter, ''ANL/CSE–24/1'').

[230] The vehicle classes considered in this project include compact cars, midsize cars, midsize SUVs, and pickup trucks.

[231] The levels of hybridization considered in this project include light-duty micro HEVs, mild HEVs, strong HEVs, and PHEVs.

[232] Production volumes were determined for each vehicle class and type for each model year. See ANL/CSE–24/1 at Equation 1 and Table 13.

[233] Battery cathode chemistries considered in this project include nickel-based materials (NMC622, NMC811, NMC95, and LMNO) as well as lower cost LFP cathodes; varying percentages of silicon content (5%, 15%, and 35%) within a graphite anode were considered, as well.

[234] ANL/CSE–24/1.

[235] FEV, Inc., 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 (2014); EPA: Washington, DC (2014), available at: *https://www.regulations.gov/document/EPA-HQ-OAR-2015-0827-0342* (accessed: Sept. 10, 2025).

[236] Colwell, K.C., The 2019 Ram 1500 eTorque Brings Some Hybrid Tech, if Little Performance Gain, to Pickups, Car and Driver, Last revised: Mar. 14, 2019, available at: *https://www.caranddriver.com/reviews/a22815325/2019-ram-1500-etorque-hybrid-pickup-drive* (accessed: Sept. 10, 2025).

[237] 2015 NAS Report, at p. 305.

[238] Moawad, A. et al., Assessment of Vehicle Sizing, Energy Consumption and Cost Through Large Scale Simulation of Advanced Vehicle Technologies, ANL/ESD–15/28 (2016), available at: *https://doi.org/10.2172/1245199* (accessed: Sept. 10, 2025).

[239] DOE's lab year equates to 5 years after a model year (*e.g.,* DOE's 2010 lab year equates to MY 2015). ANL/ESD–15/28 at 116.

[240] Islam, E. et al., Energy Consumption and Cost Reduction of Future Light-Duty Vehicles Through Advanced Vehicle Technologies: A Modeling Simulation Study Through 2050, ANL/ESD–19/10, ANL (2020), available at: *https://publications.anl.gov/anlpubs/2020/08/161542.pdf* (accessed: Sept. 10, 2025); Islam, E. et al., A Comprehensive Simulation Study to Evaluate Future Vehicle Energy and Cost Reduction Potential, ANL/ESD–22/6, Alexandria: VA (2022), available at: *https://publications.anl.gov/anlpubs/2023/11/179337.pdf* (accessed: Sept. 10, 2025).

curves for non-battery electrification component costs; however, given the uncertainty surrounding extrapolating costs out to MY 2050, NHTSA believes these learning curves provide a reasonable estimate.

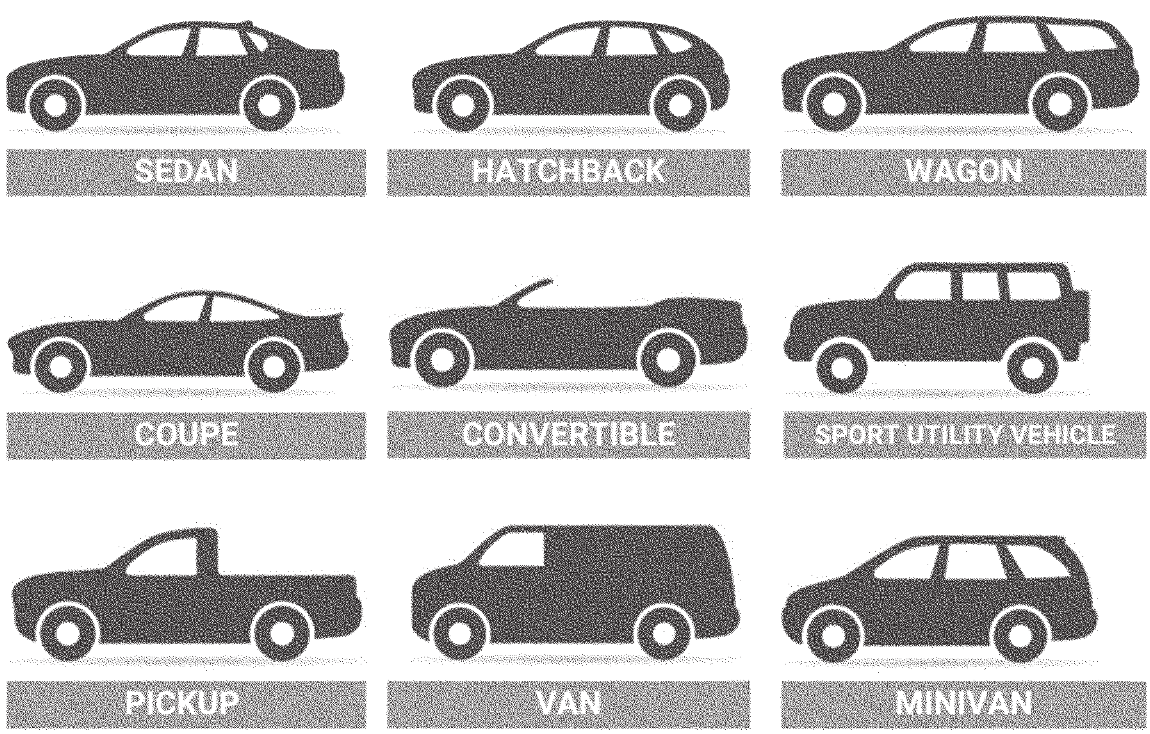
In summary, NHTSA calculates the total hybrid powertrain costs by summing individual component costs, which ensures that all technologies in a hybrid powertrain appropriately contribute to the total system cost. NHTSA combines the costs associated with the ICE (if applicable) and transmission, non-battery hybridization 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 hybrid powertrain option, broken out by the components NHTSA discussed throughout this section. In addition, the section 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 percent 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. Instead, most of the energy is lost due to thermal and frictional losses in the engine and drivetrain and drag from ancillary systems (*e.g.,* the air conditioner, alternator generator, or various pumps). 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 increase these losses rapidly become dramatically higher than any other road load. Drag from the brakes in most cars is practically negligible. Tire rolling resistance losses can be significant: at low speeds rolling resistance losses can be more than aerodynamic losses. Whatever energy is left after these road loads is spent on accelerating the vehicle anytime 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, at freeway speeds, aerodynamics plays a more dominant role in determining fuel economy than any other road load or vehicle mass.

NHTSA includes three road load reducing technology paths in this analysis: the Mass Reduction Path, Aerodynamic Improvements (AERO) Path, and Low Rolling Resistance Tires (ROLL) Path. For all three paths, NHTSA assigns analysis fleet technologies and identifies adoption features based on the vehicle's body style. The light-duty fleet body styles NHTSA includes in the analysis are convertible, coupe, sedan, hatchback, wagon, SUV, pickup, minivan, and van. Figure II–3 shows the light-duty fleet body styles used in the analysis.

Figure II-3: Light-Duty Fleet Body Styles



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.

5. 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 (*e.g.,* advanced high strength steel (AHSS), aluminum, magnesium, and plastics, including carbon fiber reinforced plastics).

For this analysis, NHTSA considers five levels of MR technology (MR1–MR5) that include increasing amounts of advanced materials and MR techniques applied to the vehicle's glider.[241] The subsystems that may make up a vehicle glider include the vehicle body, chassis, interior, steering, electrical accessory, brake, and wheels systems. NHTSA accounts for mass changes associated with powertrain changes separately.[242] The agency's estimates of how manufacturers could reach each level of MR technology, and a discussion of advanced materials and MR techniques can be found in Chapter 3.4 of the Draft TSD.

The MR5 technology represents a high level of MR and requires a blend of aluminum and carbon fiber components. Achieving MR5 with aluminum exclusively is unlikely to be achievable by manufacturers during the rulemaking timeframe. While aluminum technology can be a potent MR pathway, it has its limitations. First, aluminum does not have a fatigue endurance limit. That is, with aluminum components there is always some combination of stress and cycles when failure occurs. Automotive design engineering teams will dimension highly stressed cross sections to provide an acceptable number of cycles to failure. But this often comes at mass savings levels that fall short of what would be expected purely based on density specific strength and stiffness properties for aluminum.

Looking at real data, the mostly aluminum (cab and bed are made from aluminum) 2021 Ford F150 achieves less than a 14-percent MR compared to its 2014 all-steel predecessor.[243] This is an especially pertinent comparison because both vehicles have the same footprint within a 2-percent margin and presumably were engineered to similar duty cycles given that they both came from the same manufacturer. Per the agency's regression analysis, the Ford F–150 achieves MR3. As mentioned in the Draft TSD Chapter 3.4, a body in white structure made almost entirely from aluminum is roughly required to get to MR4. It may be possible to achieve MR5 without the use of carbon fiber, but the resultant vehicle would not achieve performance parity with customer expectations in terms of crash safety, noise and vibration levels, and interior content. The discontinued Lotus Elise is an example of an aluminum and fiberglass car that achieved MR5 but represents an extremely niche vehicle application that is unlikely to translate to mainstream, high-volume models. Therefore, it is entirely reasonable to assume that carbon fiber ''hang on'' panels and closures would be necessary to achieve MR5 at performance parity.

In past rules, commenters have noted that the NAS study relies on very little application of carbon fiber technology to achieve their highest level of MR technology. NHTSA notes that the NAS study espouses a maximum level of MR of approximately 14.5 percent using composites (*e.g.,* fiberglass) and carbon fiber technology only in closures structures (*e.g.,* doors, hoods, and decklids) and hang-on panels (*e.g.,* fenders). This is the ''alternative scenario 2'' in the NAS study and is a similar light-weighting technology application strategy to what the analysis roughly associates with MR5, but MR5 requires a 20-percent MR. In this scenario, NHTSA is allotting more MR potential for the same carbon fiber technology application than the NAS study does.

NHTSA assigns MR levels to vehicles in the analysis fleet by using regression analyses that consider a vehicle's body design[244] and body style, in addition to several vehicle design parameters, like footprint, power, bed length (for pickup trucks), and battery pack size (if applicable), among other factors. NHTSA has been improving on the light-duty regression analysis since the 2016 Draft Technical Assessment Report (TAR) and continues to find that it reasonably estimates MR technology levels of vehicles in the analysis fleet. Chapter 3.4 of the Draft TSD contains a full description of the regression analyses used for the analysis fleet and examples of results of the regression analysis for select vehicles.

There are several ways NHTSA ensures that the CAFE Model considers MR technologies in the way that 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 same 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 family. 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 ''levels 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 2024, and a ''follower'' starts at MR0 in MY 2024, 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, NHTSA also restricts MR5 technology to platforms that represent 80,000 vehicles or fewer. The CAFE Model does not apply MR5 technology to platforms representing high-volume sales, like a Chevrolet Traverse, for example, where hundreds of thousands of units are sold

[241] Note that in the previous analysis associated with the MYs 2024–2026 final rule, 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.

[242] Glider mass reduction can sometimes enable a smaller engine while maintaining performance neutrality. Smaller engines typically weigh less than bigger ones. NHTSA captures 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.

[243] Ford, 2021 F–150 Technical Specifications, available at: *https://www.fromtheroad.ford.com/content/dam/fordmediasite/us/en/library/2021/specs/2021-F-150-Technical-Specs.pdf* (accessed: Sept. 10, 2025); Ford, 2014 F–150 Technical Specifications, available at: *https://www.edmunds.com/ford/f-150/2014/features-specs/* (accessed: Sept. 10, 2025).

[244] The body design categories NHTSA uses are 3-box and 2-box pickup trucks. A 3-box has 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.

per year. NHTSA uses the combination of the leader-follower logic and 80,000-unit threshold to make the simulation of MR technologies more realistic. This is because NHTSA assumes that MR5 would require carbon fiber technology.[245] 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 about 10 percent of the global dry carbon fiber supply is allocated to the automotive industry, limiting the global supply base to supporting approximately 70,000 vehicles.[246] In addition, the production process for carbon fiber components is significantly different than for traditional vehicle materials. NHTSA uses 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 and equipment that would be required to support molding carbon fiber panels. There are no other adoption features for MR in the 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[247] and two NHTSA-sponsored studies that examined light-weighting a passenger car and light truck. NHTSA accounts 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.[248] With regard to the light-duty vehicle 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.[249] 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 resized only when MR of 10 percent or greater is applied to the glider mass or when one powertrain architecture replaces another architecture. A summary of how the different MR technology levels improve fuel consumption is shown in Draft TSD Chapter 3.4.4.

NHTSA's 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[250]—and the 2021 NAS report.[251] 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. Unlike the other technologies in this analysis that have a fixed technology cost (for example, it costs about $3,000 to add an AT10L3 transmission to a light-duty 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, an initial 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 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 MR4. 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 NHTSA relied on for MR costing, and NHTSA believes that it reasonably represents what manufacturers would expect to pay for using increasing amounts of carbon fiber on their vehicles.

Like past analyses, NHTSA considers several options for MR technology costs. The agency has determined that the NHTSA-sponsored studies accounted for significant factors the agency believes are important to include in this 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 and noise, vibration, and harshness (NVH)), and gradeability in the pickup truck study.[252]

First, NHTSA limits application of MR5 in the analysis to represent the limited volume of available dry carbon fiber and the resultant high costs of the raw materials. This constraint is described above and in more detail in Draft TSD Chapter 3. The CAFE Model assumes that there is not enough carbon fiber readily available to support vehicle platforms with more than 80,000 vehicles sold per year. NHTSA believes this volume constraint does more to limit the application of MR5 technology in the analysis than does its high price. Even if a lower price is used, the dominant constraint would still be volume. Second, NHTSA does not believe that a lower price would prove to be a competitive pathway to compliance with exotic materials technology compared to other less expensive technologies with higher effectiveness. The MR5 effectiveness as applied to vehicles in this analysis considers the total effect of reducing that level of mass from the vehicle, from the vehicle's starting MR level. As an example, while the cost of going from MR0 or MR1 to MR5 may be slightly overstated (but still limited in total application by the volume cap), the cost of going from MR4 to MR5 is not. NHTSA continues to consider the balance of carbon fiber and other

[245] 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.

[246] Sloan, J., Carbon Fiber Suppliers Gear Up for Next Generation Growth, Last revised: Feb. 11, 2020, available at: *https://www.compositesworld.com/articles/carbon-fiber-suppliers-gear-up-for-next-gen-growth* (accessed: Sept. 10, 2025).

[247] A2Mac1: Automotive Benchmarking, available at: *https://portal.a2mac1.com/* (accessed: Sept. 10, 2025). 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.

[248] Though NHTSA does not account for mass reduction in transmissions, NHTSA does 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.

[249] 2015 NAS Report

[250] Singh, H., Mass Reduction for Light-Duty Vehicles for Model Years 2017–2025, Final Report, DOT HS 811 666 (2012), available at: *https://static.nhtsa.gov/nhtsa/downloads/CAFE/2017-25_Final/811666.pdf* (accessed: Sept. 10, 2025); Singh, H. et al., Mass Reduction for Light-Duty Vehicles for Model Years 2017–2025, Report No. DOT HS 812 487, NHTSA: Washington, DC (2018), available at: *https://downloads.regulations.gov/NHTSA-2021-0053-0011/attachment_5.pdf* (accessed: Sept. 10, 2025).

[251] 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.

[252] Draft TSD Chapter 7.3 has additional detail on this analysis.

advanced materials for MR to meet MR5 levels and may update that value in future rules.

6. Aerodynamic Improvements

The energy required for a vehicle to overcome wind resistance, or more formally what is known as aerodynamic drag, ranges from minimal drag at low speeds to extremely significant drag at highway speeds.[253] 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 vehicle 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.[254]

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. Examples of active aerodynamic technologies are grille shutters, active air dams, and 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 AERO0, the first level) available in the analysis (AERO5, AERO10, AERO15, AERO20). Refer to Figure II–3 for a visual of each body style considered in the analysis. Each AERO level is associated with 5-, 10-, 15-, or 20-percent aerodynamic drag improvement values over a reference value computed for each vehicle body style. These levels, or bins, respectively correspond to the level of aerodynamic drag reduction over the reference value (*e.g.,* ''AERO5'' corresponds to the 5-percent aerodynamic drag improvement value over the reference value). 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—NHTSA estimates a pathway to each technology level based on data from a National Research Council of Canada-sponsored wind tunnel testing program. The program included an extensive review of production vehicles utilizing aerodynamic drag improvement technologies and of industry comments.[255] NHTSA's example pathways for achieving each level of aerodynamic drag improvement are discussed in Chapter 3.5 of the Draft TSD.

NHTSA assigns aerodynamic drag reduction technology levels in the analysis fleets based on vehicle body styles.[256] NHTSA computes an average coefficient of drag based on vehicle body styles, using coefficient of drag data from the MY 2015 analysis fleet. Different body styles offer different utility and have varying levels of form drag. This analysis considers both frontal area and body style as unchangeable utility factors affecting aerodynamic forces; therefore, the analysis assumes all reductions in aerodynamic drag forces come from improvements in the drag coefficient. Then NHTSA uses drag coefficients for each vehicle in the analysis fleet to establish an initial aerodynamic technology level for each vehicle. NHTSA compares the vehicle's drag coefficient to the calculated drag coefficient by body style mentioned above to assign initial levels of aerodynamic drag reduction technology to vehicles in the analysis fleets. NHTSA can find most vehicles' drag coefficients in manufacturers' publicly available specification sheets; however, in cases where this information cannot be found, NHTSA uses engineering judgment to assign the initial technology level.

NHTSA looks at vehicle body style and vehicle HP to determine which types of vehicles can adopt different aerodynamic technology levels. For this analysis, AERO15 and AERO20 cannot be applied to minivans, and AERO20 cannot be applied to convertibles, pickup trucks, and wagons. NHTSA does not allow application of AERO15 and AERO20 technology to vehicles with more than 780 HP. This threshold is informed by information about performance of ICE vehicles. NHTSA recognizes 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 ICE vehicles without reducing HP. This threshold for performance vehicles only limits the application of aerodynamic technologies on 2,518 units of sales volume in the analysis fleet.[257]

The aerodynamic technology effectiveness values that show the potential fuel consumption improvement from AERO0 technology are found and discussed in Chapter 3.5.4 of the Draft TSD. For example, the AERO20 values represent the range of potential FCIVs that could be achieved through the replacement of AERO0 technology with AERO20 technology for every technology key that is not restricted from using AERO20. NHTSA uses 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 complementary or non-complementary interactions among technologies.

NHTSA has carried forward the established AERO technology costs previously used in the 2020 final rule, the MYs 2024–2026 standards analysis,[258] and the 2024 rulemaking and has updated those costs to the dollar-year used in this analysis. For light-duty 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

[253] 2015 NAS Report, at p. 207.

[254] See, *e.g.,* Pannone, G., Technical Analysis of Vehicle Load Reduction Potential for Advanced Clean Cars, Final Report (2015), available at: *https://ww2.arb.ca.gov/sites/default/files/2020-04/13_313_ac.pdf* (accessed: Sept. 10, 2025). The graph on p. 20 shows how the aerodynamic force becomes the dominant load force at higher speeds.

[255] Larose, G. et al., 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,* Vol. 9(2): pp. 772–84 (2016), available at: *https://doi.org/10.4271/2016-01-1613* (accessed: Sept. 10, 2025).

[256] These assignments do not necessarily match the body styles that manufacturers use for marketing purposes. Instead, NHTSA makes these assignments based on engineering judgment and the categories used in the modeling, considering how this affects a vehicle's AERO and vehicle technology class assignments.

[257] See the Market Data Input File.

[258] Note the FRIA accompanying the 2020 final rule, Chapter VI.C.5.e.

of several passive aerodynamic technologies, and consecutively the cost to achieve AERO15 and AERO20 is much higher than AERO10 due to use of both passive and active aerodynamic technologies. The cost estimates are based on CBI submitted by the automotive industry in advance of the 2018 CAFE NPRM and on the agency's assessment of manufacturing costs for specific aerodynamic technologies. The 2018 FRIA contains discussion of the cost estimates.[259] NHTSA has not received additional comments in previous rulemakings from stakeholders regarding the AERO costs since they were established in the 2018 FRIA during the MYs 2024–2026 standards analysis and has 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 model years are in the CAFE Model's Technologies Input File.

7. 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 pavement. 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 stretching a rubber band requires 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. Larger deformations consume even more energy, which results in worse fuel economy. Low 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.

NHTSA uses three levels of low rolling resistance tire technology for the light-duty analysis. Each level of low rolling resistance tire technology reduces rolling resistance by 10 percent from an industry-average rolling resistance coefficient (RRC) value of 0.009.[260] RRC data from a NHTSA-sponsored study shows that similar vehicles across the light-duty vehicle categories have been able to achieve similar RRC improvements. Chapter 3.6 of the Draft TSD presents more information on this comparison. Draft TSD Chapter 3.6.1 shows the light-duty low rolling resistance technology options and their associated RRC.

NHTSA has been using ROLL10 and ROLL20 in the last several CAFE Model analyses. NHTSA has only recently included 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 the possibility that there would be additional tire improvements over the next decade.[261] NHTSA has received comments in previous CAFE rules that also reflect the application of ROLL30 by OEMs, though they discourage considering the technology due to high cost and possible wet traction reduction. With increasing use of ROLL30 application by OEMs,[262] 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), NHTSA considers ROLL30 as a viable future technology during this rulemaking period. NHTSA believes that the tire industry is in the process of moving automotive manufacturers towards higher levels of low rolling resistance technology in the vehicle fleet. NHTSA believes that, at this time, the emerging tire technologies that would achieve 30-percent improvement in rolling resistance, like changing tire profile, stiffening tire walls, employing novel synthetic rubber compounds, or adopting improved tires along with active chassis control, among other technologies, may be available for commercial adoption in the fleet during this rulemaking timeframe.

Assigning low rolling resistance tire technology to the analysis fleet is difficult because RRC data are 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, NHTSA uses a combination of CBI, data from a NHTSA-sponsored ROLL study, and assumptions about parts-sharing to assign tire technology in the analysis fleet. A slight majority of vehicles (54.9 percent) in the analysis fleet do not use any ROLL improvement technology, while 13.0 percent of vehicles use ROLL10, and 28.4 percent of vehicles use ROLL20. Only 3.7 percent of vehicles in the analysis fleet use ROLL30.

The CAFE Model can apply ROLL technology at either a vehicle refresh or redesign. NHTSA recognizes that some vehicle manufacturers prefer to use higher RRC tires on some performance cars and SUVs. Since many 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, NHTSA applies ROLL technology adoption features based on vehicle HP and body style. All vehicles in the light-duty fleet that have below 350 hp can adopt all levels of ROLL technology. Draft TSD Chapter 3.6.3 shows that all light-duty vehicles under 350 hp can adopt ROLL technology, and as vehicle HP increases, fewer vehicles can adopt the highest levels of ROLL

[259] Note the PRIA accompanying the 2018 NPRM, Chapter 6.3.10.1.2.1.2 for a discussion of these cost estimates.

[260] See Technical Analysis of Vehicle Load Reduction by CONTROLTEC for California Air Resources Board (Apr. 29, 2015). NHTSA 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 light-duty 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.

[261] See The Safer Affordable Fuel-Efficient (SAFE) Vehicles Rule for Model Years 2021–2026 Passenger Cars and Light Trucks, Docket No. NHTSA–2018–0067–11985.

[262] See 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; Technical Analysis of Vehicle Load Reduction by CONTROLTEC for California Air Resources Board, Docket No. NHTSA–2021–0053–0010 (Apr. 29, 2015); Evans, L. R. et al., NHTSA Tire Fuel Efficiency Consumer Information Program Development: Phase 2—Effects of Tire Rolling Resistance Levels on Traction, Treadwear, and Vehicle Fuel Economy, Report No. DOT HS 811 154, Docket No NHTSA–2008–0121–0035 (2009).

technology. Draft TSD Chapter 3.6 shows how effective the different levels of ROLL technology are at improving vehicle fuel consumption.

DMCs and learning rates for ROLL10 and ROLL20 are the same as prior analyses [263] but are updated to the dollar-year used in this analysis. In the absence of ROLL30 DMCs from tire manufacturers, vehicle manufacturers, or studies, NHTSA extrapolated the DMCs from ROLL10 and ROLL20 to develop the DMC for ROLL30. NHTSA believes 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.

8. Simulating Air-Conditioning Efficiency and Off-Cycle Technologies

For this proposal, NHTSA's analysis of the regulatory alternatives removes FCIVs) for AC efficiency and OC technologies starting in MY 2028. NHTSA is making this change to align with its conclusion that technology specific incentives should not be considered when running the compliance simulation that informs its consideration of maximum feasible standards. Instead, NHTSA's analysis for MY 2028 and beyond is based on simulating compliance based on 2-cycle testing. To simulate compliance pathways using the CAFE Model without AC efficiency and OC technologies, NHTSA sets the maximum allowable FCIV to 0g carbon dioxide (CO_2)/mi in the Scenarios Input File. Section VI contains a more detailed discussion of how AC efficiency and OC benefits affect compliance with NHTSA's fuel economy standards.[264]

Under EPA's current procedures for determining fleet average fuel economy for CAFE compliance, manufacturers may generate FCIVs, which improve their fuel economy values. Manufacturers may generate FCIVs for the addition of OC and AC efficiency technologies, which can provide fuel economy benefits in real-world vehicle operation that are not fully captured using the 2-cycle test procedures (*e.g.,* FTP and HFET) used to measure fuel economy.[265] Starting in MY 2027, only automobiles powered by ICEs are eligible to generate FCIVs, and the OC FCIV program is currently being phased out between MYs 2031–2033, with manufacturers no longer being able to generate OC FCIVs for MY 2033 and beyond. OC technologies can include, but are not limited to, thermal control technologies, high-efficiency alternators, and high-efficiency exterior lighting. As an example, manufacturers can generate FCIVs for the addition of 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.

Since EPA first proposed allowing manufacturers to earn FCIVs for AC efficiency and OC technologies, NHTSA has not modeled AC efficiency and OC technologies in the CAFE Model like other vehicle technologies, for several reasons. Each time NHTSA adds a technology option to the CAFE Model's technology pathways, the agency increases the number of Autonomie simulations by approximately a hundred thousand. This means that adding just five AC efficiency and five OC technology options would double the agency's Autonomie simulations to around 2 million total simulations. Instead, for applicable model years, the CAFE Model applies predetermined AC efficiency and OC 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 OC technologies in a way that both minimizes cost and allows the manufacturer to meet a given CAFE standard without over-or under-complying. The predetermined benefits that the CAFE Model applies for AC efficiency and OC technologies are based on manufacturers' MY 2024 mid-model year CBI compliance reports.

NHTSA uses manufacturers' MY 2024 AC efficiency and OC FCIVs they achieved via the ''menu'' as a starting point for each regulatory class, then holds those values constant from MYs 2024–2031 for the No-Action Alternative and through MY 2027 for action alternatives. Unlike previous versions of this analysis, NHTSA does not extrapolate the MY 2024 values to future model years. Instead, the CAFE Model assumes that FCIVs for MY 2027 will be the same as they were for MY 2024. Manufacturers have been able to settle in on a level of AC efficiency and OC technologies that maximize their return on investment (ROI); therefore, NHTSA does not anticipate a significant increase in manufacturers' AC efficiency and OC FCIVs between MYs 2024–2027 for any regulatory category. Additional details about how NHTSA determines AC efficiency and OC technology application rates are discussed Chapter 3.7 of the Draft TSD.

Because the CAFE Model applies AC efficiency and OC technology benefits independent of the technology pathways, NHTSA must account for the costs of those technologies independently, as well. NHTSA generates costs for these technologies on a dollars per gram of CO_2 per mile ($ per g/mi) basis, as AC efficiency and OC technology benefits are applied in the

[263] See Transportation Research Board, Tires and Passenger Vehicle Fuel Economy: Informing Consumers, Improving Performance, Special Report 286 (2006), available at: *https://nap.nationalacademies.org/catalog/11620/tires-and-passenger-vehicle-fuel-economy-informing-consumers-improving-performance* (accessed: Sept. 10, 2025); NHTSA, Corporate Average Fuel Economy for MY 2011 Passenger Cars and Light Trucks, Final Regulatory Impact Analysis (2009), available at: *https://www.nhtsa.gov/sites/nhtsa.gov/files/cafe_final_rule_my2011_fria.pdf* (accessed: Sept. 10, 2025); EPA and NHTSA, Joint Technical Support Document: Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards 3–77 (2010), available at: *https://www.federalregister.gov/documents/2010/05/07/2010-8159/light-duty-vehicle-greenhouse-gas-emission-standards-and-corporate-average-fuel-economy-standards* (accessed: Sept. 10, 2025); EPA and NHTSA, 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 at 5–153 and 154, 5–419, EPA–420–D–16–900 (July 2016), available at: *https://www.nhtsa.gov/sites/nhtsa.gov/files/draft-tar-final.pdf* (accessed: Sept. 10, 2025). 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 are seen to be fairly consistent with CBI suggestions by tire suppliers.

[264] Compliance with NHTSA's fuel economy standards is determined in accordance with EPA's calculation procedures at 40 CFR 600.512.

[265] *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. . . . [T]he 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.'').

CAFE Model on a gram per mile basis (as in the regulations). NHTSA updates the AC efficiency and OC technology costs by implementing an updated calculation methodology and converting the DMCs to 2024 dollars. The AC efficiency costs are based on data from EPA's 2010 FRIA and the 2010 and 2012 Joint NHTSA/EPA TSDs.[266 267 268] NHTSA has used data from EPA's 2016 Proposed Determination TSD[269] to develop the updated OC costs that were used for the 2022 final rule and now this proposed rule.

For this rulemaking, NHTSA is removing FCIVs from its standard-setting analysis starting with MY 2028, which is the first year in which a removal of FCIVs could go into effect.[270] NHTSA believes that the FCIVs generated under the OC and AC efficiency programs are no longer representative of real-world fuel savings. The values for adding such technologies were estimated from emission-reduction assessments performed on MY 2008 automobiles. As fuel economy has improved in the model years since these assessments were performed, the FCIVs for adding OC technologies have increasingly represented a larger percentage improvement in putative fuel economy values. As a result, the values for FCIVs have become less representative of real-world fuel savings and have created market distortions that undermine EPCA's purposes by incentivizing the addition of technology that does not provide commensurate fuel savings in the real world. NHTSA seeks comment on this determination. Additional details and assumptions used for AC efficiency and OC costs are discussed in Chapter 3.7.2 of the Draft TSD.

E. Consumer Responses to Manufacturer Compliance Strategies

The prior subsections of Section II have discussed how manufacturers might respond to the proposed standards. While the technology analysis outlined different compliance strategies available to manufacturers, the costs and benefits that would accrue because of the proposed standards are dependent on how consumers respond to manufacturers' compliance decisions. The next few subsections describe how the agency models how consumers may respond to changes in vehicle prices and attributes caused by manufacturers' compliance decisions, as simulated by the CAFE Model.

1. Consumer Responses to Manufacturer Compliance Strategies for 2027–2031

a. Macroeconomic and Consumer Behavior Assumptions

Most of the economic effects simulated within the analysis are influenced by macroeconomic conditions that are outside the agency's influence. For example, fuel prices are determined mainly by global petroleum supply and demand, yet they affect how much fuel efficiency-improving technology U.S. manufacturers would apply to their vehicles, how much more consumers would be willing to pay to purchase models offering higher fuel economy, how much buyers would drive those vehicles, and the value of each gallon of fuel saved from improved fuel efficiency. Constructing these forecasts of the consequences of CAFE standards requires robust projections of demographic and macroeconomic variables that span the full timeframe of the analysis, including real GDP, consumer confidence, U.S. population, and real disposable personal income.

The analysis presented with the proposal employs fuel price projections developed by EIA, an agency within DOE, which collects, analyzes, and disseminates independent and impartial energy information to promote sound policy-making and public understanding of energy. EIA uses its National Energy Modeling System (NEMS) to produce its AEO, which presents projections of future fuel prices (among many other economic and energy-related variables), and these are the source of some inputs to the agency's analysis. The agency's analysis for the proposal uses AEO's 2025 Alternative Transportation Case projections of U.S. population, GDP, disposable personal income, GDP deflator, and fuel prices. NHTSA uses AEO's 2025 Alternative Transportation Case because this case is intended to reflect recent policy directives and therefore provides a more informed analysis of conditions that will affect fuel prices than the reference case (which is tied, in part, to Federal energy policies that are no longer in place), especially in the near-term. The analysis also relies on S&P Global's forecasts of the total number of U.S. households[271] and the University of Michigan's Consumer Sentiment Index from its fall 2024 U.S. Economic Forecast, which EIA also uses to develop the projections it reports in its AEO.

These macroeconomic assumptions are important inputs to the analysis, but they are also uncertain, particularly over the long lifetimes of the vehicles affected by this proposed rule. To reflect the effects of this uncertainty, the agency also uses AEO's Low Oil Price and High Oil Price side cases to analyze the sensitivity of its analysis to alternative fuel price projections. The purpose of the sensitivity analysis, which is discussed in greater detail in Chapter 9 of the PRIA, is to measure the degree to which different assumptions about fuel prices can change simulated outcomes. NHTSA similarly uses low and high economic growth cases from S&P Global's March 2025 forecast as bounding cases for the macroeconomic variables in its analysis.

The agency will consider updating these inputs if newer versions of the data are available prior to conducting the analysis for the final rule. NHTSA seeks comments on these data sources. If commenters feel that there are better alternative sources of the same or similar data, the agency requests commenters to identify their preferred data source and explain why they believe it is more appropriate within the context of this CAFE rulemaking.

The analysis presented for this proposed rulemaking uses a 2024 base year, consistent with the use of vehicle data for MY 2024, and data for that year represents actual observations rather than estimates to the extent possible. Chapter 4.1 of the Draft TSD discusses macroeconomic forecasts and assumptions NHTSA uses in this analysis.

Another key assumption that permeates the agency's analysis is how much consumers are willing to pay for improved fuel economy. The payback period assumption also has important implications for other regulatory analysis results, including the effect of standards on sales and the use of new vehicles, as well as the number and use

[266] EPA, Final Rulemaking to Establish Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards Regulatory Impact Analysis for MYs 2012–2016, Last revised: May 14, 2025, available at: *https://www.epa.gov/regulations-emissions-vehicles-and-engines/final-rule-model-year-2012-2016-light-duty-vehicle* (accessed: Sept. 10, 2025) (hereinafter, ''Final Rulemaking MYs 2012–2016'').

[267] Final Rulemaking MYs 2012–2016.

[268] EPA, Joint Technical Support Document: Final Rulemaking for 2017–2025 Light-Duty Vehicle Greenhouse Gas Emission Standards and Corporate Average Fuel Economy Standards, EPA–420–R–12–901, EPA: Washington, DC (2012) available at: *https://www.nhtsa.gov/sites/nhtsa.gov/files/joint_final_tsd.pdf* (accessed: Sept. 10, 2025).

[269] EPA, 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, EPA–420–R–16–020 (2016).

[270] 49 U.S.C. 32904(d).

[271] NHTSA sourced the data from IHS-Polk. S&P Global purchased IHS Markit and rights to this data in 2022.

of older, used vehicles. The agency has updated its review of the academic literature on willingness to pay as part of its analysis of this proposal, which is discussed in Draft TSD Chapter 4.21 and PRIA Chapter 2.1.2. As noted in previous rulemakings, the range of estimates presented in the literature is wide. Some of the studies conclude that consumers value much of the potential savings in fuel costs from driving higher mpg vehicles, while others conclude that consumers significantly undervalue expected fuel savings. The more recent studies suggest that consumers value somewhere between 24 and the full lifetime value of undiscounted fuel savings, which is also supported by several of the older studies.

Manufacturers have repeatedly informed the agency that they believe that consumers only value between 2 to 3 years of fuel savings when choosing among competing models to purchase,[272] and the plurality of consumers when surveyed about their payback preferences have stated they are willing to pay for technology that repays the upfront cost within 24 months.[273] The agency also performed a retrospective analysis using the CAFE Model with reference fleets created to support prior rules. The agency modeled how the 2020 reference fleet (used for the 2022 final rule), similarly projected forward, compared with the 2022 reference fleet (used in the 2024 final rule), and how the 2022 reference fleet (used for the 2024 final rule) projected forward with different payback assumptions compared with the 2024 reference fleet used in this NPRM. These simulations provided model predictions about the technology penetration rates under different assumptions about the length of the payback period and under different projections of future fuel prices and technology costs. By comparing these to actual penetration rates NHTSA could judge the Model's ability to predict technology adoption under each payback assumption. The payback assumption that most accurately predicted technology adoption is 36 months, followed by 30 months. Both longer and shorter payback periods create a larger divergence.

After weighing the results from the academic literature, previous statements from manufacturers, and the agency's retrospective analysis, NHTSA is using a 36-month payback assumption for the analysis of this proposal. While this estimate represents a longer payback period assumption than was applied in the analysis of the previous three CAFE rules, the agency tentatively believes that the preponderance of the evidence suggests that 36 months is appropriate. NHSTA seeks comments on whether this represents an appropriate representation of consumer willingness to pay higher upfront prices for future fuel savings. Recognizing the consequences of the payback assumption in the agency's regulatory analysis, NHTSA also includes sensitivity cases to examine the impacts of longer and shorter payback periods in Chapter 9 of the PRIA. These concepts are explored more thoroughly in Chapter 4.2.1.1 of the Draft TSD and Chapter 2.1 of the PRIA.

b. Fleet Composition

The composition of the on-road fleet—and how it changes in response to standards—determines many of the costs and benefits of the proposed rule. For example, how much fuel is consumed depends on the number and efficiency of new vehicles sold and how rapidly older, less efficient, less safe vehicles are retired. Reducing the stringency of the CAFE standards would lower the price of new vehicles compared to the No-Action Alternative and would lead to a relative increase in sales of newer, safer vehicles, which in turn would decrease the price of used vehicles leading to the quicker retirement of the oldest, least safe, and less fuel-efficient vehicles on the road.

The analysis accompanying the proposal 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 composed of two forces: how sales of new vehicles and their integration into the existing fleet change in response to each regulatory alternative, and how economic and regulatory factors influence the retirement of used vehicles from the fleet (scrappage). NHTSA models sales and scrappage independently.

CAFE standards have been rising every year for nearly two decades. This constant increase in standards has been accompanied by a rise in both the costs of new vehicles and the age of the on-road fleet. The average selling price for new cars and light trucks rose nearly 50 percent between 2012 and 2024 and now approaches $50,000, while U.S. households' average income increased only about half as much over that same period. As the financial burden on households to purchase a new vehicle has increased substantially, recent annual sales of new cars and light trucks have been slightly lower than they were immediately before and after the 2008 recession. Meanwhile, the total number of cars and light trucks in use rose by about 30 million, with the entire increase representing used vehicles, while their average age rose from 10.6 to 12.6 years.[274]

Below are brief descriptions of how the agency models sales and scrappage; for full explanations, readers should refer to Chapter 4.2.1 of the Draft TSD.

(1) Sales

By reducing the regulatory costs of complying with fuel economy standards, the proposal would lead to an increase in new vehicle sales relative to the No-Action Alternative. For the purposes of regulatory evaluation, the relevant metric is the *difference* in the number of new vehicles sold between the baseline and each alternative rather than the absolute number of sales under any alternative. The agency's analysis of the response of new vehicle sales to different stringencies of fuel economy standards includes three components: a forecast of sales based exclusively on macroeconomic factors, which is used to determine the sales quantity for the No-Action Alternative; the assumed price elasticity of new vehicle demand, which interacts with estimated price increases under each alternative to create differences in sales relative to the No-Action Alternative; and a fleet share model that projects differences in the passenger and non-passenger automobile fleet shares under each alternative.

The first component of the sales response model is the nominal total new vehicle sales forecast, which is based on a small set of macroeconomic inputs that together determine the size of the new vehicle market in each future year under the baseline alternative. This statistical model is intended to provide only an initial forecast of light-duty vehicle sales; it does not incorporate the effect of prices on sales and is not intended to be used for analysis of the response to price changes in the new vehicle market. NHTSA's projection oscillates in the early model years

[272] *See, e.g.,* 87 FR 25710, 25856 (May 2, 2022).

[273] Some survey data such as Consumer Reports shows consumers with lower payback periods (around 24 months). However, the methodology employed by surveys like Consumer Reports are less rigorous than the revealed preferences data from the other sources, which is why Circular A–4 directs the agencies to attempt to use studies that rely on revealed preferences when feasible.

[274] Parekh, N., & Campau T., Average Age of Vehicles Hits New Record in 2024, Last revised: May 22, 2024, available at: *https://www.spglobal.com/mobility/en/research-analysis/average-age-vehicles-united-states-2024.html* (accessed: Sept. 10, 2025).

before settling to follow a constant trend in the 2030s. This result is generally consistent with the continued response to sales volatility in the years following the coronavirus disease of 2019 (COVID–19) pandemic and the supply chain challenges immediately thereafter. NHTSA acknowledges that excluding the regulatory costs to comply with the baseline standards has the potential to underestimate the effect of prevailing conditions on vehicle sales; however, given that the macroeconomic assumptions used in this analysis take into account the effects of various regulatory policies and the fact that the relevant metric is the differences created by alternative CAFE stringencies, the agency feels that this approach provides a reasonable starting point. NHTSA will continue to monitor changes in macroeconomic conditions and their effects on new vehicle sales and will update its baseline forecast for use in the final rule analysis as appropriate.

The agency's baseline sales forecast assumes that total new vehicle sales are driven primarily by conditions in the U.S. economy that are outside the influence of 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 changes to vehicles' designs and prices that occur as consequences of manufacturers' compliance with earlier standards (and with regulations on vehicles' features other than fuel economy) exert some influence on the volume of new vehicle sales, they are far less influential than macroeconomic conditions. The effects of compliance are not large enough to reverse broader cyclical trends in sales; instead, they produce the marginal differences in sales among regulatory alternatives that the agency's sales module is designed to simulate. Increases in new models' prices caused by higher regulatory costs reduce sales below the cyclical trend, and slow fleet turnover, while decreases in prices have the opposite effect.

NHTSA is statutorily barred from considering the fuel economy of dedicated automobiles (*e.g.,* battery electric or hydrogen vehicles) and therefore has removed dedicated automobiles from the sales forecast it uses to analyze the proposed rule. NHTSA uses market penetration rates from the AEO 2025 Alternative Transportation Case to estimate the market share of the gasoline-powered fleet. The agency then applies this market share to the total light-duty forecast produced by the nominal forecast.[275] An independent projection like the AEO 2025 Alternative Transportation Case is a reliable estimate of the future market share for gasoline-powered vehicles.

The second component of the sales response model captures how price changes affect the number of vehicles sold. NHTSA estimates the change in sales from its initial forecast during future years under each regulatory alternative by applying an assumed price elasticity of new vehicle demand to the percent difference in average price between the regulatory alternatives and the No-Action Alternative. This price change does not represent an increase or decrease from the previous model year, but rather the percent difference in the average price of new vehicles between the baseline and each regulatory alternative for that particular model year. The average new vehicle price in the baseline is defined as the observed price in 2024 (the last historical data year before the simulation is run) plus the average regulatory cost associated with the No-Action Alternative for each future model year.[276] The agency also subtracts any tax credits for which a PHEV may qualify from those regulatory costs to simulate sales.[277]

Within the CAFE Model's logic, there is an implicit assumption that new vehicle models within the same regulatory class (*e.g.,* passenger automobiles) are close substitutes for one another, including vehicles with differing powertrains.[278] NHTSA recognizes that different vehicle attributes may alter the perceived value of vehicles. NHTSA implements several guardrails to prevent the CAFE Model from adopting technologies for fuel economy that could adversely affect the utility of vehicles, such as maintaining performance neutrality, including phase-in caps, and defining technology pathways by using engineering judgement. The agency acknowledges that, even with these constraints, it is possible that CAFE standards may influence attributes other than price or fuel economy that are unaccounted for in the agency's sales analysis.

NHTSA has previously invested considerable resources in developing a discrete choice model of the new automobile market that would (1) enable the agency to incorporate the effect of additional vehicle attributes on buyers' choices among competing models; (2) reflect consumers' differing preferences for specific vehicle attributes; and (3) provide the capability to simulate responses, such as strategic pricing strategies by manufacturers intended to alter the mix of models they sell and enable them to comply with new CAFE standards. However, those efforts have not yet produced a satisfactory and operational model.[279] Instead, NHTSA accounts for the possibility of decreased utility of vehicles because of CAFE standards outside of the sales module.

Because the price elasticity that is applied in the Model 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 change to which the elasticity is applied in this analysis represents the residual price difference *between the baseline and each regulatory alternative* after deducting the value of fuel savings over the first 3 years of each model year's lifetime.

The price elasticity is also specified as an input, and for the proposal, the agency assumed a value of –0.4, meaning that a 5-percent increase in the average price of a new vehicle produces a 2-percent decrease in total sales.

[275] NHTSA also considers other approaches, such as assuming the full fleet in future model years would be composed of gasoline-powered vehicles or holding the current market penetration rate for dedicate automobiles constant. Draft TSD Chapter 4.2.1.2 provides more discussion of the selected approach and alternatives considered.

[276] The CAFE Model currently operates as if all costs incurred by the manufacturer as a consequence of meeting regulatory requirements, whether those costs 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.

[277] For additional details about how NHTSA models tax credits, see Section II.C.5b above.

[278] The CAFE Model does not assign different preferences between technologies, and outside the standard-setting restrictions, the Model will apply technology on a cost-effectiveness basis. Similarly, outside of the sales response to changes in regulatory costs, consumers are assumed to be indifferent to specific technology pathways and will demand the same vehicles despite any changes in technological composition.

[279] NHTSA's experience partly reflects the fact that these models are highly sensitive to their data inputs and estimation procedures, and even versions that fit well when calibrated to data from a single period—usually a cross section of vehicles and shoppers or actual buyers—often produce unreliable forecasts for future periods, which NHTSA's regulatory analyses invariably require. This occurs because they are often unresponsive to relevant shifts in economic conditions or consumer preferences, and also because it is difficult to incorporate factors such as the introduction of new model offerings—particularly those utilizing advances in technology or vehicle design—or shifts in manufacturers' pricing strategies into their representations of choices and forecasts of future sales or market shares. For these reasons, most vehicle choice models have been better suited for analysis of the determinants of historical variation in sales patterns than for forecasting future sales, volumes and market shares of particular categories.

NHTSA has used this same elasticity in prior rulemakings. Estimates of this parameter reported in published literature vary widely,[280] and NHTSA believes that its choice is a reasonable one within this range, but NHTSA also presents sensitivity cases that explore higher and lower elasticities in PRIA Chapter 9. Chapter 4.2.1.2 of the Draft TSD further presents the evidence that NHTSA believes supports its decision. The agency seeks comment on this sales elasticity assumption—including whether NHTSA should consider applying separate short-run and long-run elasticity assumptions in the analysis. If commenters believe that an alternative assumption would be appropriate, NHTSA requests that they provide specific references to estimates in the econometric literature that would support such alternatives.

The third and final component of the sales model is the dynamic fleet share module (DFS). This analysis uses the DFS developed during the previous rulemaking. The baseline fleet share projection is derived from the agency's own compliance data for the 2024 fleet and from the 2025 AEO projections for subsequent model years. These shares are applied to the total industry sales derived in the first stage of the total sales model to estimate sales volumes of car and light truck body styles. NHTSA determines individual model sales using the following sequence: (1) individual manufacturer shares of each regulatory class (either passenger cars or light trucks) are multiplied by total industry sales of vehicles in that regulatory class and then (2) each vehicle within a manufacturer's volume of that regulatory class is assigned the same percentage share of that manufacturer's sales as in MY 2024. This assumes that consumer preferences for particular styles of vehicles are determined in the aggregate (*i.e.,* at the industry level), but that manufacturers' sales shares of those body styles are consistent with their MY 2024 sales. Within a given regulatory class, NHTSA assumes a manufacturer's sales shares of individual models are also constant over time.

This approach also 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 manufacturer's true cost of production, including its fixed and variable components and its target profit margins for its 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 applies an elasticity to the change in price between each regulatory alternative and the No-Action Alternative to determine the change in fleet share from its baseline value. 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 relative price coefficient of −0.000042. NHTSA selects this methodology and price coefficient based on a review of academic literature.[281] When the total regulatory costs for passenger automobiles of meeting standards minus the value of the resulting fuel savings exceed that of non-passenger automobiles, the market share of non-passenger automobiles will rise relative to passenger automobiles. For example, a $100 net regulatory cost increase in passenger automobiles relative to light trucks would produce around a 0.1-percent shift in market share towards light trucks, assuming the latter initially represent 60 percent of the fleet.

As discussed in preamble Section VI, the agency proposes to modify its regulatory definitions for vehicle classification starting with MY 2028. The agency takes account of this reclassification after it simulates the aggregate sales and dynamic fleet share responses to changes in vehicle prices. NHTSA assigns vehicles both an ''initial'' classification based on how they are classified under the current regulations and a ''revised'' classification for how they would be classified under the proposed regulations. The aggregate sales response is calculated at the fleetwide level, so regulatory classification only affects changes in sales insofar as a reclassified vehicle model incurs a different regulatory cost to comply with the requirements of its new regulatory class. For the dynamic fleet share model, the regulatory costs are borne by a vehicle's ''initial'' classification, so an SUV that is reclassified from the light truck fleet to the passenger car fleet has its regulatory costs for the dynamic fleet share analysis attributed to the light truck fleet throughout the analysis. This method assumes that each individual model's sales shares within the ''initial'' regulatory class remain constant. This may cause the counterintuitive effect of an increase in a vehicle's price, leading to an increase in that vehicle's sales. NHTSA considered applying its existing model to sales shares determined by the ''revised'' classification but decided against this due to the cross-elasticities used in this analysis being estimated based on the current classification system. NHTSA includes several sensitivity cases to explore different approaches, as presented in PRIA Chapter 9. NHTSA seeks comment on this approach and whether it is appropriate to apply the dynamic fleet share's price coefficient to the ''revised'' regulatory classes, and if not, if there is an alternative elasticity or methodology the agency could employ in its analysis.

(2) Scrappage

New and used vehicles can substitute for each other within broad limits. When the price of a good increases, so does the demand for its substitutes, causing the equilibrium price and quantity of substitutes supplied to rise. Because the proposal would lower the price of new vehicles, demand for used vehicles would decrease, causing the equilibrium market price for used vehicles to decrease and simultaneously increasing the rate at which used vehicles are retired. Because used vehicles are not manufactured, their supply only can be increased by keeping more of those that would otherwise be retired in use longer, which corresponds to a reduction in their scrappage or retirement rates. As older vehicles are used longer, the average age of the fleet rises and the safety risk to all road users likewise increases, because older vehicles are less safe than newer ones.

When new vehicles become more expensive, demand for used vehicles increases. Because used vehicles are more valuable in such circumstances, they are scrapped at a lower rate, and just as rising new vehicle prices push some prospective buyers into the used vehicle market, rising prices for used vehicles force some prospective buyers to acquire even older vehicles or models with fewer desired attributes. The effect of fuel economy standards on scrappage is partially dependent on how consumers value future fuel savings; NHTSA assumes consumers values only the first 36 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

[280] See Jacobsen, M. et al., The Effects of New-Vehicle Price Changes on New- and Used-Vehicle Markets and Scrappage, EPA–420–R–21–019 (2021), available at: *https://cfpub.epa.gov/si/si_public_record_Report.cfm?Lab=OTAQ&dirEntryId=352754* (accessed: Sept. 10, 2025) (reporting a range of estimates, with a value of approximately −0.4 representing an upper bound of this range). NHTSA selects this point estimate for the central case and explores alternative values in the sensitivity analysis.

[281] NHTSA 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.''

household's demand for vehicle miles traveled (VMT), the cost of alternative means of transportation, and the value that can be attained through reselling or scrapping the vehicle for parts. In theory, a car owner will decide to scrap a vehicle when the value of the vehicle minus the cost to insure, register, maintain, and repair the vehicle is less than its value as scrap material; in other words, when the owner realizes more value from scrapping the vehicle than from continuing to drive it or from selling it. Typically, the owner that scraps the vehicle is not the original owner.

While scrappage decisions are made at the household level, NHTSA is unaware of sufficiently detailed household data to capture scrappage at that level. Instead, NHTSA uses aggregate data measures that capture broader market trends. In addition, the aggregate results are consistent with the rest of the CAFE Model, as the Model does not attempt to project manufacturers' pricing strategies; the Model assumes instead that all regulatory costs to make a particular vehicle compliant are passed on to the purchaser who buys the vehicle.

The dominant source of scrappage is ''engineering scrappage,'' which is largely determined by the age of a vehicle and the durability of the specific model year or vintage it represents. NHTSA uses proprietary vehicle registration data from S&P Global to estimate vehicle age and durability. Other factors affecting owners' decisions to retire used vehicles or retain them in service include fuel economy and new vehicle prices; for historical data on new vehicle transaction prices, NHTSA uses National Automobile Dealers Association (NADA) data.[282] The data consists of the average transaction price of all light-duty vehicles; because the transaction prices are not broken down by body style, the scrappage module may miss unique trends within a particular vehicle body style. The transaction prices reflect the amount consumers paid for new vehicles and exclude any trade-in value credited towards the purchase. This may be relevant particularly 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 versions of the agency's scrappage module may consider incorporating price series that consider the price trends for cars, SUVs and vans, and pickups separately, and NHTSA asks commenters to identify any data or resources that could assist the agency in this pursuit.

Vehicle survival rates, which are determined over time by scrappage, follow 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 each year, and the annual rate at which vehicles are scrapped reaches a peak. Scrappage then declines as vehicles enter their later years, as fewer and fewer vehicles in the cohort remain on the road. The analysis uses a logistic function to capture this trend of vehicle scrappage with age. The data shows that the durability of successive model years generally increases over time; 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 lower generally for more recent vintages up to a certain age, but must increase thereafter so that the final share of vehicles remaining converges to a similar share remaining for historically observed vintages.[283] NHTSA's scrappage model uses fixed effects to capture potential changes in durability across model years and ensures that vehicles approaching the ends of their lives are scrapped in the analysis.

The final source of vehicle scrappage is from cyclical effects, which the Model captures using forecasts of GDP and fuel prices. 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 36 months of fuel savings and any tax credits passed through to the consumer) is included, and changes in this variable are the source of differing scrappage rates among regulatory alternatives. NHTSA seeks comment on its scrappage module and asks that commenters with any suggested revisions provide resources with sufficient detail to analyze alternative methodologies.

In addition to the variables included in the scrappage module, NHTSA considers several other potential 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 are excluded from the scrappage module either because of difficulties in obtaining data to measure them accurately or other modeling constraints. Their exclusion from the module is not intended to diminish their importance but rather highlights the practical constraints of modeling intricate decisions like scrappage. NHTSA seeks comments on whether it should include any of these variables and, if so, requests that commenters suggest specific methodologies that would produce robust and unbiased estimates that could be used in a regulatory analysis setting.

NHTSA expects that the proposed reset would accelerate the retirement of older vehicles compared to the No-Action Alternative. Because the proposed standard would reduce the regulatory burden on manufacturers and by extension the price of new vehicles, the demand and price for used vehicles would decrease, which would incentivize households to replace the older vehicles that are costly to maintain with newer, cheaper options—including newer used vehicles.

c. Changes in Vehicle-Miles Traveled

As described in the fleet turnover section, fuel economy standards influence the quantity of new vehicles sold and how quickly older vehicles are retired. Model years of different vintages possess distinguishable characteristics, with newer vehicles typically being more fuel efficient and safer than their older contingents. While the decision itself to buy a new vehicle or retire an older vehicle may confer certain costs and benefits to their owners, most of the effects are realized only through the use of those vehicles. The agency's proposal to lower standards would accelerate fleet turnover compared to the baseline, which would result in more miles being driven in newer, safer vehicles compared to older, less safe vehicles. As a result, fewer miles would be driven in the oldest, least safe vehicles on the road, and the number of fatal accidents would be expected to decrease as well.

Deciphering which vehicles are being driven is just as important as how many miles are being driven. Any shift in miles driven by older vehicles to newer vehicles creates a corresponding shift in societal benefits, which include both safety and environmental benefits. To capture how CAFE standards influence the distribution of miles across the fleet, NHTSA estimates VMT based on the average use of vehicles at different ages, the total number of vehicles in use, and the composition of the fleet by ages.

[282] The data can be obtained from NADA. For reference, the data for MY 2024 may be found at *https://www.nada.org/nada/research-data/nada-data*.

[283] Some possible reasons for 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.

These three components—average vehicle usage, new vehicle sales, and older vehicle scrappage—jointly determine total VMT projections for each alternative.

VMT is determined by how much households want to drive and how much they can afford to do so. NHTSA believes that a significant portion of light-duty VMT is unaffected by fuel economy standards. Households have some basic level of travel demand that needs to be met such as driving to work or school, and those households will drive those miles regardless of the imposition that fuel economy standards may impose. NHTSA's perspective is that the total demand for VMT should not vary excessively across alternatives. To prevent large differences from arising among the regulatory alternatives, the agency constrains the aggregate amount of VMT—besides VMT attributable to the ''rebound effect''—across alternatives to be equal with the No-Action Alternative.

In prior rules, the agency used the Federal Highway Administration (FHWA) VMT Forecasting Model to project total VMT in future calendar years and then adjusted alternatives based on fleet composition. NHTSA employed this methodology because it used a reliable, external projection of annual VMT as a starting point. However, since the FHWA model includes miles that will be driven in dedicated automobiles, NHTSA reconsidered for this analysis how to calculate VMT.

The No-Action Alternative's projection of VMT for this proposal uses the simulated projections of the gas-powered fleet produced by the sales and scrappage models and applies it to estimates of VMT per vehicle. Vehicles of different ages and body styles have different costs to own and operate, and usage changes across vehicle ages independent of CAFE standards. 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. Using S&P Global odometer data, NHTSA creates ''mileage accumulation schedules'' as an initial estimate of how much a vehicle is expected to drive at each age throughout its life. The mileage accumulation schedules also account for differences in driving habits based on body style. Multiplying the numbers of each vehicle projected to be in the fleet by the per-vehicle VMT estimates from the mileage accumulation schedules creates a forecast of VMT in each calendar year.

The methodology to allocate miles within the regulatory alternatives is similar. NHTSA uses the forecasts of the fleet produced by the sales and scrappage models and multiplies those by mileage accumulation schedules to create a total estimate of VMT. NHTSA then scales the alternative's VMT to match the No-Action Alternative's aggregate VMT, preserving the percentage of VMT driven by each model.

NHTSA seeks comments on whether it should remove the VMT constraint and allow alternatives to have differing levels of VMT. While much of household VMT is likely inelastic, it may be reasonable to assume that fleets with differing sizes, age distributions, and inherent cost of operation may have marginally different annual VMT (even without considering VMT associated with rebound miles). In previous rules, NHTSA elected to continue to constrain VMT across alternatives in part because of the difficulty of determining whether VMT would shift to other modes of transportation and, if so, how to account for the impacts of any such mode shift. NHTSA seeks comments on whether it is appropriate to consider mode shifts if the agency removes the VMT constraints and asks commenters to provide either any data or suggested modeling approaches that could assist the agency.

An example of a portion of household travel that *is* elastic is known as ''rebound'' mileage. The fuel economy rebound effect—a specific example of the well-documented energy efficiency rebound effect for energy-consuming capital goods—refers to motorists who choose to increase vehicle use (as measured by VMT) when fuel economy is improved and, as a result, the cost per mile (CPM) of driving declines. If fuel economy increases, the cost to drive additional miles decreases, resulting in vehicles with better fuel efficiency being driven more. For the proposed rule, reducing the level of fuel economy required by government regulation would reduce the number of miles driven.

NHTSA has employed several different rebound effect estimates through the years. Until recently, the agency had historically used an estimate between 15 and 20 percent. The agency lowered its estimate in the 2022 final rule to 10 percent, a value that was also carried forward in the 2024 final rule. To support this proposal, NHTSA re-reviewed the literature related to the fuel economy rebound effect, which is extensive and covers multiple decades and geographic regions.[284] The totality of evidence, without artificially excluding certain studies based on arbitrary selection criteria, 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 between 1 to 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 utilize 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.

When NHTSA reviewed the literature for both the 2022 and 2024 rules, the agency arrived at a similar result. However, NHTSA chose to use an estimate at the lowest end supportable by the academic literature. NHTSA argued that both economic theory and empirical evidence suggested that the rebound effect was declining over time due to factors such as increasing income (which increases the value of travelers' time), progressively 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. The agency also noted that certain studies with lower estimates of the rebound effect were associated with recently published studies that rely on U.S. data, measure vehicle use using actual odometer readings, control for the potential endogeneity of fuel economy, and—critically—estimate the response of vehicle use to variation in fuel economy itself rather than to fuel cost per distance driven or fuel prices. The agency gave greater weight to these studies, which suggested a rebound effect in the 5–15 percent range.

Consistent with NHTSA's surveys of the latest available data for each successive CAFE analysis, as discussed above, the agency reconsidered for this analysis its prior assumptions about rebound effect trends discussed in the 2022 and 2024 final rules—in particular assumptions about the rebound effect declining over time—and concluded that a rebound estimate of 15 percent is appropriate. In particular, a meta-analysis of 74 recently published studies of the rebound effect noted that ''the magnitude of the rebound effect in

[284] Draft TSD Chapter 4.3.4 provides more information.

road transport can be considered to be, on average, in the area of 20 [percent],'' and that the most likely long-run estimate was about 32 percent [285]—both significantly higher than the agency's prior 10 percent-value and higher than the 15 percent-value employed in this analysis. The agency believes that selecting a rebound estimate that is well-supported by the scientific consensus is more appropriate than speculating about trends that have yet to manifest. NHTSA examines the sensitivity of estimated impacts to values of the rebound effect ranging from 10 to 20 percent to account for the uncertainty surrounding its exact value. NHTSA seeks comments on its approach to accounting for the rebound effect. For a more complete discussion of the rebound literature, refer to Draft TSD Chapter 4.3.4.

In order to calculate total VMT after allowing for the rebound effect, the CAFE Model applies the price elasticity of VMT (taken from the FHWA forecasting model) to the change in fuel cost per mile resulting from higher fuel economy and uses the result to adjust the initial estimate of each model's annual use accordingly. The CAFE Model applies this adjustment after the reallocation step described previously, because that adjustment is intended to ensure that total VMT is identical among alternatives *before* considering the contribution of increased driving due to the rebound effect. Its contribution differs among regulatory alternatives because alternatives requiring higher fuel economy lead to larger reductions in the per-mile fuel cost of driving and thus to larger increases in vehicle use.

To summarize, because the proposed standards would lower the cost of newer vehicles, more of the base household travel demand will be satisfied by safer, newer vehicles, and simultaneously, newer vehicles will have lower fuel economy, leading to fewer miles being driven and resulting in a further reduction in fatalities and fuel expenditures.

Chapter 4.3 of the Draft TSD provides more information on how NHTSA accounts for and models VMT.

d. Changes to Fuel Consumption

NHTSA uses the fuel economy, age, and 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

Changes in fuel consumption because of changes in CAFE standards (and resulting technology application) will result in changes in emissions of various pollutants.[286] Vehicle-related emissions are computed by multiplying vehicle activity (*e.g.,* miles traveled, hours operated, or gallons of fuel burned), population (or number of vehicles), and emission factors. An emission factor is a representative rate that attempts to relate the quantity of a pollutant released to the atmosphere per unit of activity. As in past rules, the CAFE Model generates vehicle activity levels (both miles traveled and fuel consumption), while emission factors have been adapted from models developed and maintained by other Federal agencies.

This section provides a brief overview of how the agency estimates the resulting changes in emissions and associated effects from emissions of those pollutants.[287] In this section, emissions that are generated between the initial point of oil extraction and delivering fuel to vehicles' fuel tanks or energy storage systems are referred to as ''upstream'' emissions, while ''downstream'' emissions refer to those emitted by vehicles' exhaust systems, and also include other emissions generated during vehicle refueling, use, and inactivity (called ''soaking''), including hydrofluorocarbons leaked from vehicles' AC systems.[288] Emissions also include particulate matter released into the atmosphere by brake and tire wear (BTW), as well as evaporation of volatile organic compounds from fuel pumps and vehicles' fuel storage systems during refueling and when parked.

For the proposed rule, the agency updated upstream petroleum emission factors using R&D GREET 2024, a lifecycle emissions model developed by Argonne.[289] As in past analyses, the agency derived emission factors for the following four upstream emission processes for gasoline and diesel: (1) petroleum extraction; (2) petroleum transportation and storage; (3) petroleum refining; and (4) fuel transportation, storage, and distribution (TS&D). A detailed description of how the agency used R&D GREET 2024 to generate upstream emission factors appears in Chapter 5 of the Draft TSD. In this proposal, NHTSA uses a simplified parameterized economic model for estimating the response of domestic fuel production to changes in U.S. fuel consumption, as such responses also affect upstream emissions estimates related to the rule. Using this model, NHTSA estimates that 20 percent of the reduction in fuel consumption will be translated into reductions in domestic fuel production.

The agency estimated downstream emission factors for gasoline and diesel fuels for the majority of pollutants using EPA's MOVES5 model, a regulatory highway emissions inventory model developed by that agency's National Vehicle and Fuel Emissions Laboratory.[290] [291]

---

[285] Dimitropoulos, A. et al., The Rebound Effect in Road Transport: A Meta-analysis of Empirical Studies, OECD Environment Working Papers, No. 113, OECD Publishing: Paris, France (2016), available at: *https://dx.doi.org/10.1787/8516ab3a-en* (accessed: Sept. 10, 2025).

[286] The various pollutants include carbon monoxide (CO), volatile organic compounds (VOCs), nitrogen oxides (NO_X), sulfur oxides (SO_X), particulate matter with a diameter of 2.5-micron (µm) or less ($PM_{2.5}$), carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).

[287] While NHTSA considers the impacts of this rulemaking on the levels of various pollutant emissions, the main analysis does not include a monetization of any changes in levels of carbon dioxide, methane, and nitrous oxide emissions. (An analysis using the domestic-only valuation of those emissions is included in a sensitivity case). Monetized changes in criteria pollutant emissions are discussed in the preamble Section II.G and Chapter 6.2.2 of the Draft TSD.

[288] Emissions from HFC leakage from air conditioner systems are not captured in the CAFE Model analysis due to limitations in the pollutants modelled by MOVES5.

[289] Argonne National Laboratory, The Research and Development Greenhouse Gases, Regulated Emissions, and Energy Use in Technologies (R&D GREET) Model 2024, Last revised: Jan. 2025, available at: *https://greet.anl.gov/* (accessed: Sept. 10, 2025).

[290] EPA, Motor Vehicle Emission Simulator: MOVES5, Office of Transportation and Air Quality, Last revised: Aug. 26, 2025, available at: *https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves* (accessed: Sept. 10, 2025).

[291] The one exception is that downstream CO_2 emission factors were generated based on the carbon content and mass density per unit of each specific type of fuel assuming each fuel's entire carbon content is converted to CO_2 emissions during combustion.

Currently, the MOVES5 methodology for projecting future emission inventories includes estimated effects from Federal emissions standards for light-duty vehicles, including EPA's CO_2 standards for MYs 2024–2026 and MYs 2027–2031. NHTSA conducted this analysis prior to EPA publishing its proposal to rescind its action titled ''Endangerment and Cause or Contribute Finding for Greenhouse Gases Under Section 202(a) of the Clean Air Act'' (Endangerment Finding) and all resulting greenhouse gas emissions standards for light-, medium-, and heavy-duty vehicles and engines [292] and is exploring options to update the relevant emission factors consistent with EPA's latest methodology for the final rule. For purposes of this proposal, NHTSA believes the existing model provides a reasonable basis for estimating emission inventories in response to the policy options analyzed but requests comments on this assumption.

Another update to the analysis that NHTSA is exploring is the methodology for applying downstream emission factors to vehicle classes within the CAFE Model. MOVES regulatory classes no longer directly map to the CAFE Model vehicle classes beginning in MY 2028, at which time NHTSA is proposing to subject vehicles to the amended vehicle classification definitions. Adjusting the downstream emission factors requires an understanding of the implications of reclassification on mapping regulatory and vehicles classes between MOVES and the CAFE Model. It is NHTSA's expectation that any modification of downstream emission factors will result in only minor changes in the magnitude of the relative differences among alternatives. Draft TSD Chapter 5.3 contains additional detail about how the agency generated the downstream emission factors used in this analysis, and Section VI presents additional information about NHTSA's proposals for vehicle reclassification beginning in MY 2028.

As with downstream emission factors, the agency generated BTW emission factors using the latest version of EPA's MOVES5 model.[293] NHTSA believes that compared to previous versions of MOVES, MOVES5's updated assumptions about brake pad composition and vehicle weights to estimate brake wear emissions that vary by model year, regulatory class, and fuel type present reasonable estimates for use in the agency's regulatory analysis. For further reading on BTW assumptions and how the agency employed those assumptions in the CAFE Model, please refer to Draft TSD Chapter 5.3.3.4. NHTSA seeks comments on this methodology.

The CAFE Model computes select health impacts resulting from localized population exposure to $PM_{2.5}$ and its precursor pollutants that are measured by the number of instances predicted to result from exposure to each ton of relevant pollutant.[294] As in past CAFE analyses, NHTSA relied on publicly available scientific literature to estimate $PM_{2.5}$-related effects for each upstream and downstream emissions source [295] and employed certain assumptions to determine the most reasonable approach to incorporate estimates from literature into the Model.[296] NHTSA includes additional discussion of the agency's approach to estimating these effects in Chapter 5.4 of the Draft TSD.

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 amending previously established CAFE standards. OMB Circular A–4 states that benefits and costs reported in regulatory analyses must be defined and measured consistently with economic theory and also should reflect how alternative regulations are anticipated to change the behavior of producers and consumers from a baseline scenario without the regulation.[297] Fuel economy standards affect vehicle manufacturers, buyers of new vehicles, owners of used vehicles, and suppliers of fuel, all of whom respond in complex ways to the standards that DOT establishes for future model years. NHTSA's accounting framework for the economic costs and benefits of CAFE standards was developed for a scenario in which standards are being set for cars and light trucks produced during future model years, for which no standards currently exist. Under this framework, NHTSA assumes hypothetical baseline standards for those future years to be identical to those in the last model year for which the agency previously established standards. Costs of alternative standards considered for future model years are measured relative to those for meeting the baseline standards, while benefits for each alternative are savings or other gains to buyers and users of new cars and light trucks or the general public, again measured in reference to the baseline alternative.

Most of the agency's rulemakings have established standards for future model years that are above their hypothetical baseline level, so the costs of meeting them have consisted primarily of manufacturers' outlays to increase the fuel economy of their car and light truck models to meet those higher standards, while benefits have consisted primarily of fuel savings for buyers and subsequent owners of models offering higher fuel economy. In rulemakings, such as this one, where the agency is proposing to *reduce* previously established standards for future model years due to updated economic, market, and technological realities, manufacturers' costs will be reduced compared to those for meeting the previous standards, while new cars and light trucks will consume more fuel

[292] Reconsideration of 2009 Endangerment Finding and Greenhouse Gas Vehicle Standards; Proposed Rule, 90 FR 36288 (2025), available at: *https://www.federalregister.gov/documents/2025/08/01/2025-14572/reconsideration-of-2009-endangerment-finding-and-greenhouse-gas-vehicle-standards* (accessed: Sept. 10, 2025).

[293] EPA, Brake and Tire Wear Emissions from Onroad Vehicles in MOVES5, EPA: Washington, DC, pp. 1–69 (2024), available at: *https://nepis.epa.gov/Exe/ZyPDF.cgi?Dockey=P101CTUW.pdf* (accessed: Sept. 10, 2025).

[294] As the health incidences for the different source sectors are all based on the emission of 1 ton of the same pollutants, NO_X, SO_X, and directly emitted $PM_{2.5}$, differences in the incidence per ton values arise from differences in the geographic distribution of each pollutant's emissions, which in turn affects the number of people exposed to the estimated concentrations of each pollutant.

[295] EPA, Estimating the Benefit per Ton of Reducing $PM_{2.5}$ Precursors from 17 Sectors, EPA: Washington, DC, pp. 1–108 (2018), available at: *https://19january2017snapshot.epa.gov/benmap/estimating-benefit-ton-reducing-pm25-precursors-17-sectors_.html* (accessed: Sept. 10, 2025); Fann, N. et al., Assessing Human Health $PM_{2.5}$ and Ozone Impacts from U.S. Oil and Natural Gas Sector Emissions in 2025, *Environmental Science & Technology,* Vol. 52(15): pp. 8095–103 (2018), available at: *https://doi.org/10.1021/acs.est.8b02050* (accessed: Sept. 10, 2025) (hereinafter, ''Fann et al.''); Wolfe, P. et al., Monetized Health Benefits Attributable to Mobile Source Emission Reductions Across the United States in 2025, *The Science of the Total Environment,* Vol. 650(Pt 2): pp. 2490–98 (2019), available at: *https://doi.org/10.1016/j.scitotenv.2018.09.273* (accessed: Sept. 10, 2025) (hereinafter, ''Wolfe et al.''). Health incidence per ton values corresponding to this paper were sent by EPA staff.

[296] Some CAFE Model upstream emissions components do not correspond to any single EPA source sector identified in available literature, so NHTSA determined the most reasonable approach was to use a weighted average of different source sectors to generate those values. NHTSA is also aware that EPA in 2023 updated its estimated benefits for reducing $PM_{2.5}$ from several sources, but those do not include mobile sources (which include the vehicles subject to CAFE standards). NHTSA has thus retained the $PM_{2.5}$ incidence per ton values from the previous CAFE analysis for consistency with the current mobile source emissions estimates.

[297] Office of Management and Budget, Circular A–4 (Sept. 17, 2003), available at: *https://www.whitehouse.gov/wp-content/uploads/2025/08/CircularA-4.pdf* (accessed Sept. 10, 2025).

than if those previous standards remained in place.

Thus, the estimated costs of meeting the revised standards are reported as negative values—representing regulatory cost savings—while vehicle buyers' increased costs for fuel are similarly reported as negative benefits. When the agency has historically raised CAFE standards, it has assumed that manufacturers' costs to increase fuel economy would be passed on to buyers as increased purchase prices for new models, and the analysis supporting this proposed rule assumes that reduced costs to manufacturers for meeting less demanding CAFE standards will be reflected in lower prices for new cars and light trucks.

NHTSA's approach to estimating the economic impacts of regulatory alternatives it considers in this rulemaking, including the assumptions it relies upon and the methodologies it employs, is discussed in detail in Chapter 6 of the Draft TSD and throughout the PRIA (particularly Chapter 5). The safety implications of the proposed rule, including monetary measures of those impacts, are covered in Section II.H below.

Regulatory analysis needs to express costs and benefits that occur at different future times in comparable terms, which is done by discounting each future year's impacts to their present values. Following guidance presented in OMB Circular A–4 (2003), NHTSA presents the current values of all economic impacts quantified in its regulatory analysis discounting using the recommended rates of 3 and 7 percent.

The categories of economic costs and benefits resulting from NHTSA's proposed amendment to its previously established CAFE standards are described in Chapter 5 of the PRIA (see in particular Table 5–1). Monetary values of those estimates are presented in Chapter 8 (for the central analysis) and Chapter 9 (showing the results of various sensitivity analyses around key parameters and assumptions) of the accompanying PRIA.

Table II–8 below lists the economic benefits and costs analyzed in conjunction with this proposal and identifies where to find explanations of how they were estimated. The organization of the table shows how individual elements of the analysis are grouped together to produce NHTSA's estimates of each alternative's private and external costs and benefits.[298] Private benefits and costs are those borne by vehicle manufacturers and by users of new cars and light trucks, including their initial purchasers and subsequent owners. External costs and benefits result indirectly from producing and consuming fuel and are borne by the public rather than just those who purchase and use vehicles. Social costs and benefits are the sum of their private and external components.

[298] Changes in tax revenues are a transfer and not an economic externality as traditionally defined, but NHTSA groups tax revenue changes together with other external costs because fuel taxes fund government activities affecting society as a whole rather than only consumers or manufacturers.

Table II-8: Benefits and Costs Resulting from NHTSA's Regulatory Action[299]

Entry	Section of Preamble Discussion	Chapter of Draft TSD Modeling Explanation	Chapter of PRIA Discussion
Private Costs			
Technology Costs	II.G.1.a(1)	Chapter 6.1	Chapter 7.1.1
Consumer Surplus Loss	II.G.1.a(2)	Chapter 6.1.2	Chapter 7.1.4
Maintenance and Repair Costs	II.G.3	-	Chapter 7.1.1
Sacrifice in Other Vehicle Attributes	II.G.1	Chapter 6.1.3	Chapters 7.1.1
Safety Costs Internalized by Drivers	II.H.3	Chapter 7.5	Chapters 7.1.5, 8.5.5
Subtotal—Internal Costs or Cost Savings			
External Costs			
Congestion and Noise Costs From Rebound-Effect Driving	II.G.2.a(1)	Chapter 6.2.3	Chapter 7.2.2, 8.4.2
Loss in Fuel Tax Revenue	II.G.2.a(2)	Chapters 6.1.4, 6.2	Chapter 7.3.1
Safety Costs Not Internalized by Drivers	II.H.1 and II.H.2	Chapter 7	Chapters 7.1.5, 8.5.5
Subtotal—External Costs or Cost Savings			
Total Costs or Cost Savings			
Private Benefits			
Fuel Cost Savings[300]	II.G.1.b(1)	Chapter 6.1.4	Chapter 7.3.1
Refueling Frequency	II.G.1.b(2)	Chapter 6.1.5	Chapter 8.4.2
Benefits From Additional Driving	II.G.1.b(3)	Chapter 6.1.6	Chapter 7.2.1
Subtotal—Private Benefits			
External Benefits			
CO_2, methane (CH_4), and N_20 Emissions	II.G.2.b(1)	Chapter 6.2.1	Chapter 8.5.1
Health Outcomes	II.G.2.b(2)	Chapter 6.2.2	Chapter 8.4.1
Petroleum Market Security	II.G.2.b(3)	Chapter 6.2.4	Chapter 7.3.2

BILLING CODE 4910–59–P

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	

BILLING CODE 4910–59–C

The remainder of this section briefly describes the key economic impacts of the proposed amendment and explains how they are categorized within the PRIA (with the exception of safety costs, which as noted earlier are covered in Section II.H).

1. Private Costs and Benefits

Manufacturers' efforts to meet CAFE standards consist primarily of adding new technology to their car and light truck models, and together with any necessary design or engineering modifications, this increases their production costs. NHTSA assumes manufacturers pass these costs on to buyers of models that offer higher fuel economy by raising their selling prices.[301] While the agency incorporates the effects of available tax credits in its analysis, these credits simply transfer revenue from taxpayers to vehicle buyers and have no net effect on the benefits or costs of the proposed rule. Estimates of technology costs reported throughout this proposed rule should be interpreted as excluding the value of tax credits unless otherwise noted.

Resetting prevailing CAFE standards would reduce the cost of technology that manufacturers would need to add to their car and light truck models in order to comply with CAFE standards, and NHTSA assumes that this reduction in regulatory costs would be passed through to vehicle buyers in the form of lower prices. Relaxing standards would reduce the regulatory burden on manufacturers and enable them to produce models that offer combinations of fuel economy, other features, and prices that align more closely with consumer demand, resulting in higher vehicle sales compared to the No-Action Alternative. The CAFE reset would improve consumer welfare for consumers who are able to purchase vehicles at lower prices, and their collective welfare gain is measured by the increase in consumer surplus from higher sales of new cars and light trucks. Consumer surplus represents the value a good or service provides to consumers (the maximum they would have been willing to pay for it) over and above its market price, and OMB guidance states that it should be accounted for in regulatory analysis.[302] Resetting previous standards will keep would-be purchasers from being priced out of the new vehicle market as manufacturers raise prices to recover their costs for applying more technology to meet higher standards, so buyers' consumer surplus will increase as sales rise rather than decline as it would have with the higher fuel economy standards in the No-Action Alternative. Section II.C.2.f of this preamble and Chapter 2.4 of the Draft TSD provide more details.

Generally, NHTSA's CAFE rulemaking analyses include estimates of benefits to consumers from improving fuel economy, measured by the resulting reduction in vehicles' fuel costs. However, while improved fuel economy reduces vehicles' fuel cost throughout their lifetimes, new car buyers and subsequent owners do not appear to value those savings fully. If they did, manufacturers would presumably offer the levels of fuel economy that buyers demand, and market-determined fuel economy levels would balance the costs of improving it against the private benefits from saving fuel. To the extent regulating fuel economy does not improve the welfare of vehicle owners, regulation can only be justified if it produces additional benefits that are not experienced by buyers themselves. As discussed in II.E, NHTSA assumes that consumers are only willing to pay for fuel economy improvements that repay the higher prices of models offering those improvements within 36 months.

In past rulemakings, the agency has described its assumption that buyers will forgo purchasing vehicles with higher fuel economy, even when they appear to offer future savings exceeding their price premiums, as an example of what is often termed an ''energy paradox'' or ''energy-efficiency gap.'' Although there has been extensive debate about whether and why such a gap might arise, NHTSA has recently justified stricter standards partly by assuming that potential car and light truck buyers act shortsightedly when they refuse to purchase models whose lower fuel costs would more than repay their higher purchase prices. This rationale is fundamentally different from the agency's traditional justification that fuel economy standards are necessary to remedy some ''externality''—whereby buyers' choices cause economic harm to others—that arises from producing and consuming fuel.

Without clear evidence of such ''myopia,'' continuing to raise CAFE standards distorts the market by constraining manufacturers to provide levels of fuel economy above those consumers demand, causing manufacturers to raise prices to recover their higher costs for producing those vehicles or to sacrifice improvements in their models' other features. Instead, the agency increasingly believes a more likely explanation for buyers' reluctance to purchase higher mpg models is that their unsatisfactory combinations of price and other features offset the attraction of lower fuel costs, and recent

[299] 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 intentionally omitted from this table. Chapters 8.2.3 and 8.3.3 of the PRIA describe consumer-specific costs and benefits.

[300] 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.

[301] While NHTSA recognizes that some manufacturers may defray their regulatory costs for meeting increased fuel economy standards through more complex pricing strategies, the agency lacks sufficient insight into manufacturers' pricing strategies to analyze such alternative approaches.

[302] OMB's Circular A–4 explains that the ''net reduction in the total surplus (consumer plus producer) is a real cost to society,'' and recommends that changes in consumer or producer surplus should be monetized ''when they are significant.''

research supports this interpretation.[303] Chapter 6.1.3 of the Draft TSD provides further detailed review of this research. NHTSA has acknowledged this potential ''opportunity cost'' of raising fuel economy standards in its recent rules but has attempted to estimate its magnitude only as one of a large number of sensitivity analyses. The agency has justified this decision by claiming there is uncertainty in the literature over the degree to which requiring higher fuel economy will lead manufacturers to delay or forgo improvements to their models' features and how consumers would react. NHTSA has also cited data from EPA's Fuel Economy Trends Report showing that HP and acceleration have not decreased even when fuel economy standards were rising. However, these arguments did not consider the possibility that manufacturers could have offered *further improvements* in their models' other features or lower prices without continuing pressure to increase fuel economy.

NHTSA includes an estimate of the extent to which relaxing standards will reduce the opportunity cost of meeting previously established standards in its primary analysis of this proposed rule. The agency assumes that this cost must be sufficient to account for buyers' apparent unwillingness to purchase models whose higher fuel economy would repay their higher purchase prices. NHTSA estimates the opportunity cost as the value of fuel savings consumers are unwilling to pay for voluntarily that accrues between years 4 and 10 of a vehicle's life.[304] In practice, manufacturers will respond to lower standards by adjusting the technologies they add to vehicles as well as by altering the tuning of these technologies and mix of vehicles in their production fleets, with the goal of increasing profits. For individual vehicle models this could result in a pure cost reduction, an improvement in other vehicle features, or a combination of the two.[305] At the vehicle level, NHTSA's estimates of changes in costs and other vehicle attributes could be over- or under-estimates. However, at the aggregate level it is reasonable to assume, as NHTSA does, that there is likely to be a combination of lower technology costs and a reduction in the implicit opportunity cost relative to the No-Action Alternative. Chapter 6.1.3 of the Draft TSD includes a detailed description of the agency's method for developing this measure, including its assumptions about manufacturers' anticipated response; the agency seeks comments on its approach as well as suggestions for improving it.

Resetting previously established CAFE standards will permit lower fuel economy for some new cars and light trucks, thus increasing their fuel consumption and raising their owners' fuel costs accordingly. The difference between fuel consumption in the No-Action Alternative and in each regulatory alternative represents that alternative's effect on total fuel use, and the cost of this additional consumption is estimated using forecasts of retail fuel prices. The agency's assumptions about future fuel prices are discussed in detail in Chapter 4.1.2 of the Draft TSD.

Lowering existing standards will lead to relatively shorter driving ranges of models that achieve lower fuel economy in the action alternatives, requiring their users to refuel more frequently than under the No-Action Alternative. Drivers (and passengers) of future new cars and light trucks will economize on refueling stops as fuel economy increases over time under each regulatory alternative. However, their savings will be more modest than under the No-Action Alternative, so it appears as an incremental increase in the frequency of refueling stops in the analysis. NHTSA estimates the cost of more frequent fill-ups by calculating the amount of time it takes to locate a retail outlet, refuel one's vehicle, and pay, accounting for the typical number of passengers traveling with the driver, and multiplying by DOT's recommended value of travel time. For a full description of the agency's methodology, refer to Chapter 6.1.5 of the Draft TSD. The agency seeks comment on whether, and the extent to which, a reasonable manufacturer may simply install a larger fuel tank—potentially eliminating any refueling time savings.

Under the regulatory alternatives, new car and light truck models that achieve lower fuel economy would be driven slightly less than in the No-Action Alternative, as their higher fuel cost reduces the fuel economy rebound effect described in preamble Section II.E.1.c. Again, the proposed rule would continue to raise fuel economy standards but at a slower rate than under the No-Action Alternative. For example, while vehicle use would continue to increase under each regulatory alternative, it would increase more slowly than under the No-Action Alternative. Additional driving enables buyers of new cars and light trucks to travel more frequently or reach more desirable destinations, but because vehicle use would grow more slowly, these benefits would be more modest when CAFE standards are reset.[306]

In addition to the private costs and benefits described above, Table II–8 includes maintenance and repair cost savings as a line item without an associated dollar value; the agency expects the proposed reset of CAFE standards to reduce technology requirements for meeting the new standards and thus to lower buyers' costs to repair and maintain new vehicles. However, the agency does not currently possess robust data to quantify maintenance and repair costs in the analysis. NHTSA requests comments on whether the agency should include estimates of repair and maintenance costs—and that interested commenters provide sufficiently robust data to support an informed analysis.

NHTSA also is aware that alternative approaches based on revealed preference have been used to estimate the implicit compliance cost of similar vehicle regulations.[307] Observed

[303] For example, Leard et al. (2023) finds that consumers value performance improvements at three times the rate at which they value improvements in fuel economy and that forgone improvements in performance from recent changes in CAFE standards have essentially offset consumer welfare improvements from the fully valued savings in fuel costs. Klier and Linn (2016) find that if performance trade-offs resulted from a hypothetical 10-percent increase in regulatory stringency, U.S. consumers would value the resulting fuel economy gains at levels approximately 65–85-percent greater than their willingness to pay for any associated forgone horsepower. Reynaert (2020) finds that the European Union's emission standards caused manufacturers to choose between fuel economy and performance, and that the standards were ultimately not welfare improving. In addition to forgoing technological improvements that would improve performance, economists have also modeled manufacturers trading off performance for fuel economy at a fixed level of technology in order to reduce compliance costs (Whitefoot et al. 2017).

[304] As explained in Chapter 6.1.3 of the Draft TSD, consumers value the first 10 years of discounted fuel savings but are unwilling to pay for more than 3 years, because the value of fuel savings during years 4 through 10 is offset by the cost of sacrifices in improvements to vehicles' other attributes.

[305] As explained in Draft TSD Chapter 2.3.5, NHTSA attempts to maintain performance neutrality when a technology is applied to a vehicle so that the change is only applied to improving fuel economy.

[306] NHTSA does not estimate benefits associated with reallocating travel among vehicles of different ages, because there is no associated change in total VMT until the rebound effect is introduced. Chapter 6.1.5 of the Draft TSD explains NHTSA's methodology for reallocating travel and discusses whether any benefits would result as well as how they would be measured. NHTSA seeks comment on its methodology for calculating the benefits from reallocated mileage, as well as on whether it is reasonable to assume that reduced sales of new vehicles leads to a transfer of some travel to older models and any welfare implications of such a transfer.

[307] EPA, Reconsideration of 2009 Endangerment Finding and Greenhouse Gas Vehicle Standards, Draft Regulatory Impact Analysis, Appendix B

behavior also shows that consumers prefer vehicles with fuel economy technologies added only if fuel savings exceed the technology costs within a fairly short period, despite the fact that estimated lifetime fuel costs are conspicuously printed on the Monroney window sticker. Analyses that rely on revealed preferences may better capture consumer preferences and the potential costs imposed by regulations than an engineering-based approach. NHTSA has included an alternative analysis of the benefits and costs of the proposed rule in Appendix II applying a revealed preference approach and seeks comment on the assumptions, methodology and data sources used in this analysis.

2. External Costs and Benefits

In general, NHTSA's CAFE rulemakings set standards for which there are no existing standards and require manufacturers to improve fuel economy. Higher fuel economy standards increase vehicle use via the rebound effect and contribute to increased traffic congestion and highway noise. These impacts are largely felt by other road users (and nearby residents) rather than the drivers generating additional mileage. Conversely, resetting previous CAFE standards will reduce fuel economy levels compared to the No-Action Alternative, and the resulting reduction in travel will lower the external costs that congestion and noise impose on others. NHTSA estimates these impacts by updating per-mile congestion and noise costs from increased automobile and light truck use originally reported in FHWA's 1997 Highway Cost Allocation Study to account for changes in congestion levels, travelers' value of time, and inflation, an approach it also used for the 2020, 2022, and 2024 final rules.

Part of the change in new car and light truck buyers' costs for fuel represents changes in tax revenue received by Federal, state, and some local government agencies. Any variation in the fuel tax burden on drivers is exactly offset by changes in tax revenues, so this transfer does not affect net benefits from changing CAFE standards. However, NHTSA estimates those offsetting changes in drivers' fuel tax payments and tax revenue received by government agencies to highlight this transfer and show its potential impact on government finances.

Fuel production, distribution, and use generate emissions of certain ''criteria'' or regulated pollutants, and the population's exposure to these pollutants causes adverse effects on public health. Raising or lowering CAFE standards affects these emissions by changing the volume of fuel produced and consumed, and NHTSA estimates these changes in emissions and their economic consequences for public health. The CAFE Model estimates monetized health effects associated with population exposure to fine particulate matter, which is emitted directly by refineries and vehicles and also formed in the atmosphere via physical and chemical reactions involving other regulated pollutants emitted by refining and using fuel.[308] Chapter 5 of the Draft TSD accompanying this proposed rule includes a detailed description of the Model's procedures for calculating emissions of these pollutants and assessing their consequences for public health.

NHTSA does not include monetized estimates of changes in so-called greenhouse gas (GHG) emissions in the central analysis.[309] There are significant uncertainties related to the monetization of GHGs that include, but are not limited to: the magnitude of the change in climate due to a change in GHG emissions; the relationship between changes in the climate and the economy and, therefore, the resulting economic impacts; future economic and population growth, which are important for estimating vulnerability, willingness to pay to avoid impacts, and the ability to adapt to future changes; future technological advancements that would reduce vulnerability and impacts; the share of impacts from GHG emissions that affect citizens and residents of the United States; and the appropriate discount rates to use when discounting in an intergenerational context.

Due to the many uncertainties related to monetizing impacts of changes in GHG emissions, NHTSA does not monetize these impacts in the central analysis. Monetizing these impacts could potentially result in flawed decision-making due to overreliance on highly uncertain values. To confirm that NHTSA's exclusion of this value does not bias the cost-benefit analysis that informs NHTSA's determination of maximum feasible standards, and in accord with the decision in *Center for Biological Diversity* v. *NHTSA*,[310] NHTSA has included a sensitivity case in PRIA Chapter 9 using the domestic-only monetization of the GHG estimate that was previously used in the 2020 final rule.

Resetting CAFE standards would increase domestic consumption of gasoline compared to the regulatory baseline, producing a corresponding increase in the Nation's demand for crude petroleum. The U.S. accounts for a significant share of global oil consumption, so the resulting increase in global petroleum demand will exert some upward pressure on worldwide prices, but the financial consequences of higher prices are transfers that do not affect economic welfare. Unlike in decades past, when the U.S. was heavily dependent upon foreign petroleum and therefore broadly exposed to price shocks attributable to supply disruption, the U.S. is now an established net exporter of petroleum. Accordingly, while domestic petroleum production does not completely insulate the U.S. from international disruptions in petroleum generation, any transfer from global consumers to petroleum producers becomes a financial benefit to the U.S. economy.

Higher U.S. petroleum consumption increases all domestic consumers' exposure to the risks of potential rapid increases in oil prices and interruptions in petroleum imports, although rising domestic production cushions the latter's effect. Individual petroleum users are unlikely to consider the effect of their own consumption on such economy-wide risks, so they may unwittingly impose costs on others that increase with domestic petroleum use. NHTSA includes this effect as a cost of the proposed standards, and Chapter 6.2.4.4 of the Draft TSD explains how the agency estimates its magnitude.

Some analysts assert that raising or lowering petroleum imports may also influence U.S. military spending, but most careful studies conclude that

(2025), available at: *https://www.epa.gov/system/files/documents/2025-07/420d25003.pdf* (accessed: Sept. 10, 2025).

[308] 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 emitted regularly by refineries and motor vehicles, cause the most severe effects on human health, and have been the subject of extensive research to quantify and monetize their health impacts. NHTSA's regulatory analysis does not attempt to quantify the adverse health effects of air toxics, which are emitted during fuel production and use, or ozone, which is formed in the atmosphere by emissions of regulated pollutants.

[309] E.O. 14154, Unleashing American Energy (Jan. 20, 2025), available at: *https://www.govinfo.gov/content/pkg/DCPD-202500121/pdf/DCPD-202500121.pdf* (accessed: Sept. 10, 2025); Office of Information and Regulatory Affairs, Guidance Implementing Section 6 of Executive Order 14154, ''Unleashing American Energy,'' M–25–27 (May 5, 2025), available at: *https://www.whitehouse.gov/wp-content/uploads/2025/02/M-25-27-Guidance-Implementing-Section-6-of-Executive-Order-14154-Entitled-Unleashing-American-Energy.pdf* (accessed: Sept. 10, 2025).

[310] *Ctr. for Biological Diversity* v. *Nat'l Highway Traffic Safety Admin.*, 538 F.3d 1172, 1198 (9th Cir. 2008).

changes in petroleum use on the scale likely to result from changing CAFE standards are unlikely to affect military activity. Thus, as Chapter 6.2.4.5 of the Draft TSD explains in detail, NHTSA does not consider the potential impact of changing CAFE standards on military spending.

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 (as well as hybrids and plug-in hybrids) also require batteries to store and deliver that electricity. Currently, the most common EV battery chemistries include relatively scarce materials (compared to other automotive parts) which are sourced, in large part, from foreign adversaries or potentially insecure or unstable overseas sites. While all mined materials (including those in vehicles powered by ICEs) can pose environmental challenges during extraction and conversion to usable material, this is particularly true with minerals used in battery production. Known supplies of some of these critical minerals are also highly concentrated in a few countries and therefore face similar market power concerns to petroleum products.

NHTSA is restricted from considering the fuel economy of alternative fuel sources in determining CAFE standards, so the agency only considers the gasoline powered fleet in simulating compliance with fuel economy regulatory alternatives and determining their effects. While the cost of critical minerals may affect the cost to supply both plug-in and non-plug-in hybrids that require larger batteries, this would apply primarily to manufacturers whose voluntary compliance strategy emphasizes hybridization. NHTSA does not include costs or benefits related to these emerging energy security considerations in its analysis for its proposal because, as noted above, pursuant to its statutory authority to set CAFE standards, NHTSA cannot consider alternative fueled vehicles when setting standards.

The analysis considers the direct labor effects that the proposed standards would have across the automotive sector. The effects include: (1) dealership labor related to new light-duty sales; (2) assembly labor for new vehicles, engines, and transmissions; and (3) labor for developing and producing technologies that improve fuel economy but exclude any broader implications of fuel economy standards for economy-wide employment. NHTSA has used this approach in several recent rulemakings but has not highlighted its results because of its limited scope and the uncertainty introduced by rapidly changing labor inputs for vehicle assembly and technology development. NHTSA seeks comment on alternative approaches to the labor analysis that the agency could consider, including approaches that could supplement the agency's current approach or succeed it in future rulemakings. Chapter 6.2.5 of the Draft TSD describes the current process NHTSA uses to estimate labor impacts in additional detail.

H. Simulating Safety Effects of Regulatory Alternatives

Fuel economy standards have the potential to lead manufacturers to alter the vehicles they produce in ways that may have unintended consequences for motor vehicle safety. The analysis accompanying the proposal includes a comprehensive measure of safety impacts from three sources:

• Changes in Vehicle Mass

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 such as pedestrians and cyclists, while reducing mass in lighter vehicles generally reduces 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 continue regardless of changes in the standards. Vehicle technologies added to comply with increased fuel economy standards increase vehicle prices, slowing the acquisition of newer vehicles and retirement of older ones.

The standards also influence the composition of the new light-duty sales mix. As the safety of light trucks, SUVs, and passenger cars is affected by technologies that manufacturers employ to meet the standards differently—particularly MR—fleets with different compositions of body styles have varying safety risks. Therefore, changing the share of each type of light-duty vehicle in the projected future fleet impacts safety outcomes.

• Changes in Safety Associated With ''Rebound Effect'' Driving

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. Slowing vehicle turnover results in an older fleet on average. As a result, this slowing turnover exacerbates the safety costs of additional driving resulting from the ''rebound effect.''

Resetting the CAFE standards as proposed would improve safety overall. Setting less stringent standards would accelerate fleet turnover, limit the amount of rebound driving, and reduce the need to apply MR across the fleet.

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 fleetwide fatality rate (fatalities per VMT) that incorporates the effects of differences in each of the three factors from the reference baseline and then multiplying it by that alternative's expected VMT. Fatalities are converted into a societal cost by multiplying estimated fatalities by the DOT-recommended value of a statistical life (VSL), supplemented by additional economic costs not considered in VSL measurements. Traffic injuries and property damage are also modeled directly using the same process and valued using costs 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 light-duty fleet in response to changes in vehicle prices—impose increased risks on drivers and passengers 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 decided 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.

NHTSA's analysis considers the safety impact to both vehicle occupants and non-occupants, such as pedestrians and cyclists. The agency categorizes safety outcomes through three measures of light-duty vehicle safety: fatalities occurring in crashes, serious injuries, and the amount of property damage incurred in crashes with no injuries. Counts of fatalities among occupants of automobiles and non-occupants are obtained from NHTSA's Fatal Accident Reporting System for 1975–2022. Estimates of the number of serious injuries to drivers and passengers of light-duty vehicles are tabulated from NHTSA's General Estimates System (GES) for 1990–2015, and from its Crash Report Sampling System (CRSS) for 2016–2021. 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 CRSS.

NHTSA does not anticipate, and does not model, any changes in safety from the proposed changes in vehicle classification. A vehicle's safety performance is unrelated to its CAFE vehicle classification; instead, the safety risk is dependent on its physical attributes, the safety technologies incorporated, and how the vehicle is used.

1. Mass Reduction Impacts

Vehicle MR can be one of the more cost-effective means of improving efficiency, particularly for makes and models built with less high-strength steel or aluminum closures or low-mass components. Manufacturers have stated that they would continue to reduce mass of some of their models to meet more stringent standards (such as those currently in place), and therefore, this expectation is incorporated into the modeling analysis supporting the proposal. Safety trade-offs associated with MR 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 is mindful of the possibility of related safety trade-offs. For this reason, NHTSA accounts for how the application of MR to meet standards affects the safety of a specific vehicle given changes in 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 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 II.D.2.e), 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 2024 and beyond. The analysis of MR includes two opposing impacts.

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. For collisions with large mass disparities, MR in heavier vehicles would be more beneficial to the occupants of lighter vehicles than it would be 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 capture the differing effect on lighter and heavier vehicles accurately, NHTSA splits vehicles into lighter and heavier vehicle classifications in the analysis. However, this poses a challenge to 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 a trade-off to capture the impact of mass-reduction across vehicle CWs and crash types while preserving the potential to identify robust estimates.

While the mass-size-safety coefficients employed in the analysis are not statistically significant at the 95th-percent confidence level, multiple coefficients are significant at the 85th-percent confidence level, and, to NHTSA's best knowledge, represent the most robust and accurate representation of the safety impact of MR. It is essential for NHTSA, as a safety agency, to consider potential safety impacts of its regulations using the best available estimates. As the agency believes that the point estimates still represent the best available data, NHTSA continues to include a measurement of mass-safety impacts in its analysis.

While the agency does not attempt to model safety impacts on a vehicle model-level basis, resetting the standards as proposed would lessen the need to apply MR broadly across the fleet and would allow manufacturers to incorporate MR more tactfully within its fleet. In addition, the agency's proposed vehicle reclassification could incentivize manufacturers to apply MR to larger vehicles, which would provide other road users tangible safety benefits.

A more detailed description of the mass-safety analysis can be found in Chapter 7.3 of the Draft TSD.

2. Sales/Scrappage Impacts

As described in Section II.E.1.b, resetting CAFE standards would have important safety consequences because of the resulting acceleration in fleet turnover. Less stringent standards would allow manufacturers to sell more vehicles demanded by consumers at cheaper prices, which would increase 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 based on the relative net price increases caused by CAFE standards. Setting less stringent standards also removes distortionary effects, pushing consumers into less preferred body styles, which may have different intrinsic safety risks. Similarly, as the price of new vehicles decreases, the fleet turnover compared to the baseline increases, meaning more newer, safer vehicles would replace older, less safe vehicles on the road. These effects would reduce the safety risk not only for both the occupants of newer vehicles but also for other road users who benefit from newer vehicles equipped with advanced driving assistance systems.

Any effect of sales and scrappage on fleet composition will affect the distribution of both ages and model years present in the on-road light-duty fleet. 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 safety performance of the fleet, affecting the total number of on-road fatalities under each regulatory alternative. Similarly, the dynamic fleet share model captures the changes in the light-duty fleet's composition of cars and light 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, NHTSA uses the distribution of miles calculated in Chapter 4.3 of the Draft TSD. 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 model year, age, and style, while controlling 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.

The vehicle fatality risk described above captures the historical evolution of automotive safety. Given that modern technologies are proliferating faster than ever and offer greater safety benefits than traditional safety improvements through crash avoidance, 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 fleetwide fatality rate, including 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 first derives 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, which are then adjusted to reflect the current pace of adoption of the technology, including any public commitment by manufacturers to install these technologies or recent regulatory actions. These technologies include Forward Collision Warning (FCW), Automatic Emergency Braking (AEB), Lane Departure Warning (LDW), Lane Keep Assist (LKA), Blind Spot Detection (BSD), Lane Change Assist (LCA), and Pedestrian Automatic Emergency Braking (PAEB). The products of these factors 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 provided in Chapter 7 of the Draft TSD.

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, but rather are a freely chosen activity resulting from reduced vehicle operational costs. As such, NHTSA has long believed that 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 internalize 90 percent of this risk, which mostly offsets the societal impact of added fatalities from this voluntary consumer choice. However, by resetting the standards, NHTSA would expect fewer rebound miles and therefore fewer crashes, injuries, and fatalities. Additional discussion of internalized risk is contained in Chapter 7.5 of the Draft TSD. NHTSA seeks comment on this assumption. In particular, the agency asks commenters for any evidence that could be used to bolster a higher or lower estimate of how much consumers internalize the risk of driving an additional mile.

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 costs related to medical and emergency care, insurance administrative costs, legal costs, and other economic impacts not captured in the VSL. These values were first derived from data in Blincoe et al. (2015), updated in Blincoe et al. (2023), adjusted to 2024 dollars, and updated to reflect DOT guidance on the VSL.[311]

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 2017–2019. This produced the MAIS-based injury profile. This profile was used to weight nonfatal injury unit costs derived from Blincoe et al. (2023), adjusted to 2024 price and income levels and updated consistently with DOT guidance on the VSL. Property-damaged vehicle costs were also taken from Blincoe et al. (2023) and adjusted to 2024 economics.

For the analysis, NHTSA assigns a societal value of $14.1 million for each fatality, $338,000 for each nonfatal injury, and $9,700 for each property damaged vehicle. As discussed in the previous section, NHTSA discounts 90 percent of the safety costs associated with the rebound effect. The remaining 10 percent 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 offset by additional benefits since manufacturers are responsible for deciding how to design and price vehicles. However, 90 percent of these costs are also treated as private costs since they are borne by owners of vehicles rather than society more broadly. The safety costs not internalized by drivers are equal to 10 percent of the sum of the mass-safety effects, fleet turnover effects, and rebound-related fatality and non-fatal injuries, plus the cost of any property damage.

III. Regulatory Alternatives Considered in This NPRM

A. General Basis for Alternatives Considered

NHTSA considers regulatory alternatives in rulemaking analyses as a way of evaluating the comparative

[311] DOT, Departmental Guidance on Valuation of a Statistical Life in Economic Analysis, Last revised: Apr. 28, 2025, available at: *https://www.transportation.gov/office-policy/transportation-policy/revised-departmental-guidance-on-valuation-of-a-statistical-life-in-economic-analysis* (accessed: Sept. 10, 2025).

effects of different potential ways of accomplishing its desired goal, which in this case is to fulfill the statutory mandate to set maximum feasible standards. E.O. 12866 and E.O. 13563, as well as OMB Circular A–4, encourage agencies to evaluate regulatory alternatives in their rulemaking analyses.

For this proposal, NHTSA developed separate alternatives for two distinct periods of time (MYs 2022–2026 and MYs 2027–2031) and two distinct fleets (passenger cars (PC) and light trucks (LT)). Alternatives analysis begins with a ''No-Action'' Alternative, typically described as what would occur in the absence of any regulatory action by the agency—in other words, the baseline.[312] Accordingly, NHTSA developed 16 total alternatives: a No-Action and three action alternatives for passenger cars for MYs 2022–2026; a No-Action and three action alternatives for light trucks for MYs 2022–2026; a No-Action and three action alternatives for passenger cars for MYs 2027–2031; and a No-Action and three action alternatives for light trucks for MYs 2027–2031. The proposed standards may, in places, be referred to as the ''Preferred Alternative(s),'' but NHTSA intends ''proposed standards'' and ''Preferred Alternative(s)'' to be used interchangeably for purposes of this document. While the agency tentatively believes the Preferred Alternative(s) represent the maximum feasible fuel economy standards for each model year under consideration when viewed in context of the proposed structural changes (*i.e.,* reclassification, elimination of FCIVs, and elimination of credit trading) and in light of statutory constraints (*i.e.,* not considering dedicated vehicles, non-petroleum performance of dual fueled vehicles, or the availability of regulatory credits), NHTSA requests comment on each alternative analyzed.

Each action alternative sets fuel economy stringency levels for each model year that can be defined in terms of percentage changes in stringency from one model year to the next, which may be different for passenger cars and light trucks.[313] Although the stringency levels can be defined in terms of percentage changes in stringency from one model year to the next for ease of understanding, pursuant to the statute they are actually defined as coefficients that define the following mathematical functions that relate fuel economy to footprint levels.

For passenger cars, NHTSA is defining final fuel economy targets as shown in Equation III–1.

Equation III–1: Passenger Car Fuel Economy Footprint Target Curve

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

Where:

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

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

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

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

The resulting functional form is depicted in graphs displaying the passenger car target function in each model year for each regulatory alternative in Sections III.B.1 and III.B.3 below.

For light trucks, NHTSA is defining fuel economy targets as shown in Equation III–2.

Equation III–2: Light Truck Fuel Economy Footprint Target Curve

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

[312] Office of Management and Budget, Circular A–4 (Sept. 17, 2003), available at: *https://www.whitehouse.gov/wp-content/uploads/2025/08/CircularA-4.pdf* (accessed Sept. 10, 2025), General Issues, 2. Developing a Baseline.

[313] Note that the percentage changes from 1 year to the next are applied to the footprint functions that define the standards, rather than to an average or summary mpg value corresponding to a given footprint function. The PC and LT target curve function coefficients are defined in Equation III–1 and Equation III–2, respectively. See Draft TSD Chapter 1.2.1 for a complete discussion of the footprint curve functions and how they are calculated.

Where:

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

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

The exception to defining action alternatives in terms of yearly stringency changes occurs in the transition from MYs 2027–2028, where NHTSA is proposing to change the regulatory classifications for non-passenger automobiles. Because NHTSA is using a different set of initial footprint curve parameters (*i.e.,* slope, intercept, and cutpoints) for each fleet starting in MY 2028, the change in stringency from MYs 2027–2028 cannot be defined using multiplication by a common factor. Instead, NHTSA first applied a year-over-year stringency adjustment to each proposed alternative for each regulatory class ''m'' in MY 2027 to generate initial target function parameters for MY 2028 shown in Equation III–3.

Equation III–3: Scaling Equations for Initial MY 2028 Target Function Parameters

$$a_{2028,0}^{m}=\frac{1}{k_1}\times a_{2027}^{m}$$
$$b_{2028,0}^{m}=\frac{1}{k_1}\times b_{2027}^{m}$$
$$c_{2028,0}^{m}=k_1\times c_{2027}^{m}$$
$$d_{2028,0}^{m}=k_1\times d_{2027}^{m}$$
$$k_1=1\text{-}\Delta_{2028}$$

Here ''Δ_{2028}'' equals the percentage year-to-year change in stringency from MYs 2027–2028 in a given alternative. The agency then uses Equation III–4 to determine the MY 2028 predicted average standard for each regulatory class without reclassification. To calculate the average standard, the agency uses the total number of automobiles in each class in the MY 2024 fleet data.

Equation III–4: Determination of MY 2028 Class Average Standards Under No Reclassification

$$\text{STANDARD}_{2028}^{m,0}=\frac{\boldsymbol{n_{m,0}}}{\sum_{j=1}^{n_{m,0}}\frac{\mathbf{1}}{\boldsymbol{TARGET_j^{2028,0}}}}$$

$$TARGET_j^{2028,0}\ \frac{1}{\text{MIN [MAX}\left(c_{2028,0}\times\text{FOOTPRINT}_j+d_{2028,0},\ \frac{1}{a_{2028,0}}\right),\frac{1}{b_{2028,0}}\text{]}}$$

Here ''$\eta_{m,0}$'' equals the total number of automobiles produced in class ''m'' according to the classifications based on existing regulations.

NHTSA then performed an analogous calculation using Equation III–5 to determine the predicted average standard for each regulatory class under the proposed reclassification condition. The alternative classification and the initial parameter estimates are described in Chapter 1 of the Draft TSD. To calculate the average standard, the agency uses the MY 2024 fleet data with the new reclassification criteria applied in each class.

Equation III–5: Determination of MY 2028 Class Average Stringencies Under Alternative Classification using Alternative Parameter Estimates

$$\textbf{STANDARD}_{\mathbf{2028}}^{\boldsymbol{m,A}}=\frac{\boldsymbol{n_{m,A}}}{\sum_{j=1}^{n_{C,A}}\frac{\mathbf{1}}{\boldsymbol{TARGET_j^{2028,A}}}}$$

$$TARGET_j^{2028,A}\ \frac{1}{\text{MIN [MAX}\left(c_{2028,A}\times\text{FOOTPRINT}_j+d_{2028,A},\ \frac{1}{a_{2028,A}}\right),\frac{1}{b_{2028,A}}\text{]}}$$

Here ''$\eta_{m,A}$'' equals the total number of automobiles produced in class ''m'' according to the proposed reclassification.

The class averages are used to generate a ratio, which is used as a scaling factor to generate the final target function coefficients in each alternative as shown in Equation III–6:

Equation III–6: Scaling Equations for Final MY 2028 Target Function Parameters

$$a_{2028}^{m} = \frac{1}{k_2} \times a_{2028,A}^{m}$$
$$b_{2028}^{m} = \frac{1}{k_2} \times b_{2028,A}^{m}$$
$$c_{2028}^{m} = k_2 \times c_{2028,A}^{m}$$
$$d_{2028}^{m} = k_2 \times d_{2028,A}^{m}$$
$$k_2 = \frac{\mathrm{STANDARD}_{2028}^{m,A}}{\mathrm{STANDARD}_{2028}^{m,0}}$$

This process ensures that a change in target function shape preserves the year-to-year change in stringency ''Δ_{2028}'' for the class.

For this proposal, NHTSA applies individual rates of change to the passenger car and the light truck fleet standards in different model years in some of the action alternatives. In the Preferred Alternative, the respective standards for both fleets change at the same rate starting in MY 2028. However, the two remaining action alternatives evaluated for this proposal have passenger car fleet rates-of-change in fuel economy that differ from the rates-of-change in fuel economy for the light truck fleet in MY 2028. NHTSA has discretion to set CAFE standards that increase at different rates for passenger cars and light trucks, because NHTSA, by law, must set maximum feasible CAFE standards separately for passenger cars and light trucks.

1. MYs 2022–2026

NHTSA's analysis resets the passenger and non-passenger automobile fuel economy target functions in 2022 and increases them through 2026 at levels consistent with the available data for that timeframe and the context for those years, as discussed in more detail in Section V. Unlike past rules that set CAFE standards, in which the last model year for which standards are currently set serves as the base year for describing the regulatory alternatives considered in terms of annual percentage increases in standards, NHTSA analyzed reset standards for this proposed rule using MY 2022 as the base year, consistent with the Secretary's memorandum titled ''Fixing the CAFE Program'' (Jan. 28, 2025).[314] NHTSA considered several potential approaches for analyzing regulatory alternatives for that model year within a reasonable range of feasible average fuel economy standards.

The agency relied in large part on the observed capabilities of the gasoline- and diesel-powered vehicle fleets over the model years covered by the standards. While NHTSA always examines manufacturer capabilities (also referred to as ''achieved'' fuel economy values for each manufacturer's fleet in each model year) relative to the proposed standards as part of its evaluation of maximum feasible standards, this analysis is unique in that the data-based projections that NHTSA would generally rely on to estimate manufacturer behavior are not necessary because, by definition, there cannot be projections for MYs 2022–2025 (and likely for MY 2026, by which time a final rule will be issued), but only observed data. That said, as discussed in Section V, NHTSA believes the appropriate qualitative context exists for giving meaning to the section 32902(f) factors related to manufacturer compliance for model years that have already passed or are currently underway.

NHTSA defined a potential standards range using the mean fit curve and the mean fit curve minus one standard deviation,[315] and then selected three levels of standards that the agency believed represented reasonable low-, medium-, and high-level resetting functions for the MY 2022 passenger car and light truck fleets, respectively. These three functions represent different ways that NHTSA could consider the available data for MY 2022, accounting for the removal of section 32902(h) technologies and compliance credits, and consistent with the agency's balancing of the four factors as described in more detail in Section V. The lowest level function for MY 2022 that NHTSA considered for this proposal represents standards that weigh economic practicability most heavily by recognizing that the prior standards for that model year were not only infeasible for the gasoline- and diesel-powered vehicle fleets (from the perspective of manufacturers reasonably being able to apply technology during the rulemaking timeframe), but also that the fleet-average performance has been below the fleet-average standards for several years and that a low-level standard represents an opportunity for vehicle manufacturers to comply with a standard that influences their obligations to improve fleet fuel economy without distorting typical design cycles or technology application in a manner inconsistent with NHTSA's statutory authority.[316] Under these standards, about 80 percent of passenger cars and light trucks would have met or exceeded their target function values for MY 2022.

On the opposite end, the high-level function considered for MY 2022 represents a balancing that still weighs economic practicability, but recognizes that some manufacturers have been able to apply technology that improves the fuel economy levels of their gasoline- and diesel-powered fleets at a cadence that, if applicable to the rest of the fleet had the model year not already passed, would have pushed the fleet to higher average fuel economy levels, thereby saving more fuel and placing more weight on energy conservation. That said, the fact that a large number of manufacturers' gasoline- and diesel-based fleets cannot comply with that standard—some by a significant amount—is evidence that such a standard is beyond maximum feasible for the gasoline- and diesel-powered passenger and non-passenger automobile fleets for MY 2022. Under these standards, about 30 percent of passenger cars and 50 percent of light trucks, by sales volume, failed to meet their target function values for MY 2022.

The MY 2022 mid-level functions that NHTSA is proposing as the Preferred Alternative for passenger and non-passenger automobiles reflect a standard that the agency tentatively concludes is maximum feasible, based on the exclusion of factors prohibited from consideration by section 32902(h) and a subsequent balancing of the section 32902(f) factors considering the real-world context for this action. The mid-level functions represent NHTSA's consideration of the actual, measured gasoline- and diesel-based fleet average

[314] See DOT, Memorandum: Fixing the CAFE Program (2025), available at: *https://www.transportation.gov/briefing-room/memorandum-fixing-cafe-program* (accessed: Sept. 10, 2025).

[315] Mean fit level here refers to standards developed based on the relationship between fuel consumption and footprint using ordinary least-squares without any further adjustment. NHTSA examined fleetwide compliance and found that around half of the vehicles produced in the MY 2022 fleet complied with these standards. For the mean fit minus standard deviation, NHTSA reasoned that focusing on the central mass of the distribution of vehicles' fuel economy values would seem to be a good indicator that the proposed level was technologically feasible and economically practicable.

[316] See ''Resetting the Corporate Average Fuel Economy Program,'' 90 FR 24518 (June 11, 2025).

fuel economy performance and represents standards at a level that the agency believes is technologically feasible and economically practicable for the entire MY 2022 fleet. NHTSA believes the mid-level function represents a balancing pursuant to section 32902(f) that recognizes the prior standards were set at levels aimed to induce changes in technology application and automobile designs beyond what the market could bear, and in doing so, considered vehicle technologies and manufacturers' use of compliance credits in a manner prohibited by section 32902(h). The failure by a significant number of manufacturers' fleets to meet these standards is evidence that they exceeded the maximum feasible standards for the model year. At the same time, the mid-level standard recognizes that compliance actions by several manufacturers may be evidence that additional fleet fuel economy improvements could have been feasible, subject to the concept expressed at the time of EPCA's passage, that NHTSA's standards should not impose impossible burdens on the automotive industry or unduly limit consumer choice as to capacity and performance of motor vehicles.

Some manufacturers have chosen to respond to prior standards—which NHTSA has determined were set in contravention of EPCA's prohibition against consideration of EVs or plug-in hybrids using the battery to facilitate propulsion—by producing electric and plug-in hybrid vehicles and applying or acquiring credits generated by such vehicles to achieve compliance. That said, the mid-level functions for MY 2022 represent NHTSA's best judgment in establishing maximum feasible standards, recognizing that inclusion of section 32902(h) factors in prior rulemakings has pushed standards beyond maximum feasible levels. The agency has tentatively concluded that the proposed standard for MY 2022 provides the most reasonable weighting of the section 32902(f) factors as an appropriate reformed starting point upon which to base increases in the stringency of standards for subsequent model years. Under these proposed standards, about 75 percent of passenger cars and 70 percent of light trucks, by sales volume, would have met or exceeded their target function values for MY 2022—but 25 percent of passenger cars and 30 percent of light trucks would have failed to do so.

For MYs 2023–2026, NHTSA considered a range of standards based on the low-, mid-, and high-range functions all increasing at the same rate—a relatively modest rate of 0.5 percent per year—from each alternative's MY 2022 starting point. This is a different approach than NHTSA has taken in previous standard-setting actions, but it is an approach that better effectuates NHTSA's reset of the CAFE standards to maximum feasible levels beginning in MY 2022. In reaching this tentative conclusion, NHTSA examined both real-world data and input on the capabilities of manufacturers' gasoline- and diesel-powered fleets to improve consistently over time. Critically, this was done while excluding consideration of prohibited technology and policy factors for the first time since alternative fueled vehicles have worked their way into the light-duty fleet in appreciable numbers.

Using data from EPA's 2024 Automotive Trends Report, the latest report available at the time this NPRM was drafted, NHTSA analyzed recent yearly improvements in ICE efficiency using data categorized by engine package.[317] That data shows that since MY 2010, gasoline- and diesel-powered vehicle fuel consumption has improved on average by 1 percent per year. In some years, fuel consumption improved by as much as 5.7 percent from the prior year; however, in some years prior to 2020, fuel consumption increased over the prior year by only 1.2 percent. From MYs 2020–2023, fuel consumption only improved by an average of 0.7 percent per year. Correspondingly, Auto Innovators (formerly known as the Alliance of Automobile Manufacturers, or the Alliance, for short) commented on NHTSA's 2023 NPRM that "[b]etween 2012 and 2022, the average 2-cycle fuel consumption (gal/mile) of non-EVs improved at an average annual rate of 1.3 [percent] (passenger cars) and 2.0 [percent] (light trucks)." [318] In addition, based on the data used for this analysis,[319] the change in fuel economy for gasoline- and diesel-powered vehicles from MYs 2022–2024 was a total of 2 percent, or an average of 1 percent per year.

NHTSA is proposing the 0.5 percent rate of increase for MYs 2023–2026 in part because the agency believes that higher rates of increase were driven by standards set by NHTSA or other agencies that either unlawfully considered prohibited statutory factors or exceeded statutory authority. In addition, to the extent that prior unrealistically high standards induced technology application that was either not ready or not attractive to the market, the proposed stringency rates afford automakers the opportunity to determine the most economically practicable and technologically feasible paths forward for their individual product mixes, while still ensuring that the gasoline- and diesel-fueled vehicle fleet sees real-world improvements in fuel economy.

While fuel-economy-improving technologies applicable to the gasoline- and diesel-powered vehicle fleet certainly exist, much of that technology has been applied to vehicles over the past 15 years—a period of rapidly increasing fuel economy standards. With a baseline fleet inclusive of EVs and plug-in hybrids using battery propulsion, manufacturers seeking to comply with standards solely using gasoline- and diesel-based powertrain efficiency improvements, cannot continually add additional technology to gasoline- and diesel-fueled vehicles at a reasonable cost. Table III–1 shows that as basic naturally aspirated engine technology penetration rates decreased sharply, there was a concurrent increase in rates of advanced powertrain technology, including the addition of mild and strong hybrid technology. As discussed in Section II above, it is unreasonable to assume that all technologies can be applied to all vehicle types, depending on vehicle functionality and capability, and technology that increases fuel economy at more than incremental levels on vehicles where it could feasibly be applied is available only at significant cost. NHTSA anticipates that the proposed rates of annual increase would allow technology penetration rates to propagate across the fleet in a cost-effective manner.

[317] EPA, Explore the Automotive Trends Data (2025), available at: *https://www.epa.gov/automotive-trends/explore-automotive-trends-data* (accessed: Sept. 10, 2025).

[318] See 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, Docket No. NHTSA–2023–0022–60652, at p. 7. The Alliance cited S&P Global Mobility research that was subsequently provided to NHTSA for review.

[319] Comparison of the MY 2022 mid-model year data set and the MY 2024 mid-model year data set, as discussed in Section II.

Table III-1: Technology Penetration Differences in MY 2022 and MY 2024[320]

Powertrain Technology	MY 2022	MY 2024
Basic Naturally Aspirated	37.9%	22.0%
Turbo Engines	36.0%	46.3%
Advanced Cylinder Deactivation	3.5%	4.3%
High Compression Ratio	18.1%	23.4%
Other Advanced Engines	4.5%	4.0%
Mild Hybrids	59.8%	67.2%
Strong Hybrids	7.3%	10.4%
Plug-in Hybrids	1.8%	2.9%

While the rate of increase for all MYs 2023–2026 alternatives is the same, the actual level of standards required by each regulatory alternative is different based on the differing MY 2022 reset points. Accordingly, NHTSA has presented a range of stringency options to allow the agency to analyze or select an alternative in its final rule from any stringency level within that range. The range of alternatives represents different ways that the agency could balance the section 32902(f) factors for MYs 2022–2026. Specifically, NHTSA considers both the unique contextual situation applicable to those model years[321] and technologically feasible and economically practicable rates of per-year increases for the gasoline- and diesel-powered fleets. NHTSA seeks comment on these alternatives for MYs 2022–2026, in addition to any other regulatory alternatives that the agency should consider for these model years.

2. MYs 2027–2031

Consistent with NHTSA's approach for MYs 2022–2026, the agency endeavored to reset future model years' standards at levels that reflect the technological and economic capabilities of the gasoline- and diesel-powered vehicle fleets, but also in a manner that reflects how proposed compliance provisions (discussed in more detail in Section VI) would impact manufacturers' ability to comply. NHTSA performed an analysis, similar to its analysis of feasible per-year rates of stringency increase for gasoline- or diesel-powered vehicle improvements for MYs 2022–2026 discussed above, to establish a range of regulatory alternatives that encompassed the ways the agency believes manufacturers could improve their fleet fuel economies year-over-year.

The agency began by using MY 2024 market data as a starting point for characterizing the technology and compliance levels of the vehicle fleet, and then relied on the CAFE Model to simulate the fleet's expected evolution under the current regulatory fleet classifications in future years in the No-Action Alternative and using the proposed alternative classification regulations starting in MY 2028 in the action alternatives. NHTSA's proposed action alternatives are consistent with footprint curves estimated using the current classification for MY 2027, and consistent with footprint curves estimated using the alternative classification for MY 2028 onward.

NHTSA developed alternatives to produce class average target function values that reflected different rates of growth from MYs 2022–2028, with MY 2027 acting as a ''bridge'' year between MYs 2026–2028, when NHTSA proposes to use updated regulatory classification definitions. Class average target functions were computed by taking the production-weighted harmonic mean of the target function values for vehicles in each class as shown in Equation III–4. To produce estimates of the class average target function values in MY 2022 and MY 2026, NHTSA used the MY 2022 fleet under current classification regulations and the proposed standards in each year. This produced a value for each fleet in MY 2022 and MY 2026. For MY 2027, NHTSA used the MY 2024 fleet under the pre-existing classification regulations and using the relevant proposed standards for each alternative. This produced a value for each class in each alternative. For MY 2028, NHTSA used the MY 2024 fleet under the proposed reclassification regulations and using the relevant proposed standards for each alternative. This once again produced a value for each class in each alternative. NHTSA followed this approach to determine class averages using standard coefficients, classifications, and fleets consistent with how the underlying footprint curves were estimated for each model year.

For Alternative 1, NHTSA set the 2028 standards such that the class average target function values were equal to those computed for 2022 using this approach. For MY 2027, standards for Alternative 1 were set such that the class average equaled the midpoint between class averages calculated for MY 2026 and those proposed for MY 2028. In this way MY 2027 acts as a link between the 2026 standards, which were developed using the MY 2022 fleet and initial classification, and the proposed MY 2028 standards, which were developed using the MY 2024 fleet and the proposed reclassification.

NHTSA used a similar approach to develop Alternative 3. For Alternative 3, NHTSA set standards in MY 2028 such that the class average target function values were equal to those obtained by applying a 1.5-percent annual increase to the MY 2022 standards. NHTSA then used the same approach as in Alternative 1 to determine the midpoint of the average target function values in MY 2026 and MY 2028 and set standards that would achieve that level of stringency based on the MY 2024 fleet and the initial classification. NHTSA estimated the 1.5-percent annual increases as an upper bound for Alternative 3 stringency based on the agency's assessment, using the EPA Automotive Trends report of gasoline- and diesel-powered vehicle fuel

[320] Some vehicles will have multiple powertrain technologies, such as pairing a turbo engine with a mild hybrid stop/start technology. This will result in the technology penetration rates adding up to more than 100 percent.

[321] NHTSA is proposing to reset standards for these model years, which have passed or for which manufacturers have already determined their fleets, or such determination is well underway, because NHTSA determined that in establishing the prior standards, the agency impermissibly considered electric vehicles in its analysis.

economy values and additional stakeholder feedback.

For Alternative 2, NHTSA proposed MY 2027 standards such that the class average target function values were equal to those obtained by applying a 0.5-percent annual growth rate to the MY 2022 standards. For MY 2028, NHTSA determined the class average target function values by applying a 0.25-percent adjustment to the class averages for 2027. While both years' standards were determined using these growth rates, the rate of change year to year between the coefficients does not exactly equal these factors due to the change in fleet and classification used to compute these averages. NHTSA estimated that these were appropriate mid-range annual increases based on the agency's assessment of feasible annual increases for gasoline- and diesel-powered vehicle fleet and because manufacturers would likely require time in MY 2028 and beyond to recalibrate production decisions based on the combination of reset stringency levels and vehicle classification updates.

For MYs 2029–2031, NHTSA applied simple year over year percentage increases to its proposed 2028 standards. For Alternative 1 and Alternative 2, NHTSA used a rate of 0.25 percent per year, while for Alternative 3, NHTSA used a rate of 1 percent per year. Alternative 3's higher rate of increase supposes that manufacturers could respond to standards that increase more rapidly in the later years, while for the other alternatives 0.25 percent was chosen to illustrate how manufacturers would be able to adjust compliance to a more moderate rate of increase following the adjustment to reclassification mentioned above and described in more detail in Section VI.

The projected levels of fuel economy under each of the three regulatory alternatives for MYs 2027–2031 continually push manufacturers to improve real-world fuel economy, and even the least stringent option would exceed fuel efficiency merely driven by market demand.[322] NHTSA treated market demand for fuel-economy improvements as a floor for determining action alternatives in MY 2027 and MY 2028 by rescaling its estimated coefficients using the approach outlined in Equation III–3 through Equation III–6 such that they produced standards achievable for manufacturers when only market demanded technology was applied. Any standard less stringent than this floor would not be projected to change manufacturers' technology adoption decisions from those they would make in the absence of standards. In accordance with the purpose of the statutory scheme to increase fleet fuel economy of gasoline- and diesel-powered vehicles, NHTSA chose alternatives lying above this floor.

NHTSA recognizes that the process for creating regulatory alternatives for this proposal is different in some ways from how the agency has created regulatory alternatives in past rules; however, the process used was necessary to effectuate a reset to bring the CAFE program into compliance with the law and require a significant reclassification of the passenger car and light truck fleets to reflect better the intent of the CAFE program established by Congress. Previously, NHTSA evaluated regulatory alternatives based on varying levels of stringency increases from the last year of the previously established standards. Since NHTSA considered the fuel efficiency of EVs in establishing those previous standards, in contravention of the law, a stringency increase from the last year of those standards is on its face higher than the maximum feasible standards NHTSA could establish if only considering gasoline- and diesel-fueled vehicles. In fact, as discussed in more detail in Section V, NHTSA is proposing to set standards that are, on their face, lower in MY 2022 than MY 2021 in part because actual compliance data clearly demonstrated that manufacturers were unable to achieve the MY 2022 standards with their gasoline- and diesel-powered vehicle fleets. Additional information on how NHTSA's development of these regulatory alternatives comports with the agency's requirements to set maximum feasible standards is discussed in Section V. Like for MYs 2022–2026, the alternatives considered for MYs 2027–2031 include a range of stringency options to allow the agency to analyze or select an alternative in its final rule from any stringency level within that range. NHTSA seeks comment on the range of alternatives presented, in addition to any other alternatives that the agency should consider.

3. Minimum Domestic Passenger Car Standard Analysis Update

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 model year. Along with calculating each regulatory alternative, NHTSA must calculate a minimum standard for domestically manufactured passenger automobiles in accordance with 49 U.S.C. 32902(b)(4)(B). Since the 2020 final rule, NHTSA has calculated the ''minimum domestic passenger car standard'' (MDPCS) using an offset to account for the fact that the agency's model cannot predict any shift in vehicle designs (as opposed to technology application) that manufacturers might make in response to CAFE standards. Additional information about the origin of the MDPCS and the related offset calculation can be found in Section V.

NHTSA reviewed the analysis it uses to calculate the MDPCS offset, which accounts for differences between the passenger car standards the agency forecasts in its rulemaking analyses and the actual passenger car standards EPA calculates for CAFE final compliance in accordance with 49 U.S.C. 32904(a). In support of its 2020 final rule, NHTSA used forecasted data from its 2009, 2010, and 2012 final rule analyses and actual CAFE final compliance data for MYs 2011–2018 to develop the initial MDPCS offset of 1.9 percent. NHTSA developed the original offset value for use in its 2020 final rule; however, the agency continued to use that same offset value in its 2022 and 2024 final rules without updating the underlying analysis. In addition to promulgating two final rules since it developed the initial MDPCS offset, NHTSA has also collected five additional model years of final compliance data—with two of those model years having been verified by EPA in accordance with 49 U.S.C. 32904(a). For this rulemaking, NHTSA updated the analysis to add new data sources and refine the methodology used to calculate the value of the offset.

NHTSA supplemented the original analysis with additional data, such as estimated passenger car standards from subsequent rulemaking analyses and calculated passenger car standards from newer CAFE final compliance data. NHTSA began with the Market Data Input File containing the MY 2017

[322] As discussed in more detail in Section II, NHTSA's assumptions about market-driven fuel economy improvements in the absence of regulatory requirements involve manufacturer application of technology that pays for itself within 36 months. NHTSA makes this assumption based on manufacturer statements over successive CAFE rulemakings and also believes that this assumption is supported by the relevant literature. NHTSA has not attempted to quantify manufacturer behavior in the absence of standards other than this payback assumption but is interested in comments on any other assumptions of manufacturer behavior in the absence of standards that the agency should consider.

baseline fleet, which the agency used in the 2020 final rule analysis, covering MYs 2021–2026. The agency then identified and removed all the model types of dedicated AFVs from the Market Data Input File, consistent with the section 32902(h) prohibition on considering the fuel economy of dedicated and dual-fueled vehicles when setting maximum feasible standards. Next, NHTSA ran the 2020 final rule version of the CAFE Model with the modified Market Data Input File to produce an analysis devoid of dedicated AFVs. The agency then extracted the passenger car standard from the resulting Compliance Output Report for MYs 2017–2050.

Next, NHTSA added the following CAFE final compliance data for additional model years to the analysis: MYs 2012–2021, which have been verified by EPA in accordance with 49 U.S.C. 32904(a), and MYs 2022–2023, which have yet to be verified. As a proxy for individual model types of dedicated AFVs, NHTSA identified and removed the manufacturers that produce only dedicated AFVs from the compliance data and calculated the passenger car standard for MYs 2012–2023.[323]

Next, NHTSA modified the methodology it uses to calculate the offset. In the original offset analysis, NHTSA included comparisons between actual passenger car standards calculated from final model year compliance data to passenger car standards projected in proposed rules, in addition to those projected in final rules. For CAFE compliance, manufacturers are required to meet only those standards estimated and published in final rules, not those estimated and published in proposed rules. Consequently, including comparisons to proposed rules may skew the results from the offset analysis. NHTSA included comparisons to passenger car standards forecasted only in final rules in the updated analysis.

NHTSA compared the MDPCSs estimated from CAFE Model outputs from MYs 2017–2050 to the MDPCSs calculated from actual compliance data from MYs 2012–2023 and calculated the relative change (in percent) between them for each model year. NHTSA then calculated the offset by taking the average of the relative changes in MDPCS for MYs 2017–2023, which are those model years where the CAFE Model outputs (excluding all individual model types of dedicated AFVs) overlapped with CAFE compliance data that excluded manufacturers that produced only dedicated AFVs. The updated MDPCS offset analysis shows that the passenger car standards projected with the MY 2017 baseline fleet and the 2020 final rule version of the CAFE Model were more stringent than the actual passenger car standards calculated for CAFE final compliance by an average of 0.7 percent, less than half of the offset calculated previously.

The MYs 2027–2031 proposed MDPCSs presented in this Table III–2 include the 0.7-percent offset. NHTSA believes that the basis for the offset, which is based on the agency's inability to project the precise mix of vehicles sold in the future, is inapplicable to the proposed MYs 2022–2026 standards because those standards incorporate the most up-to-date data available to the agency for vehicle sales volume and footprint sizes in MY 2022. The agency's proposed MDPCSs for MYs 2027–2031 include this offset to ensure that the standard is sufficiently reflective of industry capabilities while still considering the original intent behind the MDPCS.

The proposed MDPCS for each model year is as follows:

BILLING CODE 4910–59–P

Table III-2: Minimum Domestic Passenger Car Standard (mpg)

2022	2023	2024	2025	2026	2027*	2028*	2029*	2030*	2031*
33.1	33.1	33.5	33.7	33.9	33.8	33.9	34.0	34.0	34.1

*Includes 0.7-percent offset

B. Regulatory Alternatives Considered

The regulatory alternatives considered by the agency in this proposed rule are presented in Table III–3 as percentage changes in stringency over the preceding model year. In the sections that follow, NHTSA presents the literal coefficients that define the standards curves in each model year for each alternative that corresponds to these percentage rates.

[323] Because NHTSA does not receive final model year data in the same format from EPA as manufacturers submit their pre-model year data and final model year data to the agency, NHTSA cannot simply remove Excel rows with dedicated vehicles as the agency did to create its MY 2022 and MY 2024 Market Data Input Files. For purposes of this analysis, NHTSA believes that final model year data are the appropriate source to use.

Table III-3: Regulatory Alternatives Under Consideration for MYs 2022-2031 Passenger Cars and Light Trucks

Name of Alternative	Passenger Car Stringency Changes	Light Truck Stringency Changes
No-Action Alternative	1.5% for MY 2023 8% per year for MYs 2024-2025 10% for MY 2026 2% per year for MYs 2027-2031	1.5% for MY 2023 8% per year for MYs 2024-2025 10% for MY 2026 0% per year for MYs 2027-2028 2% per year for MYs 2029-2031
Alternative 1	80% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.1% for MY 2027 0.3% for MY 2028** 0.25% per year for MYs 2029-2031	80% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.8% for MY 2027 0.6% for MY 2028** 0.25% per year for MYs 2029-2031
Alternative 2 (Preferred)	75% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.35% for MY 2027 0.25% for MY 2028** 0.25% per year for MYs 2029-2031	70% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.7% for MY 2027 0.25% for MY 2028** 0.25% per year for MYs 2029-2031
Alternative 3	70% compliance share* MY 2022 0.50% per year for MYs 2023-2026 1.4% for MY 2027 1.5% for MY 2028** 1% per year for MYs 2029-2031	50% compliance share* MY 2022 0.50% per year for MYs 2023-2026 0.4% for MY 2027 0.2% for MY 2028** 1% per year for MYs 2029-2031

* Compliance shares were determined based on the production-weighted share of vehicles that met or exceeded their target function value for each regulatory alternative in MY 2022.

** Stringency change reflects the growth rate in class average standard value from MYs 2027-2028.

The following subchapters define the regulatory alternatives (including the No-Action Alternative) by time period and provide details on how NHTSA developed them.

1. No-Action Alternatives for Passenger Cars and Light Trucks

a. No-Action Alternative for MYs 2022–2026 Amendment

The analysis of the No-Action Alternative assumes that the following CAFE standards remain in place: the CAFE standards for MYs 2022–2023 that were finalized in the 2020 final rule,[324] and the CAFE standards for MYs 2024–2026 that were finalized in the 2022 final rule.[325] The analysis also applies the statutory limitations in 49 U.S.C. 32902(h) in all model years in the analysis; specifically, the fuel economy of dedicated automobiles is not considered, dual-fueled automobiles are considered only when operated on gasoline or diesel fuel, and the trading, transferring, or availability of credits is not considered.

The No-Action Alternative standards for the existing MYs 2022–2026 passenger car and light truck fleets are defined by the following coefficients:

Table III-4: Passenger Car CAFE Target Function Coefficients for the No-Action Alternative for the MYs 2022-2026 Amendment

	2022	2023	2024	2025	2026
a (mpg)	50.24	51.00	55.44	60.26	66.95
b (mpg)	37.59	38.16	41.48	45.08	50.09
c (gpm per s.f)	0.00044662	0.00043992	0.00040473	0.00037235	0.00033512
d (gpm)	0.00159413	0.00157022	0.00144460	0.00132903	0.00119613

[324] 85 FR 24174 (Apr. 30, 2020).

[325] 87 FR 25710 (May 2, 2022).

Table III-5: Light Truck CAFE Target Function Coefficients for the No-Action Alternative for the MYs 2022-2026 Amendment

	2022	2023	2024	2025	2026
a (mpg)	40.31	40.93	44.48	48.35	53.73
b (mpg)	26.02	26.42	26.74	29.07	32.3
c (gpm per s.f)	0.00049869	0.00049121	0.00045191	0.00041576	0.00037418
d (gpm)	0.00436016	0.00429476	0.00395118	0.00363509	0.00327158

These equations are represented graphically below, where the x-axis represents vehicle footprint and the y-axis represents fuel economy.

Figure III-1: No-Action Alternative, Passenger Car Fuel Economy, Target Curves for the MYs 2022-2026 Amendment

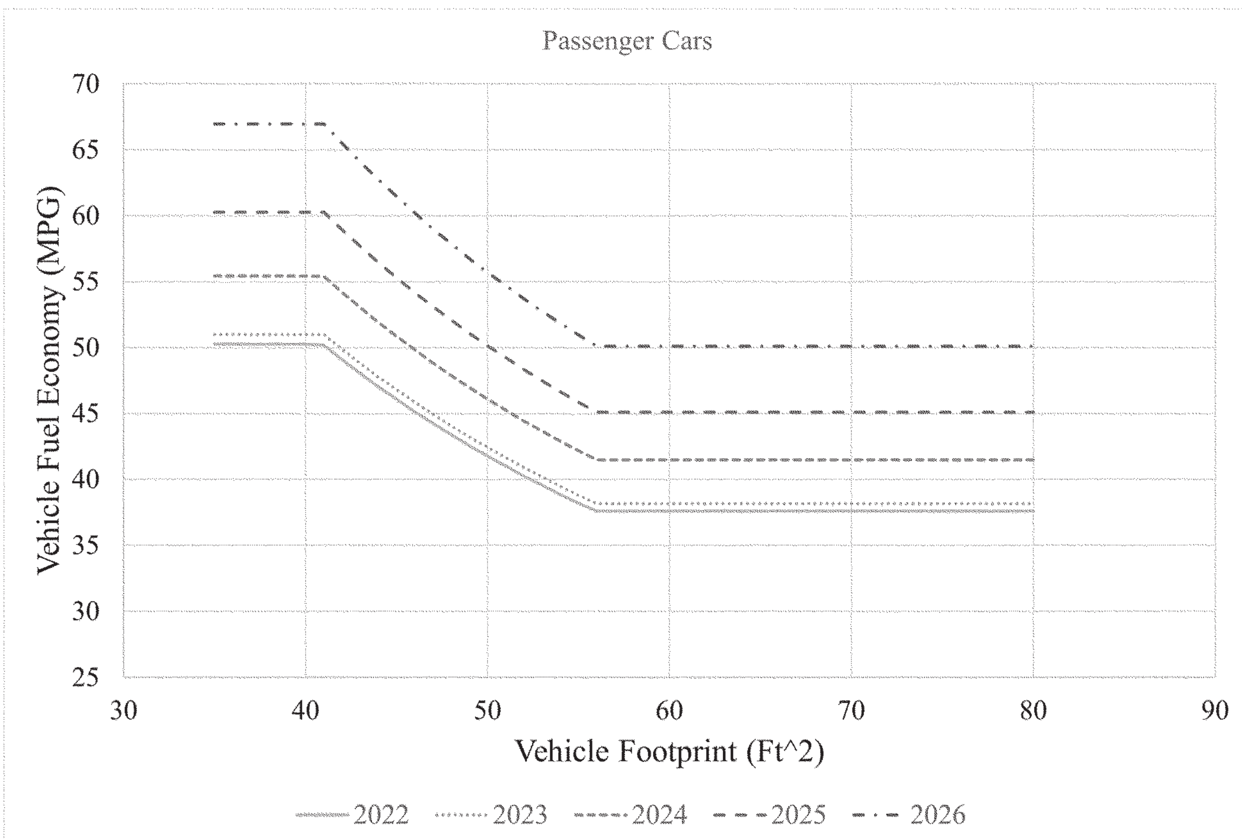
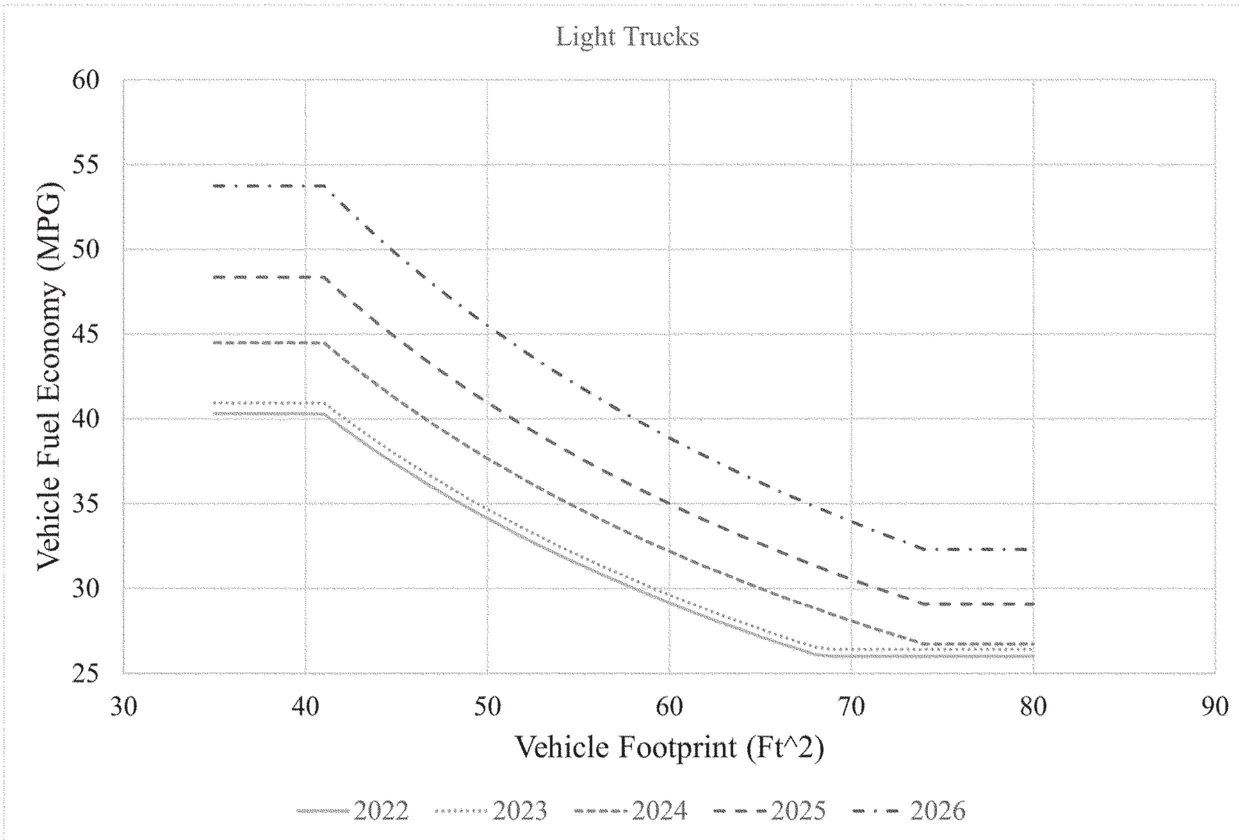


Figure III-2: No-Action Alternative, Light Truck Fuel Economy, Target Curves for the MYs 2022-2026 Amendment



For the No-Action Alternative for MYs 2022–2026, the MDPCS is applied as it was established in the 2020 and 2022 final rules, including the offset originally calculated in those rules to account for recent projection errors as part of estimating the total passenger car fleet fuel economy standard.

Table III-6: No-Action Alternative – MDPCS (MPG) for the MYs 2022-2026 Amendment

2022	2023	2024	2025	2026
40.6	41.1	44.3	48.1	53.5

b. No-Action Alternative for MYs 2027–2031 Amendment

The analysis of the No-Action Alternative assumes the following CAFE standards remain in place: the CAFE standards for MYs 2024–2026 that were finalized in the 2022 final rule[326] and the CAFE standards for MYs 2027–2031 that were finalized in the 2024 final rule.[327] The analysis also applies the statutory limitations in 49 U.S.C. 32902(h) in all model years in the analysis; specifically, the fuel economy of dedicated automobiles is not considered, dual-fueled automobiles are considered only as operated on gasoline or diesel fuel, and the trading, transferring, or availability of credits is not considered.

The No-Action Alternative standards for the existing MYs 2027–2031 passenger car and light truck fleets are defined by the following coefficients, which (for the purposes of this analysis) are assumed to persist without change in subsequent model years:

[326] 87 FR 25710 (May 2, 2022).

[327] 89 FR 52540 (June 24, 2024).

Table III-7: Passenger Car CAFE Target Function Coefficients for the No-Action Alternative for the MYs 2027-2031 Amendment

	2027	2028	2029	2030	2031
a (mpg)	68.32	69.71	71.14	72.59	74.07
b (mpg)	51.12	52.16	53.22	54.31	55.42
c (gpm per s.f)	0.00032841	0.00032184	0.00031541	0.00030910	0.00030292
d (gpm)	0.00117220	0.00114876	0.00112579	0.00110327	0.00108120

Table III-8: Light Truck CAFE Target Function Coefficients for the No-Action Alternative for the MYs 2027-2031 Amendment

	2027	2028	2029	2030	2031
a (mpg)	53.73	53.73	54.82	55.94	57.08
b (mpg)	32.30	32.30	32.96	33.63	34.32
c (gpm per s.f)	0.00037418	0.00037418	0.00036670	0.00035936	0.00035218
d (gpm)	0.00327158	0.00327158	0.00320615	0.00314202	0.00307918

These equations are represented graphically below:

These equations are represented graphically below:

Figure III-3: No-Action Alternative, Passenger Car Fuel Economy, Target Curves for the MYs 2027-2031 Amendment

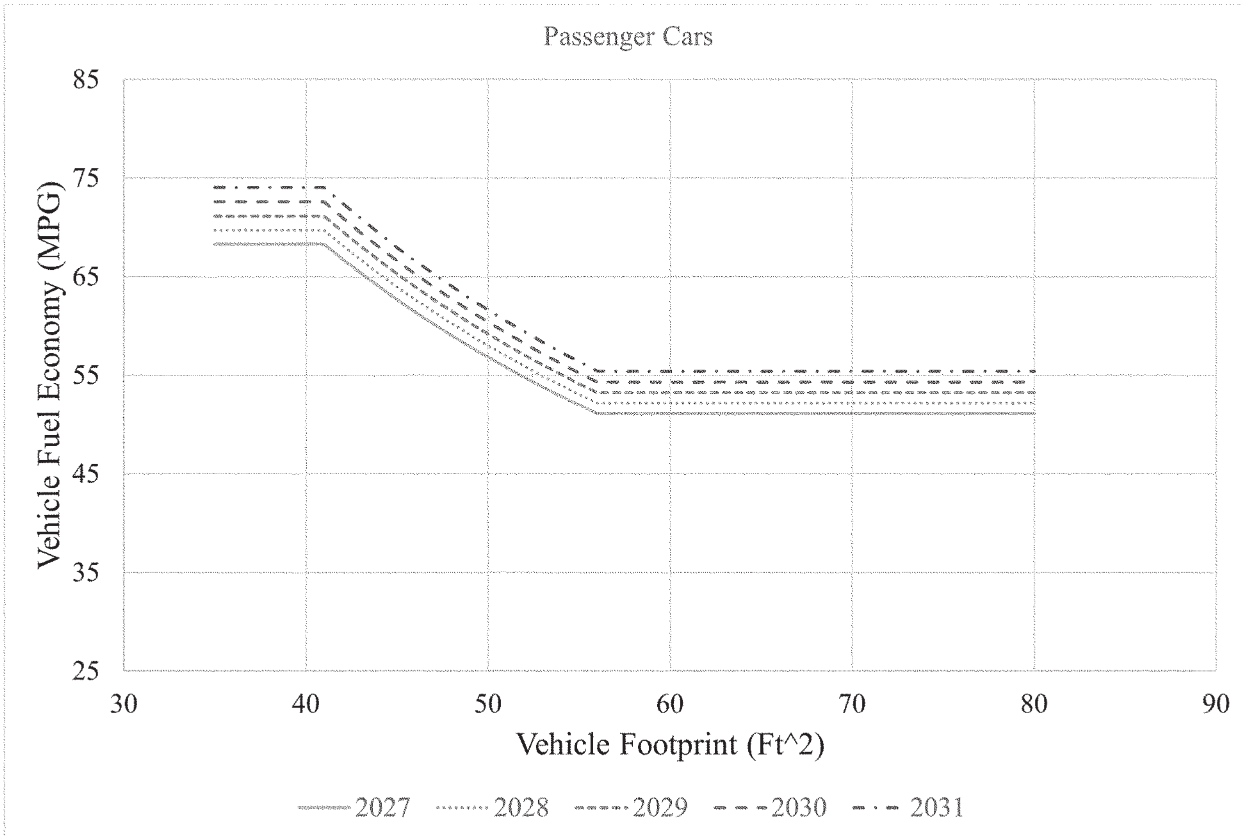
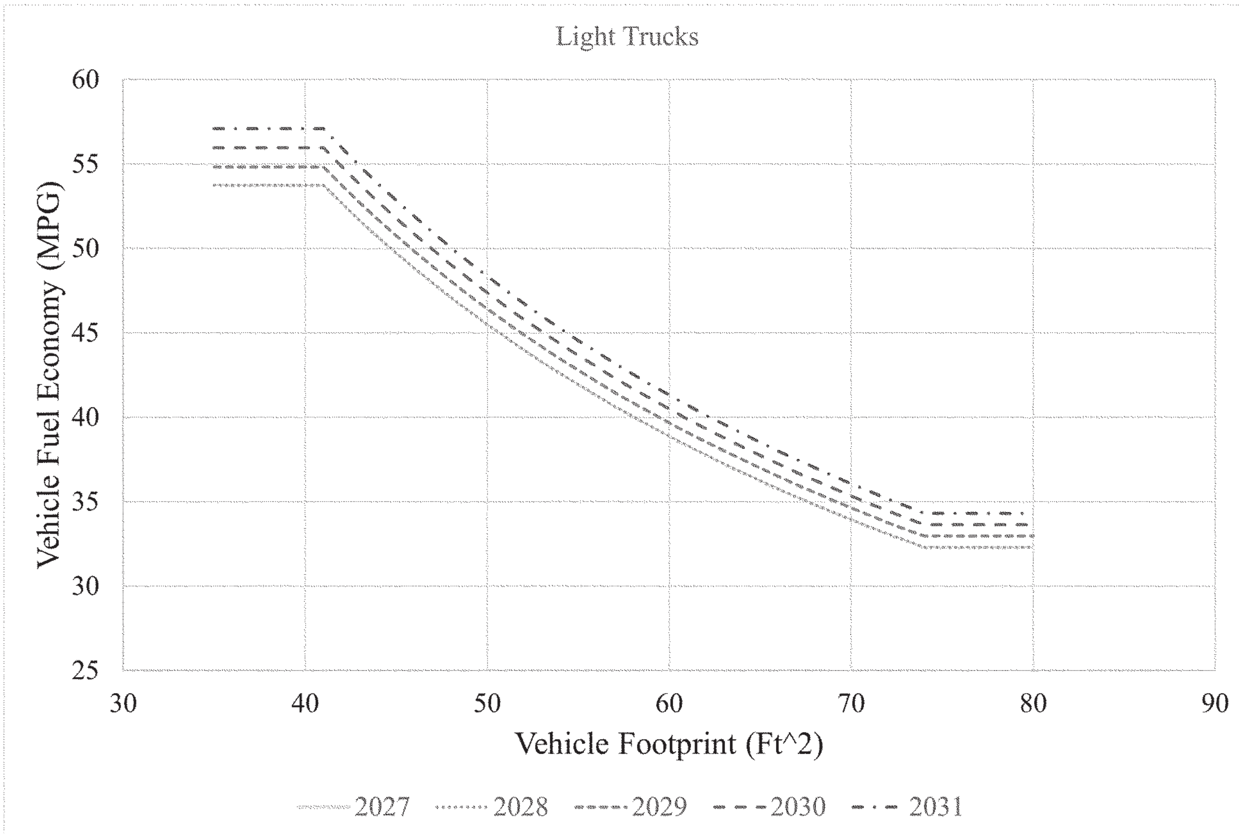


Figure III-4: No-Action Alternative, Light Truck Fuel Economy, Target Curves for the MYs 2027-2031 Amendment[328]



For the No-Action Alternative for MYs 2027–2031, the MDPCS is applied as it was established in the 2024 final rule.

Table III-9: No-Action Alternative – Minimum Domestic Passenger Car Standard (MDPCS) (MPG) for the MYs 2027-2031 Amendment

2027	2028	2029	2030	2031
54.2	55.5	56.4	57.5	58.7

2. Action Alternatives for Passenger Cars and Light Trucks

In addition to the No-Action Alternative, NHTSA has considered three action alternatives for passenger cars and light trucks. These action alternatives are specified below and demonstrate different possible approaches to balancing the statutory factors applicable for setting fuel economy standards for passenger cars and light trucks, as discussed in more detail in Section V.

a. Action Alternatives for MYs 2022–2026 Amendment

(1) Alternative 1

Alternative 1 begins with a MY 2022 set of target function parameters with which 80 percent of the passenger car fleet complied in MY 2022, and with which 80 percent of light trucks complied in MY 2022. From there, Alternative 1 would increase CAFE stringency by 0.5 percent per year for MYs 2022–2026 for passenger cars and light trucks.

[328] The light truck CAFE target function coefficients established in the 2024 final rule are identical for MY 2027 and MY 2028. As a result, the MY 2027 and MY 2028 lines overlap with each other.

Table III-10: Passenger Car CAFE Target Function Coefficients for Alternative 1 for the MYs 2022-2026 Amendment

	2022	2023	2024	2025	2026
a (mpg)	37.10	37.28	37.47	37.66	37.85
b (mpg)	31.62	31.78	31.94	32.10	32.26
c (gpm per s.f)	0.00042463	0.00042251	0.00042041	0.00041832	0.00041624
d (gpm)	0.00869688	0.00865362	0.00861056	0.00856772	0.00852510

Table III-11: Light Truck CAFE Target Function Coefficients for Alternative 1 for the MYs 2022-2026

	2022	2023	2024	2025	2026
a (mpg)	33.96	34.12	34.30	34.47	34.64
b (mpg)	19.78	19.88	19.98	20.08	20.18
c (gpm per s.f)	0.00065929	0.00065601	0.00065275	0.00064950	0.00064627
d (gpm)	0.00176047	0.00175171	0.00174300	0.00173432	0.00172570

These equations are represented graphically below:

Figure III-5: Alternative 1, Passenger Car Fuel Economy, Target Curves for the MYs 2022-2026 Amendment

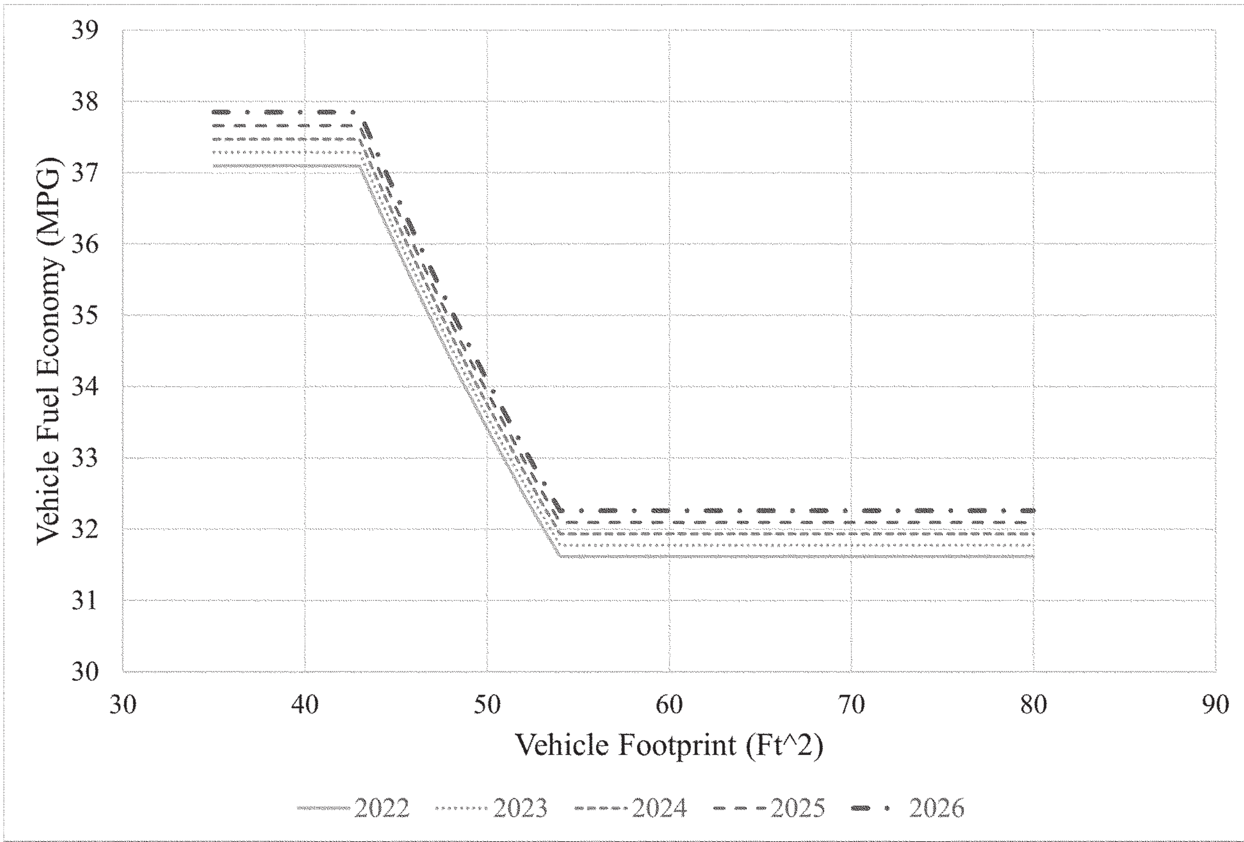
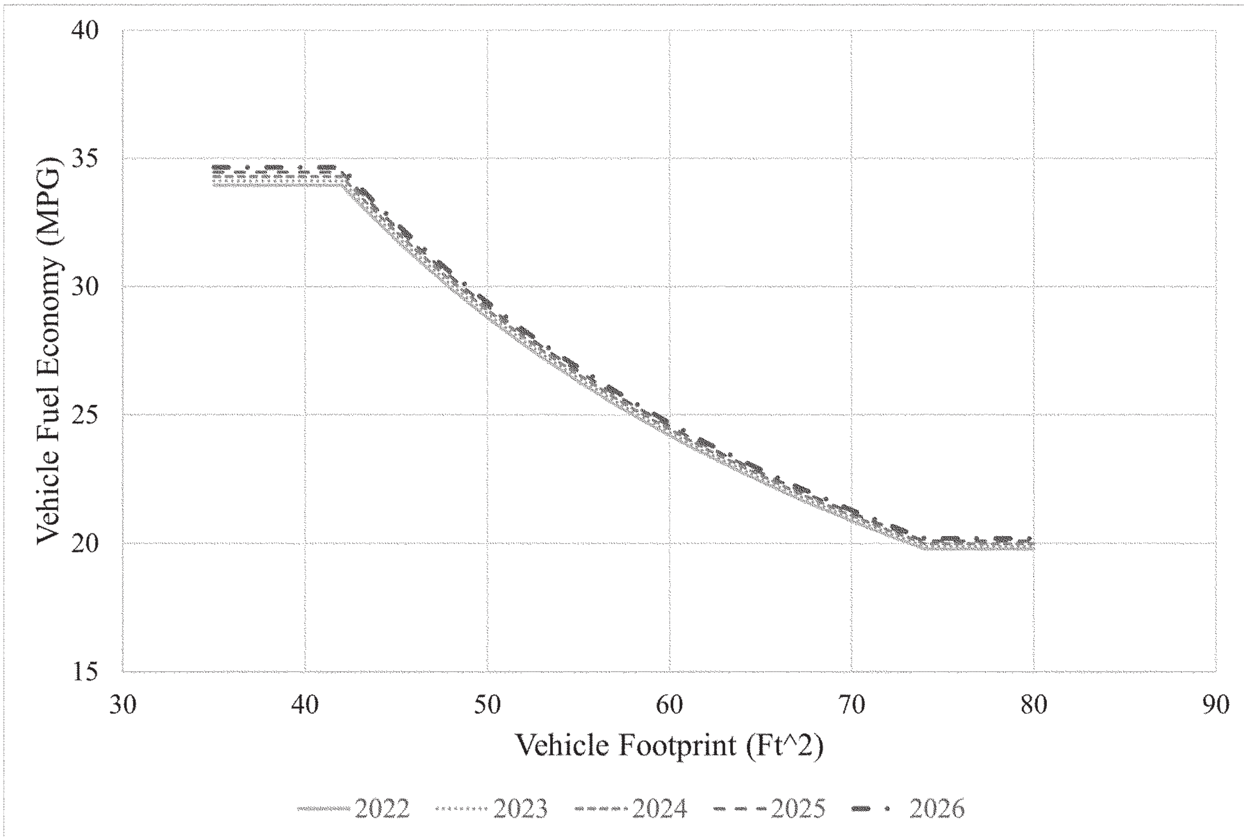


Figure III-6: Alternative 1, Light Truck Fuel Economy, Target Curves for the MYs 2022-2026 Amendment



Under this alternative, the MDPCS is as follows:

Table III-12: Alternative 1 – Minimum Domestic Passenger Car Standard (MDPCS) (MPG) for the MYs 2022-2026 Amendment

2022	2023	2024	2025	2026
32.2	32.2	32.6	32.8	33.0

(2) Alternative 2—Preferred Alternative

The Preferred Alternative begins with a MY 2022 set of target function parameters with which 75 percent of the passenger car fleet complied in MY 2022, and with which 70 percent of light trucks complied in MY 2022. From there, the Preferred Alternative would increase CAFE stringency by 0.5 percent per year for MYs 2022–2026 for passenger cars and light trucks.

Table III-13: Passenger Car CAFE Target Function Coefficients for Alternative 2 for the MYs 2022-2026 Amendment

	2022	2023	2024	2025	2026
a (mpg)	38.14	38.33	38.52	38.71	38.91
b (mpg)	32.51	32.67	32.83	33.00	33.16
c (gpm per s.f)	0.00041302	0.00041097	0.00040892	0.00040689	0.00040487
d (gpm)	0.00845926	0.00841718	0.00837530	0.00833363	0.00829217

Table III-14: Light Truck CAFE Target Function Coefficients for Alternative 2 for the MYs 2022-2026 Amendment

	2022	2023	2024	2025	2026
a (mpg)	34.89	35.06	35.24	35.41	35.59
b (mpg)	20.33	20.43	20.53	20.63	20.74
c (gpm per s.f)	0.00064166	0.00063847	0.00063529	0.00063213	0.00062899
d (gpm)	0.00171340	0.00170487	0.00169639	0.00168795	0.00167955

These equations are represented graphically below:

Figure III-7: Alternative 2, Passenger Car Fuel Economy, Target Curves for the MYs 2022-2026 Amendment

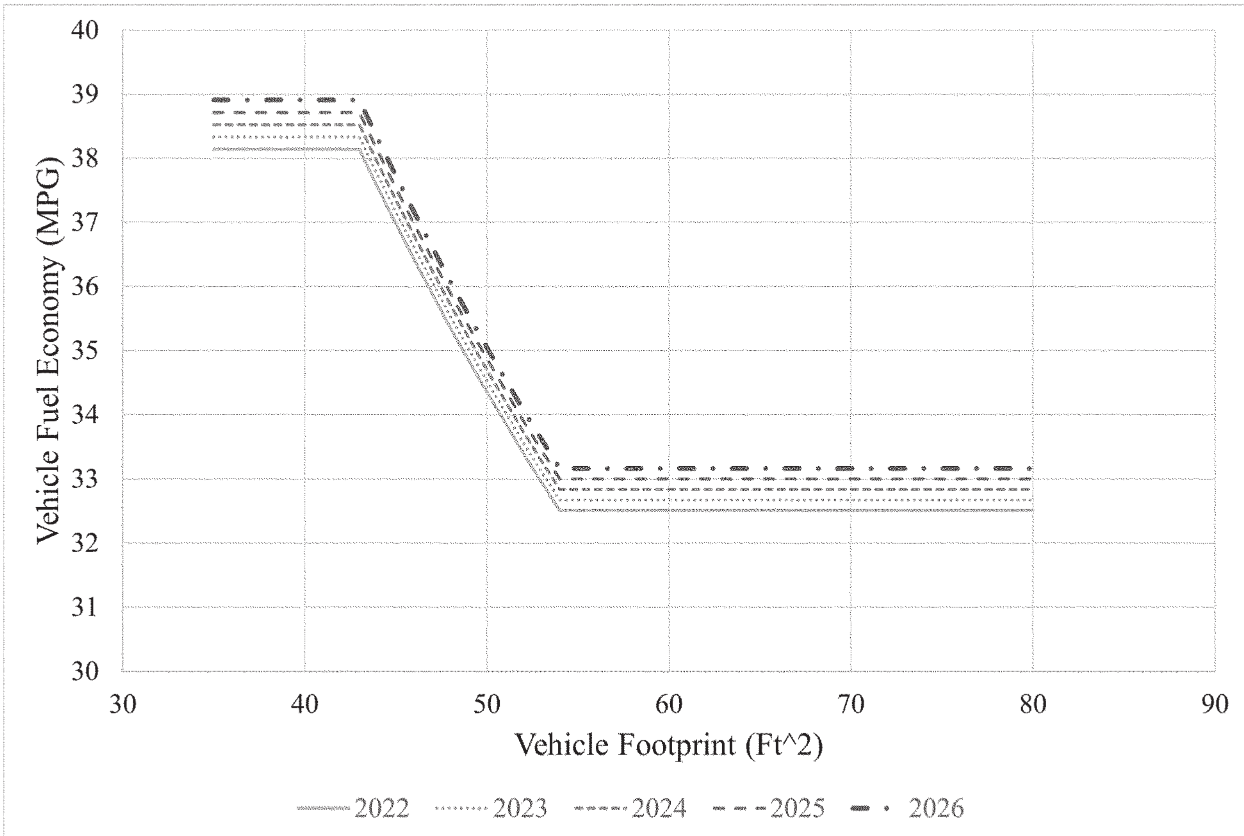
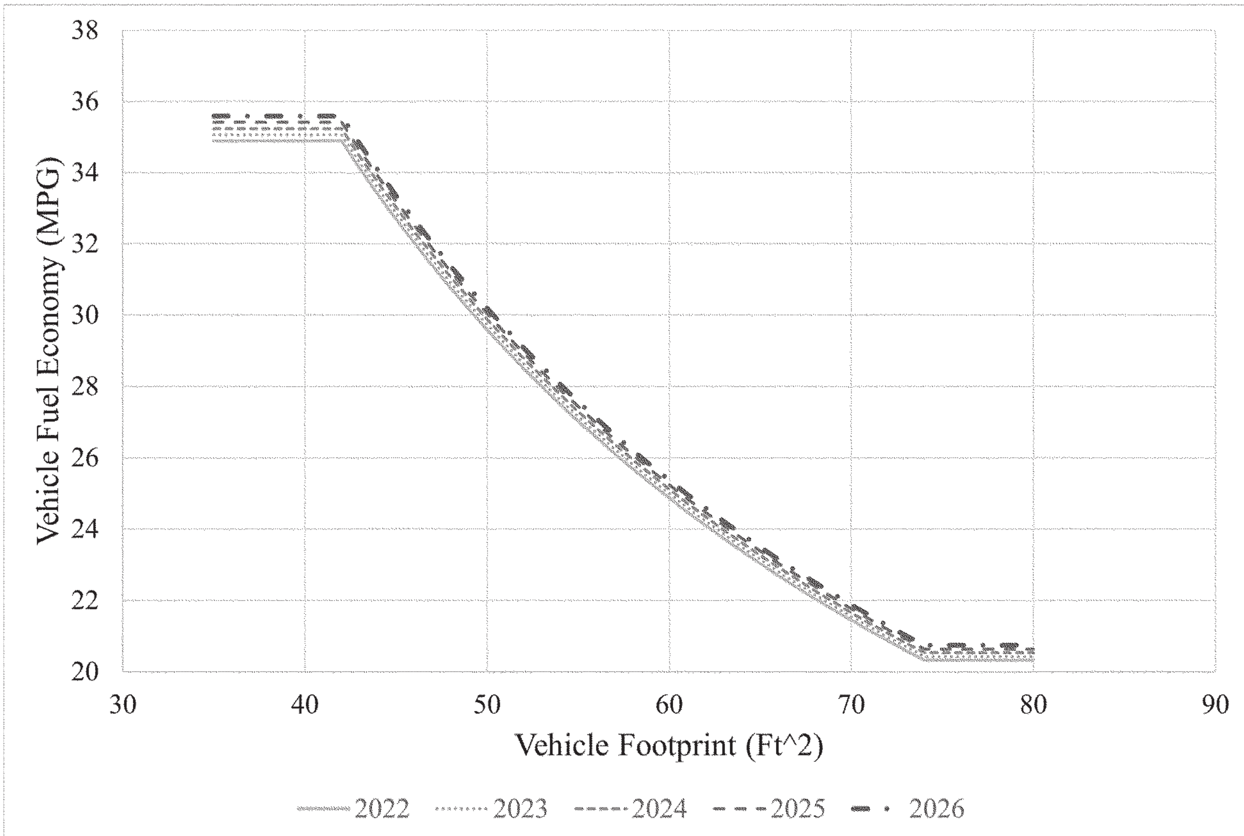


Figure III-8: Alternative 2, Light Truck Fuel Economy, Target Curves for the MYs 2022-2026 Amendment



Under this alternative, the MDPCS is as follows:

Table III-15: Alternative 2 – Minimum Domestic Passenger Car Standard (MDPCS) (MPG) for the MYs 2022-2026 Amendment

2022	2023	2024	2025	2026
33.1	33.1	33.5	33.7	33.9

(3) Alternative 3

Alternative 3 begins with a MY 2022 set of target function parameters with which 70 percent of the passenger car fleet complied in MY 2022, and with which 50 percent of light trucks complied in MY 2022. From there, Alternative 3 would increase CAFE stringency by 0.5 percent per year for MYs 2022–2026 for passenger cars and light trucks.